Fruit and vegetable Preservation

N.P. SINGH

Fruit and Vegetable Preservation

"This page is Intentionally Left Blank"

Fruit and Vegetable Preservation

N. P. Singh

Oxford Book Company
Jaipur, India

ISBN : 978-81-89473-12-9

First Published 2007

Oxford Book Company
267, 10-B-Scheme, Opp. Narayan Niwas,
Gopalpura By Pass Road, Jaipur-302018
Phone: 0141-2594705, Fax: 0141-2597527
e-mail: oxfordbook@sify.com
website: www.abdpublisher.com

Typeset by :
Shivangi Computers
267, 10-B-Scheme, Opp. Narayan Niwas,
Gopalpura By Pass Road, Jaipur-302018

Printed at :
Rajdhani Printers, Delhi

Preface

Why Preserve Food? – When you walk into a grocery store, it is obvious that commercially-preserved food is big business. Even so, there are a number of good reasons to preserve food at home. Many people enjoy gardening and caring for fruit trees as a hobby.

Although it is hard work, it can serve as an outlet to relieve stress. A sense of satisfaction can come from caring for a garden and seeing the end result. The fruits and vegetables produced in the garden can be enjoyed for a long time after the growing season if preserved by canning, drying, or freezing.

Preserving food can save money. If you do not grow your own food, canning may cost more than purchasing food from the grocery store because of the expense for equipment. If you do grow your own garden and have time to care for it, food preservation can be economical. The cost of canning depends in part on the food you can and the amount.

N. P. Singh

"This page is Intentionally Left Blank"

Contents

"This page is Intentionally Left Blank"

1

Introduction

IMPORTANCE OF FRUIT AND VEGETABLES

In developing countries agriculture is the mainstay of the economy. As such, it should be no surprise that agricultural industries and related activities can account for a considerable proportion of their output. Of the various types of activities that can be termed as agriculturally based, fruit and vegetable processing are among the most important.

Both established and planned fruit and vegetable processing projects aim at solving a very clearly identified development problem. This is that due to insufficient demand, weak infrastructure, poor transportation and perishable nature of the crops, the grower sustains substantial losses. During the post-harvest glut, the loss is considerable and often some of the produce has to be fed to animals or allowed to rot.

Even established fruit and vegetable canning factories or small/medium scale processing centres suffer huge loss due to erratic supplies. The grower may like to sell his produce in the open market directly to the consumer, or the produce may not be of high enough quality to process even though it might be good enough for the table. This means that processing capacities will be seriously underexploited.

The main objective of fruit and vegetable processing is to supply wholesome, safe, nutritious and acceptable food to consumers throughout the year. Fruit and vegetable processing projects also aim to replace imported products like squash, yams, tomato sauces, pickles, etc., besides earning foreign exchange by exporting finished or semi-processed products.

The fruit and vegetable processing activities have been set up, or have to be established in developing countries for one or other of the following reasons:

- Diversification of the economy, in order to reduce present dependence on one export commodity;
- Government industrialisation policy;
- Reduction of imports and meeting export demands;
- Stimulate agricultural production by obtaining marketable products;
- Generate both rural and urban employment;
- Reduce fruit and vegetable losses;
- Improve farmers' nutrition by allowing them to consume their own processed fruit and vegetables during the off-season;
- Generate new sources of income for farmers/artisans;
- Develop new value-added products.

THE WORLD OF AGRICULTURE

Fruit and vegetables represent an important part of world agriculture production; some figures are seen in Table given below.

Table: Fruit and Vegetable World Production, 1991

Crop (Fruit)	Production, 1000 T Total World	Dev.ping all
Appies	39404	14847
Apricots	2224	1147
Avocados	2036	1757
Bananas	47660	46753
Citrus fruits NES	1622	1231
Cantaloupes and other melons	12182	8733
Dates	3192	3146
Grapes	57188	14257

Grapefruit and pomelo	4655	2073
Lemons and limes	6786	4457
Mangoes	16127	16075
Oranges	55308	40325
Peaches and nectarines	8682	2684
Pears	9359	4431
Papayas	4265	4205
Plantains	26847	26847
Plums	5651	1806
Pineapples	10076	9183
Raisins	1041	470
Tangerines, mandarines, clementines	8951	4379
Watermelons	28943	19038
Currants	536009	
Raspberries	369087	
Strawberries	2469117	342009
Beans, green	3213	1702
Cabbages	36649	15569
Cauliflower	5258	2269
Carrots	13511	4545
Chilies + peppers, green	9145	6440
Cucumbers and gherkins	13619	7931
Eggplants	5797	4608
Garlic	3102	2446
Onions, dry	27977	17128
Peas, green	4856	1038
Pumpkins, squash, gourds	7933	6245

Fruit and Vegetables can be Processed

Practically any fruit and vegetable can be processed, but some important factors which determine whether it is worthwhile are:

a. The demand for a particular fruit or vegetable in the processed form;

b. The quality of the raw material, i.e. whether it can withstand processing;

c. Regular supplies of the raw material.

For example, a particular variety of fruit which may be excellent to eat fresh is not necessarily good for processing. Processing requires frequent handling, high temperature and pressure.

Many of the ordinary table varieties of tomatoes, for instance, are not suitable for making paste or other processed products. A particular mango or pineapple may be very tasty eaten fresh, but when it goes to the processing centre it may fail to stand up to the processing requirements due to variations in its quality, size, maturity, variety and so on.

Even when a variety can be processed, it is not suitable unless large and regular supplies are made available. An important processing centre or a factory cannot be planned just to rely on seasonal gluts; although it can take care of the gluts it will not run economically unless regular supplies are guaranteed. To operate a fruit and vegetable processing centre efficiently it is of utmost importance to pre-organise growth, collection and transport of suitable raw material, either on the nucleus farm basis or using outgrowers.

Processing Planning

The secret of a well planned fruit and vegetable processing centre is that it must be designed to operate for as many months of the year as possible. This means the facilities, the buildings, the material handling and the equipment itself must be inter-linked and coordinated properly to allow as many products as possible to be handled at the same time, and yet the equipment must be versatile enough to be able to handle many products without major alterations.

A typical processing centre or factory should process four or five types of fruits harvested at different times of the year and two or three vegetables. This processing unit must also be capable of handling dried/dehydrated finished products, juices, pickles, tomato juice, ketchup and paste, jams, jellies and marmalades, semi-processed fruit products.

Advanced planning is necessary to process a large range of products in varied weather and temperature conditions, each requiring a special set of manufacturing and packaging formulae. The end result of the efforts should be a well-managed processing unit with lower initial investment.

A unit which is sensibly laid out and where one requirement co-relates to another, with a sound costing analysis, leads to an integrated operation. Instead of over-sophisticated machinery, a sensible simple processing unit may be required when planned production is not very large and is geared mainly to meet the demand of the domestic market.

Location

The basic objective is to choose the location which minimises the average production cost, including transport and handling. It is an advantage, all other things being equal, to locate a processing unit near the fresh raw material supply. It is a necessity for proper handling of the perishable raw materials, it allows the processing unit to allow the product to reach its best stage of maturation and lessens injury from handling and deterioration from changes during long transportation after harvesting.

An adequate supply of good water, availability of manpower, proximity to rail or road transport facilities and adequate markets are other important requirements.

Processing systems

a. Small-Scale Processing. This is done by small-scale farmers for personal subsistence or for sale in nearby markets. In this system, processing requires little investment: however, it is time consuming and tedious. Until recently, small-scale processing satisfied the needs of rural and urban populations. However, with the rising rates of population and urbanisation growth and their more diversified food demands, there is need for more processed and diversified types of food.

b. Intermediate-Scale Processing. In this scale of processing, a group of small-scale processors pool their resources. This can also be done by individuals.

Processing is based on the technology used by small-scale processors with differences in the type and capacity of equipment used. The raw materials are usually grown by the processors themselves or are purchased on contract from other farmers. These operations are usually located on the production site of in order to assure raw materials availability and reduce cost of transport. This system of processing can provide quantities of processed products to urban areas.

c. Large-Scale Processing. Processing in this system is highly mechanised and requires a substantial supply of raw materials for economical operation. This system requires a large capital investment and high technical and managerial skills. Because of the high demand for foods in recent years many large-scale factories were established in developing countries. Some succeeded, but the majority failed, especially in West Africa. Most of the failures were related to high labour inputs and relatively high cost, lack of managerial skills, high cost and supply instability of raw materials and changing governmental policies. Perhaps the most important reason for failure was lack of adequate quantity and regularity of raw material supply to factories. Despite the failure of these commercial operations, they should be able to succeed with better planning and management, along with the undertaking of more in-depth feasibility studies.

It can be concluded that all three types of processing systems have a place in developing countries to complement crop production to meet food demand. Historically, however, small and intermediate scale processing proved to be more successful than large-scale processing in developing countries.

Choice of Processing Technologies for Developing Countries

FAO maintains, that the basis for choosing a processing technology for developing countries ought to be to combine labour, material resources and capital so that not only the type and quantity of goods and services produced are taken into account, but also the distribution of their benefits and the prospects of overall growth. These should include:

a. Increasing farmer/artisan income by the full utilisation of available indigenous raw material and local manufacturing of part or all processing equipment;
b. Cutting production costs by better utilisation of local natural resources (solar energy) and reducing transport costs;
c. Generating and distributing income by decentralising processing activities and involving different beneficiaries in processing activities (investors, newly employed, farmers and small-scale industry);
d. Maximising national output by reducing capital expenditure and royalty payments, more effectively developing balance-of-payments deficits through minimising imports (equipment, packing material, additives), and maximising export-oriented production;
e. Maximising availability of consumer goods by maximisation of high-quality, standard processed produce for internal and export markets, reducing post-harvest losses, giving added value to indigenous crops and increasing the volume and quality of agricultural output.

Knowledge and control of the means of production, local manufacturing of processing equipment and development of appropriate/new technologies and more suitable raw material for processing must all be better researched.

Decentralisation of activities must be maintained and coordinated. The introduction of more sophisticated processing equipment and packaging material must be subordinated to internal and export marketing references.

Choosing a technology solely to maximise profits can actually work against true development. Choice should also be based on a solid, long-term market opportunity to ensure viability. The internal market should be given greater consideration, safeguarded and supported. Training courses, at all levels, in processing and preservation of indigenous crops, must be expanded.

Global Marketing View

Fruit and vegetables have many similarities with respect to their compositions, methods of cultivation and harvesting, storage properties and processing. In fact, many vegetables may be considered fruit in the true botanical sense. Botanically, fruits are those portions of the plant which house seeds. Therefore such items as tomatoes, cucumbers, eggplant, peppers, and others would be classified as fruits on this basis.

However, the important distinction between fruit and vegetables has come to be made on an usage basis. Those plant items that are generally eaten with the main course of a meal are considered to be vegetables. Those that are commonly eaten as dessert are considered fruits. That is the distinction made by the food processor, certain marketing laws and the consuming public, and this distinction will be followed in this document.

Vegetables are derived from various parts of plants and it is sometimes useful to associate different vegetables with the parts of the plant they represent since this provides clues to some of the characteristics we may expect in these items. A classification of vegetables based on morphological features is seen in Table given below.

Table: Classification of Vegetables

Category	Examples
Earth vegetables roots	sweet potatoes, carrots
modified stems tubers	potatoes
modified buds bulbs	onions, garlic
Herbage vegetables	
leaves	cabbage, spinach, lettuce
petioles (leaf stalk)	celery, rhubarb
flower buds	cauliflower, artichokes

sprouts, shoots (young stems)	asparagus, bamboo shoots
Fruit vegetables	
legumes	peas, green beans
cereals	sweet corn
vine fruits	squash, cucumber
berry fruits	tomato, egg plant
tree fruits	avocado, breadfruit

Fruit as a dessert item, is the mature ovaries of plants with their seeds. The edible portion of most fruit is the fleshy part of the pericarp or vessel surrounding the seeds. Fruit in general is acidic and sugary. They commonly are grouped into several major divisions, depending principally upon botanical structure, chemical composition and climatic requirements.

Berries are fruit which are generally small and quite fragile. Grapes are also physically fragile and grow in clusters. Melons, on the other hand, are large and have a tough outer rind. Drupes (stone fruit) contain single pits and include such items as apricots, cherries, peaches and plums. Pomes contain many pits, and are represented by apples, quince and pears.

Citrus fruit like oranges, grapefruit and lemons are high in citric acid. Tropical and subtropical fruits include bananas, dates, figs, pineapples, mangoes, and others which require warm climates, but exclude the separate group of citrus fruits. The compositions of representative vegetables and fruits in comparison with a few of the cereal grains are seen in Table given below.

Table: Typical Percentage Composition of Foods from Plant Origin
Percentage Composition-Edible Portion

Food	Carbohydrate	Protein	Fat	Ash	Water
Cereals					
wheat flour, white	73.9	10.5	1.9	1.7	12
rice, milled, white	78.9	6.7	0.7	0.7	13
maize, whole grain	72.9	9.5	4.3	1.3	12
Earth vegetables					
potatoes, white	18.9	2.0	0.1	1.0	78
sweet potatoes	27.3	1.3	0.4	1.0	70

Vegetabless					
carrots	9.1	1.1	0.2	1.0	88.6
radishes	4.2	1.1	0.1	0.9	93.7
asparagus	4.1	2.1	0.2	0.7	92.9
beans, snap, green	7.6	2.4	0.2	0.7	89.1
peas, fresh	17.0	6.7	0.4	0.9	75.0
lettuce	2.8	1.3	0.2	0.9	94.8
Fruit					
banana	24.0	1.3	0.4	0.8	73.5
orange	11.3	0.9	0.2	0.5	87.1
apple	15.0	0.3	0.4	0.3	84.0
strawberries	8.3	0.8	0.5	0.5	89.9

Compositions of vegetables and fruit not only vary for a given kind in according to botanical variety, cultivation practices, and weather, but change with the degree of maturity prior to harvest, and the condition of ripeness, which is progressive after harvest and is further influenced by storage conditions. Nevertheless, some generalisations can be made.

Most fresh vegetables and fruit are high in water content, low in protein, and low in fat. In these cases water contents will generally be greater than 70% and frequently greater than 85%. Commonly protein content will not be greater than 3.5% or fat content greater than 0.5 %. Exceptions exist in the case of dates and raisins which are substantially lower in moisture but cannot be considered fresh in the same sense as other fruit.

Legumes such as peas and certain beans are higher in protein; a few vegetables such as sweet corn which are slightly higher in fat and avocados which are substantially higher in fat. Vegetables and fruit are important sources of both digestible and indigestible carbohydrates. The digestible carbohydrates are present largely in the form of sugars and starches while indigestible cellulose provides roughage which is important to normal digestion.

Fruit and vegetables are also important sources of minerals and certain vitamins, especially vitamins A and C. The precursors of vitamin A, including beta-carotene and certain other carotenoids, are to be found particularly in the yellow-orange fruit and vegetables and in the green leafy vegetables.

Citrus fruit are excellent sources of vitamin C, as are green leafy vegetables and tomatoes. Potatoes also provide an important source of vitamin C for the diets of many countries. This is not so much due to the level of vitamin C in potatoes which is not especially high but rather to the large quantities of potatoes consumed.

CHEMICAL COMPOSITION

Water

Vegetal cells contain important quantities of water. Water plays a vital role in the evolution and reproduction cycle and in physiological processes. It has effects on the storage period length and on the consumption of tissue reserve substances.

In vegetal cells, water is present in following forms:

- Bound water or dilution water which is present in the cell and forms true solutions with mineral or organic substances;
- Colloidal bound water which is present in the membrane, cytoplasm and nucleus and acts as a swelling agent for these colloidal structure substances; it is very difficult to remove during drying/ dehydration processes;
- Constitution water, directly bound on the chemical component molecules and which is also removed with difficulty.

Vegetables contain generally 90-96% water while for fruit normal water content is between 80 and 90%.

Mineral Substances

Mineral substances are present as salts of organic or inorganic acids or as complex organic combinations (chlorophyll, lecithin, etc.); they are in many cases dissolved in cellular juice.

Vegetables are more rich in mineral substances as compared with fruits. The mineral substance content is normally between 0.60 and 1.80% and more than 60 elements are present; the major elements are: K, Na, Ca, Mg, Fe, Mn, Al, P. Cl, S.

Among the vegetables which are especially rich in mineral substances are: spinach, carrots, cabbage and tomatoes. Mineral rich fruit includes: strawberries, cherries, peaches and raspberries. Important quantities of potassium (K) and absence of sodium chloride (NaCl) give a high dietetic value to fruit and to their processed products. Phosphorus is supplied mainly by vegetables.

Vegetables usually contain more calcium than fruit; green beans, cabbage, onions and beans contain more than 0.1% calcium. The calcium/phosphorus or Ca/P ratio is essential for calcium fixation in the human body; this value is considered normal at 0.7 for adults and at 1.0 for children. Some fruit are important for their Ca/P ratio above 1.0: pears, lemons, oranges and some temperate climate mountain fruits and wild berries.

Even if its content in the human body is very low, iron (Fe) has an important role as a constituent of haemoglobin. Main iron sources are apples and spinach. Salts from fruit have a basic reaction; for this reason fruit consumption facilitates the neutralisation of noxious uric acid reactions and contributes to the acid-basic equilibrium in the blood.

Carbohydrates

Carbohydrates are the main component of fruit and vegetables and represent more than 90% of their dry matter. From an energy point of view carbohydrates represent the most valuable of the food components; daily adult intake should contain about 500 g carbohydrates.

Carbohydrates play a major role in biological systems and in foods. They are produced by the process of photosynthesis in green plants. They may serve as structural components as in the case of cellulose; they may be stored as energy reserves as in the case of starch in plants; they may function as essential components of nucleic acids as in the case of ribose; and as components of vitamins such as ribose and riboflavin.

Carbohydrates can be oxidised to furnish energy, and glucose in the blood is a ready source of energy for the human body. Fermentation of carbohydrates by yeast and other microorganisms can yield carbon dioxide, alcohol, organic acids and other compounds.

Some Properties of Sugars

Sugars such as glucose, fructose, maltose and sucrose all share the following characteristics in varying degrees, related to fruit and vegetable technology:

- They supply energy for nutrition;
- They are readily fermented by micro-organisms;
- In high concentrations they prevent the growth of micro-organisms, so they may be used as a preservative;
- On heating they darken in colour or caramelise;
- Some of them combine with proteins to give dark colours known as the browning reaction.

Some properties of starches:

- They provide a reserve energy source in plants and supply energy in nutrition;
- They occur in seeds and tubers as characteristic starch granules.

Some properties of celluloses and hemicelluloses:

- They are abundant in the plant kingdom and act primarily as supporting structures in the plant tissues;
- They are insoluble in cold and hot water;
- They are not digested by man and so do not yield energy for nutrition;
- The fibre in food which produces necessary roughage is largely cellulose.

Some properties of pectins and carbohydrate gums.

- Pectins are common in fruits and vegetables and are gum-like (they are found in and between cell walls) and help hold the plant cells together;
- Pectins in colloidal solution contribute to viscosity of the tomato paste;
- Pectins in solution form gels when sugar and acid are added; this is the basis of jelly manufacture.

Fats

Generally fruit and vegetables contain very low level of fats, below 0.5%. However, significant quantities are found in nuts (55%), apricot kernel (40%), grapes seeds (16%), apple seeds (20%) and tomato seeds (18%).

Organic Acids

Fruit contains natural acids, such as citric acid in oranges and lemons, malic acid of apples, and tartaric acid of grapes. These acids give the fruits tartness and slow down bacterial spoilage. We deliberately ferment some foods with desirable bacteria to produce acids and this give the food flavour and keeping quality.

Examples are fermentation of cabbage to produce lactic acid and yield sauerkraut and fermentation of apple juice to produce first alcohol and then acetic acid to obtain vinegar. Organic acids influence the colour of foods since many plant pigments are natural pH indicators.

With respect to bacterial spoilage, a most important contribution of organic acids is in lowering a food's pH. Under anaerobic conditions and slightly above a pH of 4.6, Clostridium botulinum can grow and produce lethal toxins. This hazard is absent from foods high in organic acids resulting in a pH of 4.6 and less.

Acidity and sugars are two main elements which determine the taste of fruit. The sugar/acid ratio is very often used in order to give a technological characterisation of fruits and of some vegetables.

Nitrogen-containing Substances

These substances are found in plants as different combinations: proteins, amino acids, amides, amines, nitrates, etc. Vegetables contain between 1.0 and 5.5 % while in fruit nitrogen-containing substances are less than 1% in most cases.

Among nitrogen containing substances the most important are proteins; they have a colloidal structure and, by heating, their water solution above 50°C an one-way reaction makes them insoluble. This behaviour has to be taken into account in heat processing of fruits and vegetables. From a biological point of view vegetal proteins are less valuable then animal ones because in their composition all essential amino-acids are not present.

Vitamins

Vitamins are defined as organic materials which must be supplied to the human body in small amounts apart from the essential amino-acids or fatty acids. Vitamins function as enzyme systems which facilitate the metabolism of proteins, carbohydrates and fats but there is growing evidence that their roles in maintaining health may extend yet further.

The vitamins are conveniently divided into two major groups; those that are fat-soluble and those that are water-soluble. Fat-soluble vitamins are A, D, E and K. Their absorption by the body depends upon the normal absorption of fat from the diet. Water-soluble vitamins include vitamin C and several members of the vitamin B complex.

Vitamin A or Retinol

This vitamin is found as such only in animal materials - meat, milk, eggs and the like. Plants contain no vitamin A but contain its precursor, beta-carotene. Man needs either vitamin A or beta-carotene which he can easily convert to vitamin A. Beta-carotene is found in the orange and yellow vegetables as well as the green leafy vegetables, mainly carrots, squash, sweet potatoes, spinach and kale.

A deficiency of vitamin A leads to night blindness, failure of normal bone and tooth development in the young and diseases of epithelial cells and membrane of the nose, throat and eyes which decrease the body's resistance to infection.

Vitamin C

Vitamin C is the anti-scurvy vitamin. Lack of it causes fragile capillary walls, easy bleeding of the gums, loosening of teeth and bone joint diseases. It is necessary for the normal formation of the protein collagen, which is an important constituent of skin and connective tissue. Like vitamin E, vitamin C favours the absorption of iron.

Vitamin C, also known as ascorbic acid, is easily destroyed by oxidation especially at high temperatures and is the vitamin most easily lost during processing, storage and cooking.

Excellent sources of vitamin C are citrus fruits, tomatoes, cabbage and green peppers. Potatoes also are a fair source (although the content of vitamin C is relatively low) because we consume large quantities of potatoes.

Enzymes

Enzymes are biological catalysts that promote most of the biochemical reactions which occur in vegetable cells.

Some properties of enzymes important in fruit and vegetable technology are the following:

- In living fruit and vegetables enzymes control the reactions associated with ripening;
- After harvest, unless destroyed by heat, chemicals or some other means, enzymes continue the ripening process, in many cases to the point of spoilage - such as soft melons or overripe bananas;
- Because enzymes enter into a vast number of biochemical reactions in fruits and vegetable, they may be responsible for changes in flavour, colour, texture and nutritional properties;
- the heating processes in fruit and vegetables manufacturing/processing are designed not only to

destroy micro-organisms but also to deactivate enzymes and so improve the fruit and vegetables' storage stability.

Enzymes have an optimal temperature - around +50°C where their activity is at maximum. Heating beyond this optimal temperature deactivates the enzyme. Activity of each enzyme is also characterised by an optimal pH.

In fruit and vegetable storage and processing the most important roles are played by the enzymes classes of hydrolases (lipase, invertase, tannase, chlorophylase, amylase, cellulase) and oxidoreductases (peroxidase, tyrosinase, catalase, ascorbinase, polyphenoloxidase).

Turgidity and Texture

The range of textures that are encountered in fresh and cooked vegetables and fruit is indeed great, and to a large extent can be explained in terms of changes in specific cellular components. Since plants tissues generally contain more than two-thirds water, the relationships between these components and water further determine textural differences.

Cell Turgidity

Quite apart from other contributing factors, the state of turgidity, determined by osmotic forces, plays a paramount role in the texture of fruit and vegetables. The cell walls of plant tissues have varying degrees of elasticity and are largely permeable to water and ions as well as to small molecules.

The membranes of the living protoplast are semi-permeable, that is they allow passage of water but are selective with respect to transfer of dissolved and suspended materials.

The cell vacuoles contain most of the water in plant cells and sugars, acids, salts, amino acids, some water-soluble pigments and vitamins, and other low molecular weight constituents are dissolved in this water.

In the living plant, water taken up by the roots passes through the cell walls and membranes into the cytoplasm of the protoplasts and into the vacuoles to establish a state of osmotic equilibrium within the cells.

The osmotic pressure within the cell vacuoles and within the protoplasts pushes the protoplasts against the cell walls and causes them to stretch slightly in accordance with their elastic properties. This is the situation in the growing plant and the harvested live fruit or vegetable which is responsible for desired plumpness, succulence, and much of the crispness.

When plant tissues are damaged or killed by storage, freezing, cooking, or other causes, an important major change that results is denaturation of the proteins of cell membranes resulting in the loss of perm-selectivity. Without perm-selectivity the state of osmotic pressure in cell vacuoles and protoplasts cannot exist, and water and dissolved substances are free to diffuse out of the cells and leave the remaining tissue in a soft and wilted condition.

Other Factors Affecting Texture

The existence of a high degree of turgidity in live fruit and vegetables or whether a relative state of flabbiness develops from loss of osmotic pressure as well as final texture depends on several cell constituents.

Cellulose, Hemicellulose, and Lignin

Cell walls in young plants are very thin and are composed largely of cellulose. As the plant ages cell walls tend to thicken and become higher in hemicellulose and in lignin. These materials are fibrous and tough and are not significantly softened by cooking.

Pectic Substances

The complex polymers of sugar acid derivatives include pectin and closely related substances. The cement-like substance found especially in the middle lamella which helps hold plant cells to one another is a water-insoluble pectic substance.

On mild hydrolysis it yields water-soluble pectin which can form gels or viscous colloidal suspensions with sugar and acid. Certain water-soluble pectic substances also react with metal ions, particularly calcium, to form water-insoluble salts such as calcium pectates. The various pectic substances may influence texture of vegetables and fruits in several ways.

When vegetables or fruit are cooked, some of the water-insoluble pectic substance is hydrolysed into water-soluble pectin. This results in a degree of cell separation in the tissues and contributes to tenderness. Since many fruits and vegetables are somewhat acidic and contain sugars the soluble pectin also tends to form colloidal suspensions which will thicken the juice or pulp of these products.

Fruit and vegetables also contain a natural enzyme which can further hydrolyse pectin to the point where the pectin loses much of its gel forming property. This enzyme is known as pectin methyl esterase. Materials such as tomato juice or tomato paste will contain both pectin and pectin methyl esterase.

If freshly prepared tomato juice or paste is allowed to stand the original viscosity gradually decreases due to the action of pectin methyl esterase on pectin gel.

This can be prevented if the tomato products are quickly heated to a temperature of about 82°C (180 F°) to deactivate the pectin methyl esterase liberated from broken cells before it has a chance to hydrolyse the pectin. Such a treatment is commonly practiced in the manufacture of tomato juice products. This is known as the "hot-break process" and yields products of high viscosity.

In contrast, where low viscosity products are desired no heat is used and enzyme activity is allowed to proceed. This is "cold-break" process. After sufficient decrease in viscosity is achieved the product can be heat treated, as in canning, to preserve it for long term storage.

It is often also desirable to firm the texture of fruit and vegetables, especially when products are normally softened by processing. In this case advantage is taken of the reaction between soluble pectic substances and calcium ions which form calcium pectates. These calcium pectates are water insoluble and when they are produced within the tissues of fruit and vegetables they increase structural rigidity. Thus, it is common commercial practice to add low levels of calcium salts to tomatoes, apples, and other vegetables and fruits prior to canning or freezing.

Sources of Colour and Colour Changes

In addition to a great range of textures, much of the interest that fruits and vegetables add to our diets is due to their delightful and variable colours. The pigments and colour precursors of fruit and vegetables occur for the most part in the cellular plastic inclusions such as the chloroplasts and other chromoplasts, and to a lesser extent dissolved in fat droplets or water within the cell protoplast and vacuoles.

These pigments are classified into four major groups which include the chlorophylls, carotenoids, anthocyanins, and anthoanthins. Pigments belonging to the latter two groups also are referred to as flavonoids, and include the tannins.

The Chlorophylls

The chlorophylls are contained mainly within the chloroplasts and have a primary role in the photosynthetic production of carbohydrates from carbon dioxide and water. The bright green colour of leaves and other parts of plants is largely due to the oilsoluble chlorophylls, which in nature are bound to protein molecules in highly organised complexes.

When the plant cells are killed by ageing, processing, or cooking, the protein of these complexes is denatured and the chlorophyll may be released. Such chlorophyll is highly unstable and rapidly changes in colour to olive green and brown. This colour change is believed to be due to the conversion of chlorophyll to the compound pheophytin.

Conversion to pheophytin is favoured by acid pH but does not occur readily under alkaline conditions. For this reason peas, beans, spinach, and other green vegetables which tend to lose their bright green colours on heating can be largely protected against such colour changes by the addition of sodium bicarbonate or other alkali to the cooking or canning water.

However, this practice is not looked upon favourably nor used commercially because alkaline pH also has a softening effect on cellulose and vegetable texture and also destroys vitamin C and thiamin at cooking temperatures.

The Carotenoids

Pigments belonging to this group are fat-soluble and range in colour from yellow through orange to red. They often occur along with the chlorophylls in the chloroplasts, but also are present in other chromoplasts and may occur free in fat droplets. Important carotenoids include the orange carotenes of carrot, maize, apricot, peach, citrus fruits, and squash; the red lycopene of tomato, watermelon, and apricot; the yellow-orange xanthophyll of maize, peach, paprika and squash; and the yellow-orange crocetin of the spice saffron. These and other carotenoids seldom occur singly within plant cells.

A major importance of some of the carotenoids is their relationship to vitamin A. A molecule of orange beta-carotene is converted into two molecules of colourless vitamin A in the animal body. Other carotenoids like alpha-carotene, gamma-carotene, and cryptoxanthin also are precursors of vitamin A, but because of minor differences in chemical structure one molecule of each of these yields only one molecule of vitamin A.

In food processing the carotenoids are fairly resistant to heat, changes in pH, and water leaching since they are fat-soluble. However, they are very sensitive to oxidation, which results in both colour loss and destruction of vitamin A activity.

The Flavonoids

Pigments and colour precursors belonging to this class are water-soluble and commonly are present in the juices of fruit and vegetables. The flavonoids include the purple, blue, and red anthocyanins of grapes, berries, plump, eggplant, and cherry; the yellow anthoxanthins of light coloured fruit and vegetables such as apple, onion, potato, and cauliflower, and the colourless catechins and leucoanthocyanins which are food tannins and are found in apples, grapes, tea, and other plant tissues. These colourless tannin compounds are easily converted to brown pigments upon reaction with metal ions.

Properties of the anthocyanins include a shifting of colours with pH. Thus many of the anthocyanins which are violet or blue in alkaline media become red upon addition of acid. Cooking of beets with vinegar tends to shift the colour from a purplish red to a brighter red, while alkaline water can influence the colour of red fruits and vegetables toward violet and gray-blue.

The anthocyanins also tend toward the violet and blue hues upon reaction with metal ions, which is one reason for lacquering the inside of metal cans when the true colour of anthocyanin-containing fruits and vegetables is to be preserved.

The water-soluble property of anthocyanins also results in easy leaching of these pigments from cut fruit and vegetables during processing and cooking. The yellow anthoxanthins also are pH sensitive tending toward a deeper yellow in alkaline media. Thus potatoes or apples become somewhat yellow when cooked in water with a pH of 8 or higher, which is common in many areas. Acidification of the water to pH 6 or lower favours a whiter colour.

The colourless tannin compounds upon reaction with metal ions form a range of dark coloured complexes which may be red, brown, green, grey, or black. The various shades of these coloured complexes depend upon the particular tannin, the specific metal ion, pH, concentration of the complex, and other factors not yet fully understood.

Water-soluble tannins appear in the juices squeezed from grapes, apples, and other fruits as well as the brews from extraction of tea and coffee. The colour and clarity of tea are influenced by the hardness and pH of the brewing water.

Alkaline waters that contain calcium and magnesium favour the formation of dark brown tannin complexes which precipitate when the tea is cooled.

If acid in the form of lemon juice is added to such tea its colour lightens and the precipitate tends to dissolve. Iron from equipment or from pitted tin cans has caused a number of unexpected colours to develop in products containing tannins, such as coffee, cocoa and foods flavoured with these. The tannins are also important because they have an astringency which influences flavour and contributes body to such beverages as tea, wine, apple cider, etc.

ACTIVITIES OF LIVING SYSTEMS

Fruit and vegetables are in a live state after harvest. Continued respiration gives off carbon dioxide, moisture, and heat which influence storage, packaging, and refrigeration requirements. Continued transpiration adds to moisture evolved and further influences packaging requirements. Further activities of fruit and vegetables, before and after harvest, include changes in carbohydrates, pectins, organic acids, and the effects these have on various quality attributes of the products.

As for changes in carbohydrates, few generalizations can be given with respect to starches and sugars. In some plant products sugars quickly decrease and starch increases in amount soon after harvest. This is the case for ripe sweet corn which can suffer flavour and texture quality losses in a very few hours after harvest.

Unripe fruit, in contrast, is frequently high in starch and low in sugars. Continued ripening after harvest generally results in a decrease in starch and a increase in sugars as in the case of apples and pears. However, this does not necessarily mean that the starch is the source of the newly formed sugars.

Further, the courses of change in starch and sugars are markedly influenced by postharvest storage temperatures

Thus potatoes stored below about 10 C° (50 F°) continue to build up high levels of sugars, while the same potatoes stored above 10 C° do not.

This property is used to help the dehydration process in potato storage. Here potatoes should have a low reducing sugar content so as to minimise Maillard browning reactions during drying and subsequent storage of the dried product. In this case potatoes are stored above 10°C prior to being further processed.

After harvest the pectin changes in fruit and vegetables are more predictable. Generally there is decrease in water-insoluble pectic substance and a corresponding increase in watersoluble pectin. This contributes to the gradual softening of fruits and vegetables during storage and ripening. Further breakdown of water-soluble pectin by pectin methyl esterase also occurs.

The organic acids of fruit generally decreases during storage and ripening. This occurs in apples and pears and is especially important in the case of oranges. Oranges have a long ripening period on the tree and time of picking is largely determined by degree of acidity and sugar content which have major effects upon juice quality.

It is important to note that the reduction of acid content on ripening influences more than just the tartness of fruit. Since many of the plant pigments are sensitive to acid, fruit colour would be expected to change. Additionally, the viscosity of pectin gel is affected by acid and sugar contents, both of which change with ripening.

Stability of Nutrients

One of the principal responsibilities of the food scientist and food technologist is to preserve food nutrients through all phases of food acquisition, processing, storage, and preparation.

Table: Specific sensitivity and stability of nutrients

Nutrient	Neutral pH 7	Acid < pH 7	Alkaline > pH 7	Air or Oxygen	Light	Heat	Cooking Losses, Range
Vitamins							
Vitamin A	S	U	S	U	U	U	0-40
Ascorbic acid(C)	U	S	U	U	U	U	0-100
Biotin	S	S	S	S	S	U	0-60
Carotenes (pro A)	S	U	S	U	U	U	0-30 0-5
Choline	S	S	S	U	S	S	0-10
Cobalamin (B12)	S	S	S	U	U	S	0-40
Vitamin D	S		U	U	U	U	0-10
Essential fatty acids	S	S	U	U	U	S	
Folic acid	U	U	S	U	U	U	0-100
Inositol	S	S	S	S	S	U	0-95
Vitamin K	S	U	U	S	U	S	0-5
Niacin (PP)	S	S	S	S	S	S	0-75
Pantbothenic acid	S	U	U	S	S	U	0-50
p-Amino Benzoic acid	S	S	S	U	S	S	0-5
Vitamin B6	S	S	S	S	U	U	0-40
Riboflavin (B2)	S	S	U	S	U	U	0-75
Tbiamin (B1)	U	S	U	U	S	U	0-80
Tocopherols	S	S	S	U	U	U	0-55

This shows the stability of vitamins, essential amino acids, and minerals to acid, air, light, and heat, and gives an indication of possible cooking losses. Vitamin A is highly sensitive to acid, air, light and heat; vitamin C to alkalinity, air, light and heat; vitamin D to alkalinity, air, light and heat; thiamin to alkalinity, air, and heat in alkaline solutions; etc. Cooking losses of some essential nutrients may be in excess of

75%. In modern food processing operations, however, losses are seldom in excess of 25%.

The ultimate nutritive value of a food results from the sum total of losses incurred throughout its history - from farmer to consumer. Nutrient value begins with genetics of the plant and animal. The farmland fertilization programme affects tissue composition of plants, and animals consuming these plants. The weather and degree of maturity at harvest affect tissue composition.

Storage conditions before processing affect vitamins and other nutrients. Washing, trimming, and heat treatments affect nutrient content. Canning, evaporating, drying, and freezing alter nutritional values, and the choices of times and temperatures in these operations frequently must be balanced between good bacterial destruction and minimum nutrient destruction.

Packaging and Subsequent Storage Affect Nutrients

One of the most important factors is the final preparation of the food in the home and the restaurant - the steam table can destroy much of what has been preserved through all prior manipulations.

Structural Features

The structural unit of the edible portion of most fruits and vegetables is the parenchyma cell. While parenchyma cells of different fruit and vegetables differ somewhat in gross size and appearance, all have essentially the same fundamental structure. Parenchyma cells of plants differ from animal cells in that the actively metabolising protoplast portion of plant cells represents only a small fraction, of the order of five per cent, of the total cell volume.

This protoplast is film-like and is pressed against the cell wall by the large water-filled central vacuole. The protoplast has inner and outer semi-permeable membrane layers; the cytoplasm and its nucleus are held between them. The cytoplasm contains various inclusions, among them starch granules and plastics such as the chloroplasts and other pigment-containing chromoplasts.

The cell wall, cellulose in nature, contributes rigidity to the parenchyma cell and limits the outer protoplasmic membrane. It is also the structure against which other parenchyma cells are cemented to form extensive three-dimensional tissue masses.

The layer between cell walls of adjacent parenchyma cells is referred to as the middle lamella, and is composed largely of pectic and polysaccharide cement-like materials. Air spaces also exist, especially at the angles formed where several cells come together. The relationships between these structures and their chemical compositions are further outlined below. The parenchyma cells will vary in size among plants but are quite large when compared to bacterial or yeast cells. The larger parenchyma cells may have volumes many thousand times greater than a typical bacterial cell.

There are additional types of cells other than parenchyma cells that make up the familiar structures of fruit and vegetables. These include various types of conducting cells which are tube-like and distribute water and salts throughout the plant.

Such cells produce fibrous structures toughened by the presence of cellulose and the woodlike substance lignin. Cellulose, lignin, and pectic substances also occur in specialised supporting cells which increase in importance as plants become older. An important structural feature of all plants, including fruit and vegetables is protective tissue. This can take many forms but usually is made up of specialised parenchyma cells that are pressed compactly together to form a skin, peel or rind.

Surface cells of these protective structures on leaves, stems or fruit secrete waxy cutin and form a water impermeable cuticle. These surface tissues, especially on leaves and young stems will also contain numerous valve-like cellular structures, the stomata, through which moisture and gases can pass.

Structural and chemical components of the vegetal cells are seen in Table given below.

Table: Structural and Chemical Components of the Cells

Vacuole	H_2O, inorganic salts, organic acids, oil droplets, sugars, water-soluble pigments, amino acids, vitamins
Protoplast	
- Membrane tonoplast	
(inner) plasmalemma (outer)	protein, lipoprotein, phospholipids, physic acid
- Nucleus	
- Cytoplasm	
*active	
chloroplasts	Chlorophyll
mesoplasm (ground substance)	enzymes, intermediary metabolites, nucleic acid
mitochondria	enzymes (protein), Fe, Cu. Mo vitamin coenzyme
microsomes	nucleoproteins, enzymes (proteins), nucleic acid
*inert	
starch grains	reserve carbohydrate (starch), phosphorus
aleurone	reserve protein
chromoplast	pigments (carotenoids)
oil droplets	triglycerides of fatty acids
crystals	calcium oxalate, etc.
Cell Wall	
- primary wall	cellulose, hemicellulose, pectic substances and non-cellulose
- middle lamella	pectic substances and non-cellulose polysaccharides, Mg, Ca
- plasmodesmata	cytoplasmic strands interconnecting cyctoplasm of cells through pores in the cell wall
- surface materials	esters of long chain fatty acids (cutin or cuticle) and long chain alcohols

2

Twentieth-Century Trends in Food Preserving

NUTRITION OR LUXURY

To set the story in a context: before the easy-to-purchase and relatively cheap food supplies of the second half of the nineteenth century, skills in the preservation of food were essential to survival. Such skills were, arguably, the most important part of the domestic economy: conserving and preserving and storing the fruits, vegetables and meats from a period of harvest or slaughter through a period of scarcity. The pattern of feast or famine was after all dependent upon unavoidable seasonal constraint on the supply of food and on the economic ability to obtain it.

Underlying all the evidence from surviving printed books, the basic necessities of sustenance depended upon a good knowledge of how to store foods and how to dry them, neither method involving any additional expenditure, and then upon salting, and to a smaller extent potting. Preserving with sugar and alcohol was, for centuries, too costly for general domestic use, and the use of vinegar, particularly in pickles and relishes, was largely for making condiments rather than preserving foods.

Knowledge of preserving techniques was so important that it must have been part of the basic training of most people up until the early nineteenth century at least, and was probably orally transmitted. In choosing to look at preserving and changing attitudes toward it from the evidence of printed books, I am taking a particular perspective that works under a number of constraints which can be touched upon by trying to respond to the question: why did people see a need to write down these accounts rather than simply transmit them orally?

One reason may have been the need to respond to entirely new social events, such as the shift from a largely rural to a concentrated urban population, or to the adulteration of foodstuffs, or the effect of changes in architecture. Another reason was the need to inform people about contemporary discoveries of new techniques and preserving agents.

A third and highly problematic reason must have been the need to adapt these essential skills to the changing activities of men and women in the household, adapt them from the more integrated domestic scene of pre-1600 to the separate and relatively isolated work of the housewife, the housekeeper and the servant. Until the early nineteenth century each of these reasons, and they are only a selected few, uses the print medium to tell a specifically middle-class audience about something new, and in this sense looking at evidence from printed books yields an atypical picture of what was happening even for the middle classes.

At the same time these books do indicate a considerable amount about the construction of domestic social activity in the middle classes from the Renaissance to the coming of industrialisation. Where the picture becomes far more complicated is during the nineteenth and twentieth centuries when the print medium reaches out to a vastly enlarged audience, and we begin to see preserving skills presented in radically different ways.

The main part of this discussion will explore the reasons behind the dearth of preserving information in most domestic cookery books from the 1830s, and its reintroduction into some groups of books from the 1880s. The chapter suggests that skills which had been necessary to survival because they ensured a supply of food, whether to the agrarian or the new family domestic economy, were, for a number of reasons, simply made redundant in the early nineteenth century. What becomes of interest is why people then chose to reintroduce these skills and what reasons they had for doing so.

The books that survive from the sixteenth to early nineteenth centuries are, for the most part, substantial cared-for products that represent a relatively affluent readership. Simply due to the way books were produced during this period, much ephemeral writing aimed at labouring people has not survived, and we have few examples to indicate what might have been the concerns of such an audience.

Of the extant books concerning food from the sixteenth to mid-seventeenth centuries, most address the courtly lady or the gentlewoman emerging from the newly landed gentry; and most present preserving skills as an important domestic responsibility with one or two writers treating the field, superficially at least, as a lady-like hobby.

The earliest cookery books were concerned with sugar cookery, much of it directed to the preserving and conserving qualities of this relatively new foodstuff which was suddenly coming into Europe in large quantities. Other aspects of preserving were primarily to do with vinegars, and these sections were often combined into books with sections on medicine or cosmetics and brewing. By the 1630s, sections on preserving were increasingly often included in books about cookery, although the two sections were kept quite separate.

Indeed one of the reasons preserving was considered a suitable activity for an aristocratic lady may well have been its separation from mundane cookery, as well as the prestige it carried with it of a knowledge essential to housekeeping. Partly, one suspects, in an attempt to imitate what was thought to be the life-style of aristocratic women, several late seventeenth and early eighteenth century books like *The Accomplished Female Instructor* (1704) aim to teach conduct, preserving, conserving, household receipts and medicines but not cookery.

After the Commonwealth period and particularly after 1695, books on food were aimed more and more at burgeoning middle-classes. The books that survive indicate that an understanding of preserving skills was still considered essential to the activity of the household. It was the fundamental knowledge upon which planning ahead, budgeting and responsible household management were founded. But the kind of household in question, and particularly the work of women within it, was becoming quite different from that of the late Renaissance.

An example of how the household was changing can be gained from a comparison of Gervase Markham's *Country Contentments* (1615) with Eliza Smith's *The Complete Housewife* (1727). Markham delineates the duties that fall to the woman of a household but also outlines their interconnection with the whole range of domestic responsibilities.

Furthermore, it is clear that Markham's woman of the household would not have been working alone. In contrast, Eliza Smith concentrated on preserving, cookery and brewing as specifically the housewife's or gentlewoman's province, and includes seasonal bills of fare, table-settings and medical recipes. It is not totally clear, but the impression is given that Smith's housewife is not working with a group of people although she may have had servants. Markham's woman of the house is working within a rural economy, firmly seasonal, and she survives into the eighteenth century, mainly in the form of the housekeeper to large landed houses and partly in the new profession of innkeeper.

Smith's housewife, still aware of the seasons, is an urban creature dependent upon street markets, whose successors become less and less gentlewomen and more plain housewives to whom preserving skills are, as in Penelope Bradshaw's *Family Companion* (1750) or Susannah Carter's *The Frugal Housewife* (1765) or E. Spencer's *The Modern Cook; and Frugal Housewife's Complete Guide* (1782), a matter of domestic management and frugal housekeeping. Until the early nineteenth century nearly all women would have had to know something about preserving food.

Apart from alerting women to the professions of housekeeper and innkeeper and popularising individual writers, the main reason for printed books on the topic must lie partly in the changing social structure of the middle-class domestic household, which gradually placed all the responsibility for these skills onto the single housewife — although she may have directed servants to help her — and partly in the market-based economy which the housewife had to learn to use frugally.

Later in the eighteenth century a better understanding about the principles of preserving food, with a new technology applying the understanding and with commercial outlets exploiting the product, fundamentally undermined the need for such skills in a domestic setting aimed at frugality and in doing so fundamentally altered the activity of the housewife: she no longer preserves but buys, she no longer produces for herself but consumes products made for her.

More than this, activities that would have occupied a large part of domestic budgeting and household management no longer needed to be carried out. In order to grasp the far-reaching effects of changes in the technology of preserving I would like to summarise some background dealt with in greater detail elsewhere in this book.

Preserving techniques in Britain until the early nineteenth century, in descending importance to the majority and in ascending cost, included drying, salting, potting, vinegar pickling, sugar-bottling or candying, and conserving in alcohol. As with all preserving techniques, they depend either on the addition of a preservative or upon the deprivation of the rotting agent which is usually either moisture, air or heat. Sometimes the former affects the latter.

The main aim of each technique was to keep the foodstuff edible until such time as it was to be eaten, although the process would have produced flavours and textures which came to be appreciated for themselves. The most widely written-about techniques in these early books for the middle-classes discuss the use of salt and sugar. The story of nineteenth century preserving technology is mainly about how the use of sugar in bottling came to be superseded by canning, and the use of salt in dry-salting, brining and pickling came to be superseded also by canning but more importantly by refrigeration. In the late medieval period sugar was a very expensive product. It was soon recognised that it could be made to go further by diluting it with water into a syrup.

Although this lessened its preserving qualities, the bottles that held the syrup served another function by excluding air. The exclusion of air was an important principle that interested many early scientists such as Robert Boyle, and people who wrote books with sections on preserving often implied and sometimes explained that bottling was the main technique allowing for economising on sugar.

Yet even in the eighteenth century there was an awareness of further complexities, and writers advise on the preference for narrow-necked jars and warn their readers not to put their fingers, or utensils that have been used for other foods on the table, into jars of preserves. Until the late eighteenth century, most recipes concentrate on excluding air from coming in: there are elaborate combinations of lids, paper, brandy-paper, leather, bladder, cork, cork and resin — and excluding materials — fat (preferably mutton because of its low setting point), oil, or juice (for example lemon).

But it was gradually recognised, particularly following Priestley's work with oxygen in the 1760s, that another problem was the 'air' already in the jar, in the very mixture to be preserved. This problem was referred to as 'oxidation' and was the main concern of the next advance in technology.

Due to a sugar shortage during the Napoleonic Wars, the post-revolutionary government established a prize to encourage new work on the preservation of food in bottles. In 1808 Saddington proposed, to the English Society for Arts, the boiling and scalding of bottles as a solution; and in 1810 Nicolas Appert finally won the large money prize from the French government for his careful organisation of heated bottles with a champagne-type seal.

The results of Appert's work were studied by the chemist Guy-Lussac, who concluded that it was the oxygen being driven out of the bottle during heating, and then prevented from reentering, which resulted in success and the prevention of oxidation. At precisely this time, again with the practicalities of army provender in mind, Peter Durand in England took out a patent on sealing food in cans. Canned food was taken on Parry's arctic explorations in 1814-16, and came into its own during the Crimean War.

By the 1830s the principles were better understood and the technology more precisely applied so that there was a reliable method for producing bottled goods, and the same could be said for canned goods by the 1850s. But the products had to reach the buying household. This they did through the explosion in retail trade outlets or shops occurring in most urban centres from the 1840s, and eventually all but supplanting the street markets. The products needed the shops and the shops needed the products. Markets were increasingly less central to the dominant urban economy and the housewife was urged instead into shop-bought bottled and canned goods by a growing advertising industry based on the packaging of the goods.

Evidence that the housewife responded does seem to be provided by the cookery books of the early nineteenth century. Elizabeth Raffald's *The Experienced English House-keeper* which was published several times between 1769 and 1796, has a large and consistent section on preserving. In contrast, an equally popular nineteenth century book, *A New System of Domestic Cookery* by Maria Eliza Rundell, includes a large number of preserving recipes in the early edition of 1807, but by 1819 there are far fewer.

Some recipes were shifted to a section specifically on sweetmeats. Also of possible significance, whereas the writer/ editor of the 1807 edition explicitly stated at the start of the sweetmeat section that these recipes were less important for private families since such things could be bought at far less expense than they could be made, the identical statement is transposed to the preserving section in the edition of 1819. By the middle of the nineteenth century, so few cookery books contain a substantial section on preserving that the exceptions to this rule are particularly informative. In Eliza Acton's *Modern Cookery* of 1845 there are detailed instructions for preserving fruit, but we have to remember that this is the same Acton who was a working journalist, concerned with issue of public welfare, and who was to write *The English Bread Book* (1857), specifically to address the problem of the adulteration of shop-bought bread by encouraging people to make their own.

By the 1868 edition of *Modern Cookery*, Acton feels the need to make the same intentions clear for her section on preserving and scathingly criticises the 'unwholesome [preserved] fruit vended and consumed in very large quantities' by the shop-buying public. Acton's stress on the 'wholesome' is a significant precursor of the direction that preserving recipes will take when they re-enter cookery books at the end of the nineteenth century. No longer can the housewife claim to be frugal when she uses preserving skills, but she can claim to produce more nutritious and healthy food. The same argument, however, did not apply to salting.

Techniques of preserving that used salt were far more widespread than those using the more expensive sugar, and much older in cultural practice. Although eggs and some vegetables, particularly green beans, were salted, the main foodstuff preserved in this way was meat. Beef cattle in particular were slaughtered wholesale in the autumn because there was rarely enough hay to keep them through the winter, so the meat had to be preserved.

Brining and dry-salting must have been such a central part of general life that it is not surprising that there are few recipes in the early cookery books, despite the fact that with the imposition of taxes on salt from 1785 to 1825, frugality with salt must have been important. By the end of the eighteenth century, most books included some recipes, for example there is almost always one for Westphalia ham and salt beef, and from the early nineteenth century there is an increasing number of recipes for foreign salted foods like polonis and salamis, presumably in response to wider continental travel of private families.

But these recipes, too, disappear from most domestic cookery books after the mid-century, only surfacing in a few trade receipt books for professional shop-keepers like James Robinson's *The Whole Art of Curing, Pickling and Preserving*. This work is addressed to the trades, particularly the fishmongers, but includes (unacknowledged) many of Rundell's recipes: the line between commercial and domestic preserving was not yet clearly drawn.

It appears that the main reason that salting recipes fade from cookery books, apart of course from the advent of the can, is the introduction both of ice-cooled and of refrigerated boxes during the 1830s. The use of cold to preserve food had fascinated the English from Bacon's experiments in 1626, to Pepys' amazed discussion in the 1670s on the frozen Baltic chickens, to the later 1799 discovery of the frozen mammoths in Russia. Since the Renaissance, several great country houses in Britain had had ice-houses, but until Rundell's advice in 1807 on unfreezing food slowly, there were few remarks in general domestic books.

From the early 1800s the trade in ice grew from the first imports from Norway in 1822, to the artificial production of ice in the 1860s. At the same time Jacob Perkins, an American engineer working in Britain, developed the ice-cooled refrigerator and produced it for sale between 1835 and 1870. From the 1860s meat was available in cans, and from the 1880s cheap imports from Australia and New Zealand were being imported in cans and by refrigerated ships.

A secondary reason for the loss of salting recipes was a growing concern with the nutritional value of preserved foods. Michael Donovan, that centre of sense, comments that 'The object is ... to preserve, as much as possible, the nutritiousness of food and its salubrity, and to prevent its doing actual injury to health ...'. Just as the French army was concerned with dependable food supply during the Napoleonic Wars, so the British army launched intensive study into methods of food preserving during the 1840s and 1850s leading up to the Crimean War.

Food and its Adulterations compiled by A. Hill Halsall in 1855 lists a series of tests conducted by and for the army in ways of keeping meat without salting it: not only canning and drying but also smoking, packing in tin foil, vacuum packing and producing extracts of vegetables and meat. In 1859 Beeton states that the action of salt on meat decreases its nutritive value, and by 1870 William Tegetmeier is advising against the consumption of much if any salted meat.

There is some evidence that American trends in health foods also began to have some influence on British attitudes toward eating at the end of the nineteenth century. Russell Trall's *The New Hydropathic Cookbook,* published in England from 1883, cites salt meat as the prime example of bad food.

Also during this period there was the vigorous commercial marketing of Liebig's 'Extract of Meat' for domestic use, by the LEMCO organisation whose advertising suggested that salting meat was deleterious to health. Indeed, apart from one or two recipes apparently included to satisfy those who craved the taste of salted meat, and a brief resurgence from 1918 to the year 1925 (when the Public Health Preservation in Food Act actively promoted domestic refrigeration), only a few recipes for salting meat occur in British cookery books until Jane Grigson's *Charcuterie* of 1967.

Some of this account may help us partly to understand the dearth of preserving recipes in domestic cookery books from the 1830s to the 1880s. What is more difficult to assess is why any such recipes should have reappeared at all. From the 1850s onward, the audience for printed cookery books expanded considerably, and exploded during the 1870s and 80s on the back of a proliferating periodical publishing industry, which was creating markets and responding to the demands for a wide-range of general topics accessible to the reading publics that were defined in the aftermath of the

Education Acts of 1867 and 1870. At the same time cookery books continued their progress into specialised genres, and focused not only on narrower topics but also on class divisions. Alexis Soyer's *The Gastronomic Regenerator* (upper-class, recherche dishes), *The Modern Housewife* (middle-class) and *Shilling* Cookery (artisan) is but one example of a specifically class-orientated approach common to many writers of the mid-century.

But for high or low, rich or poor, few of these books contained advice on preserving although several contained advice on how to use canned goods, for instance Emily de Vere Matthew on *Tinned Meats* (1887), and Jane Panton's *From Kitchen to Garret* (1888) which advised on the use of cheap canned and frozen New Zealand meat. One exception which *may* indicate a group of "lost" books is the publication from the Labourer's Friend Society *A Second Series of Useful Hints for Labourers* aimed at the artisan with an allottment and containing advice on how to salt your pig.

However, in the explosion of the 1870s and 1880s a distinct pattern emerges: books for working-class women do not contain recipes for preserving while those for middle-class women, and slightly later also for wives of artisans, do. *The Official Handbook for the Training School for Cookery,* published from 1888 for many years, contains recipes for using canned meat, one recipe for pickling meat and one for pickling cabbage.

The foremost reason for the lack of preserving recipes is economic. The wider ranging household management and planning requirements of preserving of any kind imply having the time to do it, the money to buy ingredients in bulk as well as preserving agents and equipment, as well as, usually, a source of heat and always space for storage.

Most of the urban working-class population would not have had easy access to all, or indeed any of these requirements. The very concept of there being periods of plenty during which people save up against periods of famine is not part of an industrial working pattern. Neither the school text-books written for this audience nor the more general books of advice to these housewives, consider preserving as an important skill. Indeed W. Tegetmeier's *A Manual of Domestic Economy* account of working-class diet assumes that any fruit and vegetables are a luxury to this class, let alone being available in quantities enough to preserve.

And fifty years later C. H. Senn's *Popular Cookery* of 1920 assumes that its readers buy in any preserved foods they need from shops — although his *Practical Gastronomy* for the middle-class housewife contains a range of recipes for conserves and pickles. Contrary to some current speculations, there is growing evidence not only from the cookery books but also from recent research in social history, that cans and can-openers were accessible to and used by the working-class population of the late nineteenth century.

Unlike schools for working-class girls, middle-class schools did not teach cookery, so the text-books on general food preparation and management for these readers were usually written for specific Cookery Schools. Apart from these books this audience was also addressed by practical household management books which assumed that the housewife had at least one servant, by textbooks written for women attending the National Training Schools of Cookery in order to teach domestic economy in schools, and by conduct or etiquette books whose purpose was to provide information about what needed to be done in your household but did not expect you to do it yourself.

There are several strands offered by these books when they include recipes for preserving, but the most important is that of nutrition. To understand the influence of this strand, it is useful to look again at changes in the understanding of the principles of food preservation. Until the early 1800s, the scientific and technological attention to preserving had focused on preventing the foods from rotting for immediate reasons of economy and frugality.

Nineteenth-century scientific advances document a shift in focus away from frugality to nutrition: a move that closely parallels and must be interconnected with the same shift in the cookery books of the period, for preceding the resurgence of preserving recipes in books for a middle class audience are the few books on vegetarianism or 'health' foods, usually beginning in the United States, directed with prophetic fervour to a more wholesome diet. These isolated books from the 1840s to the 1880s are being produced at the same time that Pasteur and Tyndall are doing their separate but related work on the effects of yeasts, moulds and bacteria on the deterioration of food.

Evidence that air carried not only 'oxidising' agents but also unseen organisms that rotted food, led to even more efficient systems for bottling and canning. However Britain, possibly because of its concentrated urban, industralised and shop-centred domestic economy, was slow to respond. Despite the success of George Fowler's patented bottling system during the 1890s, even in 1916 the Royal Horticultural Society is complaining about the need to import good bottles from the Continent, and canning was never a serious proposition for domestic preservation even in National Training School text-books, although some books from the United States containing substantial instructions on canning were published here from 1890 to 1920 and there was certainly a domestic canning machine on the market.

At the turn of the century scientific attention began to focus on the newly-discovered presence of enzymes, along with an extended understanding of fermentation processes and an appreciation of the role of vitamins in body chemistry. For food preservation, the end result of this attention was a proliferation of suggestions for preserving food with as little heat as possible. Concern for the role that enzymes played in determining the taste of food as well as concern for the delicate biochemical balance maintained at body temperatures, meant the recognition that heating foods to preserve them in bottles was destroying their nutritional and gastronomic value.

One solution was a short-lived attempt to promote the pressure cooking of cans for brief time periods, and another was the extensive and helpful experiment by the Royal Horticultural Society on the shortest effective heating times and lowest effective temperature for bottling which led to a classic book on bottling which has been adapted and revised for nearly a century: *Fruit Bottling*. But, ironically, the primary response to the deleterious effects of heat was to consider what could be 'added' to the environment of the food to stop rotting agents getting to it while preserving its natural processes. In the balance were two processes.

The first concentrated on providing a surrounding unfriendly to bacteria and moulds, and here chemical additives came into their own. In 1859 Isabella Beeton, among a few others, had advocated using alum in bottling fruit in order to increase the dependability of preserving, but from the late 1800s more and more chemicals were added for this purpose, the most common being sodium sulphite.

The second process to which people at that time paid increasing attention, was that these additives might not only prevent the entry of external rotting agents but might also slow down, possibly by altering it, the natural maturation of the foods themselves.

It is difficult to differentiate between the two processes and the second clearly changes the nutritional value and probably also the taste of the foodstuff. Worry about exactly what these additives were doing became so widespread, as use of them became more and more ubiquitous, that the government had to control them, and in 1925 published the Public Health Preservation in Food Act, which is in effect an early listing of allowable and prohibited E-numbers.

The focus on the wholesome and the nutritious by scientists and technologists, was filtered out into books for a middle-class audience primarily through the text-books for training domestic economy teachers. These text-books, initially appearing in the 1870s and 1880s, claim for those who study them a serious area of learning. In most the pedagogic tone is based on the rhetoric of modern science: fact, proof, method and explanation.

It has been suggested elsewhere, and I think it is underwritten by these books, that domestic economy teachers were trying to define a field of academically respectable study in order to justify the serious status of their work; and since there were more obviously scientific aspects in preserving than elsewhere in cookery, it was a clear field for emphasis in their training.

The kind of book produced for these training schools, such as Catherine Buckton's *Food and Home Cookery* or E. G. Mann's *Domestic Science Manuals* among very many others, drew on an earlier tradition of male writers who had worked in the technical schools of the 1850s to 1870s. John Buckmaster's lectures on cookery were brought together into *Buckmaster's* Cookery and William Mattieu Williams produced The Chemistry of Cookery. Both writers were widely influential, particularly Buckmaster who lectured at the National Training School for Cookery in London, and both focused on science as the basis for domestic cookery, Williams stating that

The kitchen is a chemical laboratory in which are conducted a number of chemical processes by which our food is converted from its crude state to a condition more suitable for digestion and nutrition, and made more agreeable to the palate.

In turn, Buckton and her colleagues in their text-books for training teachers, are concerned to discuss oxidation, fermentation, fibres, yeasts, moulds, bacteria, pasteurisation, sterilisation and so on; and they do so largely in the context of the preservation of wholesome and nutritious food.

When the students of the training schools went on to write domestic cookery books of their own at the turn of the century, as many of them did, preserving once more found a place, again firmly in terms of nutrition and wholesomeness. For example there is M. Fairclough's *The Ideal Cookery Book,* written for her cookery school, and containing a large section on preserving.

The domestic reader had books such as *The Housewife's Cookery Book* published in 1920 but in effect an update of

Warne's Model Cookery from 1871, which begins with the claim that 'The science of cookery is a knowledge of the choice of food and food materials, for just as an engine requires food to enable it to work, so the body requires certain foodstuffs to keep it in working order', yet continues much as the 1871 edition, but with the addition of a substantial section on bottling.

Less pretentious were the many specialised books focusing on preserves such as Helen Souter's *Aunt Kate's Jams and Jellies Book* or Rose Brown's *Pastry and Preserves* or S. Beaty Pownall's *Queen Cookery: Pickles and Preserves*. These writers also contributed to a small group of books aimed at teaching the newly impoverished genteel lady how to make delicacies that one could no longer afford to buy: an interesting index to the fact that economy could be reintroduced as an element.

Furthermore, they also produced a well-defined but still limited group of books aimed at the upper-middle class lady with time on her hands and searching for something to do. Just as this lady was usually expected to be able to produce at least one meal on her own, a star turn, for the delight of her husband, she could also turn to the making of preserves as a delicate hobby. Like the newly-emerging monied woman of the early seventeenth century to whom she was occasionally compared, the late nineteenth-century lady could not be involved in mundane cookery but could take on the role of producing elegant gifts, acting the Lady Bountiful.

These Lady Bountiful books formed a curious partnership with the other main promoter of new preserving skills: the Royal Horticultural Society. Possibly due to the Allotment Act of 1887 which made it legally necessary for all local authorities to provide allotments, large numbers of people were growing their own vegetables and fruits, and from 1910 the Royal Horticultural Society was awarding prizes and medals for preserved fruits and vegetables.

In 1916 the society published Wilks' *Fruit Bottling*, its flagship guide to preserving. However, the response from individual members of the Horticultural Society began earlier with for example the series of articles by May Crooke in the 1905 *Farm and Garden* on the small holdings commission, or the Stoney's *A Simple Method for Bottling Fruit at Home* or Edith Bradley's *The Book of Fruit Bottling*. This last contains an introduction by Wilks in which he comments that fruit bottling had gone downhill from the 1840s when he was a boy to its nadir in 1885, when 'I doubt whether there were a dozen ladies in the land who did their own bottling and preserving'.

These books arrived just in time to lay a basis for response to the demands of World War I. Ernest Oldmeadow straightforwardly entitles his contribution: *Home Cookery in War-Time*, and resuscitates many eighteenth-century preserving methods such as the use of mutton fat to seal jars, in an attempt at economy.

While the Great War did remind people that domestic preserving could save money, the stress was still on health. Louise Andrea's *Home Bottling Drying and Preserving* emphasises the conservation of 'nutritive value' and the 'wholesome', but in the light of war-time experience she proclaims 'Empty jars can be put to splendid use; if allowed to remain empty they are voiceless but eloquent reproaches'; indeed 'Empty jars are slackers'. By the end of the war Bristol University had established a Fruit and Vegetable Preservation Research Station.

After the war there was another wave of books specifically on preserves and of general books containing substantial sections on preserves. Among the former are the Banks's *Fruit and Vegetable Bottling*, the Royal Horticultural Society's update on Wilks' *Fruit-Bottling*, and the closely related *Domestic Preservation of Fruit and Vegetables*, edited by M. L. Adams for the Ministry of Agriculture. Among the latter are found the Good Housekeeping Institute's newly influential guides.

The Good Housekeeping Institute's director, D. Cottington Taylor, also published *Frigidaire Recipes* which is by and large cooking with refrigerated foods in 1930, and by 1938 the Canned Foods Advisory Bureau employed Janet Bond to write *Janet Bond's Book: A Practical Guide to the Use of Canned*

Foods, in which she claims that canned goods not only preserve more vitamins than domestic preserving, but have also arrested the decline in fruit culture, freed women from the kitchen into careers and acted as the guardian of the Nation's Health.

But 1939 and World War II shifted the emphasis firmly back on to preserving within the home and the 1940s saw a whole series of guides to effective methods, led by Crang and Mason's revision of Adams' book, for the Ministry of Agriculture, under the same title *Domestic Preservation of Fruit and Vegetables*. The book begins resolutely on the first page saying that: the object of preservation is to take food at its point of maximum palatability and nutritive value and keep it at this stage ... a study of these changes has shown that they are due partly to the action of enzymes in the food, partly to the growth of micro organisms in contaminating them.

It proceeds with instructions for jams, jellies, marmalade, cheeses and butters, bottling, canning, deep-freezing, chemicals, syrups, candying, preserving vegetables, vinegars, pickles, chutneys, sauces, drying, salting beans and storing. Crang and Mason's work, apart from the sections on deep freezing, could have been written before World War I, but it includes a rather different audience, the working class, in its address.

Most of these books on preserving from the 1880s to the 1940s were resolutely directed towards a middle- and upper middle class audience, and the class specificity raises a difficult problem. Ever since domestic preserving as an essential for survival was superseded by shops and their cheap goods, it had occupied a tenuous place in cookery books. Exactly because it moved out of the mundane, or those things essential for everyday survival, it had nothing to fall back on to prove its necessity or relevance. Preserving, while attempts were being made to reclaim it in terms of nutrition, became fundamentally superfluous to daily needs.

In a curious way the situation focuses on the fact that during the nineteenth century preserving in any but the most basic sense was beyond the poor, and then the working-classes: they were too impoverished to practice frugality and thereafter too impoverished to practice nutrition. It is ironic that while the Napoleonic and Crimean Wars precipitated the processes of domestic preserving out of women's hands, World War I and particularly World War II, partially put it back.

The events related to these two twentieth-century wars also broadened the constituency for preserving by changing food supply routes, by making preserving once again essential to survival; and, possibly most importantly, because there had been a radical break in the oral history of preserving techniques, from say 1830 or 1840 to 1910, the surge of printed book instructions at the turn of the century were not just addressed to a privileged audience but to a much wider range of reader.

An introduction to the basics went hand in hand with an introduction to condiments, relishes and conserves that were not strictly essential. General cookery books from the immediate post-1939 period invariably contain a section on preserving techniques, although these largely diminish to conserves and pickles by the end of the 50s. Why do people continue to preserve on any scale? This is an extremely difficult question to answer. After all we do not technically need to do so for survival or nutrition, and there are many cheerful commercially-produced gift bottles around.

For certain generations, in which I would include my own, there is a nostalgic remembrance of childhood post-war rationing days when it was necessary to bottle and jam, to harvest in plenty, to put up against want and to waste not: then as now it was often a communal and social activity. For some, there is the confidence of knowing exactly what has gone into the foodstuff: home preserving is the only sure way of evading major additives and of controlling sugar content, and so on.

For many, there is the delight in the activity of cooking and in the beauty of the product, neither of which is strictly necessary. Possibly for most people preserving has become a kind of signature. Making our own preserves, conserves and pickles allows us to vary the flavour and taste of a recipe that is frequently traditional, and to recognise quite precisely how the network of food distribution and supply, quality and quantity, changes from year to year.

The products are also often communally distributed, so that every year you wait with anticipation for one friend's pickle and with dread for another's jam; they are the staple of countless school sales and fund-raising fairs. Preserving brings the general domestic cook closer to the subtleties of cooking than our mundane cooking normally allows, and in our culture it is looked upon primarily as a leisure activity. How long it will remain so is unclear.

3

Banana and its Market

The present study is directed neither toward justification nor criticism of the United Fruit Company's operations over the more than half century of its history. We feel that it would be an essentially sterile exercise to attempt to disentangle the skein of events since 1899. Since then, a banana industry of sufficient size to assume importance in international commerce literally has been created by imaginative traders, with the United Fruit Company exercising a dominant role in the process. To reconstruct and appraise the historical record in a way that would allow recriminations to be balanced against solid accomplishments would call for an omniscient judgment that we do not feel we possess.

Rather, we have set ourselves the much more modest, though still not unambitious, task of attempting to contribute toward an understanding of what the banana industry is, of who benefits from it and by how much, and to appraise the record of the United Fruit Company in the industry as it operates today. Our perspective, then, is contemporary rather than historic. Most of our field work was completed in 1956, and our major concentration is upon operations in the year 1955, the latest year for which national accounts data for the several banana-producing countries were available in relatively complete form.

We are acutely conscious of the fact that our study deals with a field in which the ideas of most people are coloured by strongly held preconceptions based upon an interpretation of past events rather than upon an examination of the current record. It has seemed to us that a useful service could be performed by describing the present organization and procedure of banana production and marketing, by measuring what can be measured, and by limiting subjective judgments to matters not susceptible to appraisal in objective terms. Where we are forced to make value judgments, it is our hope that at least relative objectivity may be achieved through the circumstance of a joint authorship that combines North American with Latin American outlooks.

More particularly, our interest in the United Fruit Company record is focused upon its impact upon the economic development process in the six Latin American republics selected for intensive study-Guatemala, Honduras, Costa Rica, Panama, Colombia, and Ecuador. These were singled out because their combined banana shipments represent close to 60 percent of the tonnage weight of world banana exports, and because about 95 percent of the bananas handled by the United Fruit Company in 1955 was produced in or purchased from these six sources. Through this sampling procedure, we could limit our field work to supportable dimension, and still cover the bulk of the world banana production for export, and a preponderant portion of United's banana procurement operations.

In concentrating upon United Fruit's contributions to economic development in these six countries, we are guided by our conviction that the widest possible diffusion of vigorous economic growth is one of the most important concerns of the contemporary free world. We are convinced that adherence to and strengthening of democratic institutions in the less developed countries of the world depends in large measure upon the demonstration that aspirations for general economic progress can be realized under free institutions. And we believe that the flow of investment capital from the capital-generating nations of high industrial development to the capital-poor countries is a major instrument for helping to stimulate balanced growth in the latter.

We start with the premise that investment capital, private or public, will not continue to flow unless it receives a return judged to be adequate. Therefore we shall examine the profitability of United Fruit investments in the six republics upon this criterion. But it seems equally clear to us that continuing hospitality for foreign private investment ventures cannot be expected to endure unless there is clear evidence that it is contributing to the development of the host nations to a degree that would not be realizable without it.

Accordingly, we shall examine the United Fruit record to see whether or not its operations present convincing evidence of satisfactory performance upon this score. Before we embark upon such an examination of the operations of the company, it is requisite that we establish a frame of reference, by presenting a picture of the world banana market as a whole.

PRODUCTION AND CONSUMPTION

The Food and Agriculture Organization of the United Nations estimates world banana production in 1955 at 11.6 million metric tons or about 25.7 billion pounds. It apportions about 46 percent of this to South America, 23 percent to Central America, 23 percent to Asia, 6.5 percent to Africa, and 1.5 percent to Oceania. As such, the banana crop is the fourth largest of the world's reported fruit crops, exceeded in tonnage production only by grapes (88.0 billion pounds), by citrus fruit (39.2 billion pounds), and by apples (29.1 billion pounds).

If the portion of the grape crop produced for making wine (71.4 billion pounds) rather than for consumption as fruit is deducted, and that of apples produced for cider (8.8 billion pounds), bananas displace both grapes and apples and are second only to citrus among the world's fruit crops consumed directly as food. Excluding grapes, citrus, and apples, the tonnage of bananas exceeds by a considerable margin the combined weight of the remaining important fruit crops of the world—pears, pineapples, dates, and figs (17.2 billion pounds, combined, for 1955).

Table: World Banana Production

Producing area	Million Pounds	% of total
Central America	5,950	23.2
South America	11,700	45.6
Asia	5,950	23.2
Africa	1,650	6.4
Oceania	400	1.6
World Total	**26,650**	**100.0**

Table given above covers a world population for 1955 estimated at 2,490 million persons. On this basis, the average consumption of bananas by each man, woman, and child was 10.3 pounds in 1955 on a stem-weight basis. Only the subcategory of citrus fruits, comprising oranges, tan gerines, and clementines shows a larger per capita consumption, 12.6 pounds; and only apples, 8.1 pounds, and grapes, 6.6 pounds, were serious rivals of the banana among the world's consumption fruits.

It is, of course, obvious that such blanket averages have little relationship to the actual pattern of fruit consumption by the world's populace. Banana production is restricted to the tropics and more particularly to humid tropic areas. For successful growth, most varieties require a temperature range between 55° and 105° F., and almost all suffer severe damage when temperatures drop below 50° to 52° F.

Since the banana cannot be grown as a seasonal crop—its cycle of development ranges from 12 to 15 months from planting to harvest—its range of cultivation is restricted to the zones in which year-round temperatures are within these extremes. It is further restricted to areas that can provide its exceptionally high moisture requirements (four to five inches monthly or 60 inches annually as a minimum) through heavy and evenly spaced rainfall or generous water supplies for irrigation.

The banana thrives best in alluvial, well-drained soils, though it will tolerate clay soils of friable consistency. Since its stalk is merely a tightly rolled cylinder of leaf sheaves, it is particularly vulnerable to blowdowns or uprooting by floods when heavy with fruit. Even relatively mild winds can seriously injure the fruit by shredding the protecting leaf structure upon which healthy fruit production depends. The areas that can grow bananas successfully upon a commercial basis must therefore provide the necessary environmental factors of temperature, moisture, soil characteristics, and freedom from damaging wind and flood recurrence.

In general, the areas that can provide a hospitable environment for banana culture are found in low-lying, high-precipitation lands between 20° North and 24° South latitude, with the extremes set by 24° North and 30° South latitude. The range of actual banana production is indicated by the areas listed in Table given above.

It might be assumed that the areas of important production would be the areas of major consumption. Yet, as indicated in Table given below, some of the broad areas of banana production are heavy banana consumers as well, while others are not. On a per capita basis, the highest level of consumption in 1955 was in South America, 80 pounds per capita; while Central America (including Mexico and islands of the West Atlantic) consumed about 52 pounds per capita; Asia less than 7 pounds; Africa about 1.5 pounds; and Oceania, 27 pounds. In the United States and Canada combined consumption of bananas was 20 pounds per capita, and for Europe it was 9 pounds—an average of almost 13.5 pounds per capita for the two combined.

Table: Banana Production and Consumption (Stem-weight basis)

Area	**Production**	**Consumption**		
	Billion lbs.	**Percent**	**Billion lbs.**	**Percent**
Central America	6.0	23	3.0	12
South America	11.7	46	9.9	38
Asia	6.0	23	6.0	23
Africa	1.6	6	0.3	1
Europe	—	—	2.5	10
Oceania	0.4	2	0.4	2
North America	—	—	3.6	14
Total	**25.6**	**100**	**25.6**	**100**

Thus, up to the present time, it is fair to say that bananas have assumed as important a place in the average diet in the two major industrialized areas of the temperate zone as for the vast majority of the people living in what we regard as tropical areas. In India, for example, the apparent annual per capita consumption of bananas is only about 11 pounds. Since there is so little inter-country trade in bananas within the tropic zones, it follows that there is an extraordinarily high annual per capita consumption in some of the major producing countries, while in other tropical countries the consumption rate of bananas is very low.

For 1955, on the basis of *reported* production minus export figures, Brazilians consumed something like 150 pounds per capita; Costa Ricans, 350 pounds; Panamanians, 380 pounds; and Ecuadorians a fantastic 500 to 600 pounds per capita. Even allowing for apparent inflation in some of the reported production figures and for the known fact that there is considerable feeding of bananas to livestock in some of these countries, the human consumption of bananas where they are grown in profusion clearly reaches heroic proportions.

International Trade in Bananas

Of the estimated 25.7 billion pounds of bananas produced for commercial sale in 1955, something over 25 percent was exported in international trade. The breakdown by areas of export and import, is adapted from figures compiled by the U. S. Department of Agriculture. We have adjusted the North American import weights slightly upward upon the basis of evidence that the official estimates of the Department of Agriculture do not give sufficient allowance to the increases in average stem weight in recent years. This has the effect of raising the world total of 1955 imports from the Department's estimate of about 6.6 billion to 6.7 billion pounds.

It is probable that, on the export side, there is a comparable degree of understatement of weights for fruit going to North America but we have not attempted to make this adjustment in the data presented. The discrepancy is not large enough to alter substantially the proportionate shipments as reported by broad area. Reported import and export figures never are in exact balance because of inevitable inaccuracies in accounting and because, due to time consumed in ocean transport, there are always some shipments credited as exports at the end of one year that only show up as imports when delivered at the beginning of the following year.

On the export side, the data show that almost 80 percent of all reported banana exports in 1955 were shipped from Middle America, including Mexico and the islands of the West Atlantic, and from the three South American banana exporters—Ecuador, Colombia, and Brazil. Africa accounted for about 20 percent; Asia (entirely from Taiwan) for a bit more than 1 percent; and Oceania for less than 1 percent. It is clear, then, that Latin America is the dominant bananaexporting area of the world, and that the West Coast of Africa (in which the tabulation includes the Canary Islands) is the only other major area that plays a significant exporting role, and that a relatively minor one, in the overall picture.

On the import side, North America (United States and Canada) and Western Europe, neither of which produces any banana on a commercial scale, are the outlets for over 90 percent of world banana trade. Argentina, Chile, and Uruguay are the principal Latin American importers, with Brazil and Ecuador as sources of supply. The breakdown of world banana imports for 1955 is shown below.

Of the North American imports, about 92 percent went to the United States and a little more than 8 percent to Canada, most of the latter transshipped in bond from U. S. ports. Of the three South American importing countries, Argentina takes more than 80 percent of the total. African imports are divided among the Union of South Africa, Algeria, French Morocco, Southern Rhodesia, and Tunisia in the order of their importance as banana importers. Japan is the only listed Asian importer, with about 54 million pounds imported in 1955; and New Zealand the sole importer in Oceania at a slightly lower level than Japan.

Table: World Imports of Bananas, 1955

Importing area	Billion lbs. imported	% of world imports
United States and Canada	3.60	53.8
Europe	2.47	36.9
South America	.43	6.4
Africa, Asia, Oceania	.20	2.9
Total	**6.70**	**100.0**

It now can be seen that this remarkable tropical fruit, originating in the Far East and for thousands of years rarely even listed in the learned chronicles of the West, has undergone a dramatic metàmorphosis—largely within the last century. Almost in the manner of historic glacial drifts, it has crept from its original domicile in the East into western zones, until today of all bananas grown, the roots of 70 percent thrust down in the soil of the Western Hemisphere.

Another 5 percent grows along the African shores that rim the Atlantic. Considered in marketing terms, within the short span of the past 60 years this exotic fruit has burst the containing bounds of its central tropic environment, and has moved northward, and to a lesser extent to the south, to find a place in the fruit bowls of temperate zone tables from the Yukon to California, from Scandinavia to Austria and Italy, and from Chile to Uruguay.

Agriculturally, bananas are chained to the tropics. Commercially, about one-fourth of all that are produced find a market outside the temperature zones in which they thrive. And nine-tenths of this fourth find their way to the industrial heart of the western world-to North America and Western Europe, whose inhabitants a century ago scarcely knew what a banana was, except for the scholarly few who read the works of Pliny the Elder or of the Swedish botanist Linnaeus. An important part of our story is concerned with how this remarkable change came to be. It is the more remarkable in that it is a phenomenon that has occurred on a comparable scale with respect to no other delicately perishable, definitely tropical fruit.

The general picture of major world fruit exports, as the average exports in metric tons, 1951-53, is adapted from a study by Erik Mortenson, entitled "Trends in Production and Consumption of Fruit and Vegetables," in the September 1955 issue of the FAO publication, *Agricultural Economics and Statistics*. The table, which was evidently compiled on the basis of official FAO trade statistics, would appear to give a reasonable basis for comparing the relative magnitudes of the reported trade in the several fruits that bulk large in international commerce.

Table: Major World Fruit Exports

Type of fruit	Export 1951- 53 average (1,000 metric tons)	% of freash fruit	% of total
Fresh fruit:			
Bananas	2, 552	40.7	36.4
Orange and tangerines	2,060	32.8	29.4
Lemons and limes	261	4.2	3.7
Grapefruit	127	2.0	1.8
Apples, table	714	11.4	10.2
Pears, table	186	3.0	2.7
Grapes, table	218	3.5	3.1
Pineapples	154	2.4	2.2
Total	6,272	100.0	89.5
Dried fruit:			
Dates	343		4.9
Raisins	285		4.0
Prunese	49		0.7
Dried figs	48		0.7
Other dried fruitf	12		0.2
Total dried fruit	737		10.5
Total all fruit	**7.009**		**100.0**

On this accounting, the trade in bananas for 1951-53 accounted for over 36 percent of all world commerce in fruit and for more than 40 percent of world trade in fresh fruits. Oranges and tangerines make up the only other fruit category that is of even proximate importance as a world trade item upon a weight basis, and the amount of bananas traded is about 25 percent larger. Citrus fruit, however, hardly classifies as a tropical fruit. Again using FAO figures, the 1954 record shows that almost two-thirds of commercially produced oranges and tangerines were grown in temperate zone areas, more than 50 percent in the United States and Western Europe alone.

Temperate zone countries furnish 70 percent of all exports. Over 85 percent of commercial grapefruit culture is restricted to the United States, and three-quarters of all commercially grown lemons and limes are produced in the United States, Europe, Japan, Argentina, and Uruguay. Aside from the fact that citrus fruit is far easier to ship than bananas, the striking fact is that all citrus shipments from *tropical areas* amount to only about one-quarter, by weight, of banana shipments, all of which originate in tropical areas.

Pineapples qualify as a tropical fruit crop, but the FOA figures show that only about 10 percent of total production is exported in world trade, and the great bulk of this was shipped in canned rather than fresh fruit form. Canned pineapples are included in the fresh fruit category upon the basis of the equivalent fresh fruit content.

Dates are preponderantly a tropical area crop, and about one-fifth of reported production is exported internationally. But the big export is in dry rather than fresh fruit form and, in 1954, world trade in dates amounted to less than one-ninth that of bananas on a tonnage basis. Figs are the other entry on the list that in most people's minds would fall into the classification of tropical fruit. Actually, FAO figures assign considerably over half of commercial fig culture to Western Europe and the United States, and total fig exports, again with shipments preponderantly in dried form, account for less than I percent of world fruit trade.

How did it come about that the banana (which is technically a herbaceous vegetable) should have become the one tropical "fruit" that has become a major item in the diet of North Americans and Europeans? Why the banana among the literally scores of fruits that are native to the tropics? Why not the mangosteen of which poet-gourmets have written in ecstatic terms, or the luscious mango, the peptic papaya, or the delicately flavored naranjilla? It is certainly not because of special qualities that make the banana easy to grow or to transport.

We already have pointed out that the banana is singularly demanding with respect to the temperature, soil, precipitation, drainage, and wind conditions of its environment. The areas that can offer an even proximate optimum of all of these factors are relatively limited. As we shall see, bananas are subject to blights of devastating intensity for which it is tantalizingly difficult and formidably expensive to find adequate controls. This is virtually a seedless plant, with new cultivations established by planting large pseudobulbs or rhizomes, and there is no wood stalk to permit grafting.

Thus, there has been no success to date in developing, through the genetic approach, man-made strains that would combine the disease-resistant characteristics of certain varieties with the better qualities for handling and ripening inherent in others that are vulnerable to disease. In addition to disease blights, insect pests that destroy plant and fruit abound wherever bananas are grown.

The banana is a bulky fruit, shipped attached to a stem that accounts for about 7 to 8 percent of worthless weight, from which the fruit fingers protrude in a fashion that invites crushing and bruising under anything less than the tenderest handling. It must be cut in a green state, before full maturity—how long before depends upon the length of haulage to ultimate market—and the permissible time span between cutting and eating by the consumer is limited to not more than 21 to 25 days.

Yet, bananas regularly travel from 2,000 to 6,000 miles by water and up to 1,500 additional miles by rail and truck to reach their ultimate markets. Any accumulation of dust or gravel before or during transit, any roughness or cramping in stowing or carriage, even fingering by customers on the retailer's shelves shows up in marring discolouration of the delicate, golden skin of the ripened fruit and depreciates its marketability. Strict temperature controls have to be maintained from the time of loading aboard ship to delivery to retailer, and the latter is under strong compulsion to sell his fruit to customers within 24 hours after receipt.

Every stage, from plantation to retail sale, requires meticulous planning and coordination, upon a time schedule far more precise than pertains to any other major commodity of world trade. Supply in every market must be geared to a demand that, in turn, is affected by the availabilities of competitive fruits. The cutting by maturity grade, the transport to shipping port, the stowing, the ocean carriage, the unloading, the sorting (by size, condition, and degree of ripeness), the shipment by truck or rail to distribution centres, the operations in the jobbers' ripening rooms, the trucking to retailers, and the sale to customers—every one of these stages is a tailored process with minimal tolerances for departure from a schedule that has to be calculated from its beginning. Even small divergences from the rigid timetable and handling requirements result in losses; whereas major departures would spell a total loss for the shipments involved.

If Captain Lorenzo Baker, Minor Keith, Thomas Hart, Andrew Preston, and even the imaginative Sam Zemurray had been able to visualize the complications that were to beset the production and marketing of bananas as a large-scale item in world trade, it is improbable that they would have had the fortitude to launch and expand the United Fruit Company. But if they had not made the start, it is probable that this thoroughly implausible commodity—implausible in the sense of its inherent lack of adaptability to the hazards of world marketing—would have bulked no larger in temperate zone food economies than do pineapples, or figs, or dates today.

Happily, for the North American and European consumer, and for the Latin American banana-producing economies as well, the vision of these pioneers was too limited to foresee the involvements or, at least, too sanguine to sense the formidable impediments that were to arise. So they built the foundations of today's giant trade, largely unaware of the whirling windmill blades before which even a Don Quixote might have quailed.

The Valuation of Market

The money value of bananas that enter into world trade, to the best of our knowledge, has had no systematic study. Values are commonly attributed to exports on an f.o.b. basis, and to imports on a c.i.f. basis. Such reporting is generally made by applying to the number of stems involved in either case a formula price that usually grossly understates the prices at which sales are actually made. Accordingly, the reported export valuation for a given country as shown in its annual trade account figures often represents 50 percent, or even less, of what it actually receives upon its adjusted accounts.

The International Monetary Fund, in its work of keeping track of international balance of payment flows, has been forced to make radical adjustments in reported banana trade figures to avoid untenably large distortions in the accounts of the major banana exporting countries. But the Fund only makes its adjustments for those countries in which banana exports account for a major portion of foreign exchange revenues.

The authors of this study, in attempting to put valuation figures on the world banana trade as a whole, have started with the North American market about which a good deal is known and which represented 54 percent of the world's total banana imports in 1955.

We have less complete data on the European marketing structure, which represented 37 percent of 1955 imports by weight, but there is sufficient evidence to indicate that an extrapolation of the American cost structure to that segment will not give any upward bias to the whole. The costs per pound of European bananas are consistently higher from original purchase in the producing areas on through the transportation and distribution chain. The remaining segment of world trade in bananas is too small to importantly distort the whole structure.

Our estimating base, combining relatively complete North American marketing data with the very detailed information made available by the United Fruit Company on all phases of its operations, is indicated in Table given below.

Table: United Fruit's Share of the World Banana Market 1955

	United Fruits		Competitions		Total	
Importing area	**Million stems**	**Million pounds**	**Million stems**	**Million pounds**	**Million stems**	**Million pounds**
United States and Canada	29.5	2,333	20.4[a]	1,271[b]	49.9	3,604[a]
Europe	7.1[c]	339	62.9[a]	2,129[b]	70.0	2,468[d]
South America	—	—	8.6[e]	492	8.6[e]	429[d]
Africa, Asia, Oceania	—	—	3.9[e]	196	3.9[e]	196[d]
Total	**36.6**	**2,672**	**95.8**	**4,025**	**132.4**	**6,697**

On a stem basis, the United Fruit Company accounted for 59 percent of North American imports, for 10 percent of European and for 28 percent of the world total. But on a weight basis—and bananas are sold by weight in markets of distribution—there are indications that the percentages of United Fruit's shipments are somewhat higher in each case, since the stem weight of the company's shipments generally runs above market averages.

Our specific data gleaned from the United Fruit Company's records furnished a far more precise base for the portion of the field that it covered than anything available in published studies. To this we added everything that could be furnished by public officials and private banana operators in the six countries in which we made detailed field surveys. As has been noted, these six, between them, produced about 60 percent of the bananas shipped in international trade in 1955. In sum, while our global estimates have been pieced together from these sources, and then blown up to represent the whole market as revealed by world trade and production statistics, we believe that our findings reasonably represent the general magnitudes of a field in which there has been no previous basis for any general appraisal.

It is our finding that, in 1955, North American consumers spent about $527 million for bananas—3,063 million pounds consumption weight; 3,604 million pounds stem weight—at an average retail price of 17.2¢ per pound. We know that Europeans paid a somewhat higher price per pound than Americans, and that other importing areas paid somewhat less. Taking the North American price as average, and knowing that this area accounted for 54 percent of all imports, we can estimate the world retail expenditure for *imported* bananas at approximately $976 million.

We have seen earlier that about three-quarters of the reported world commercial production of bananas is consumed in the countries where they are produced. We have no overall reporting of what consumers paid for bananas in the producing countries, but we have some data on this for our six-country sample. In these countries, bananas sold on the local market for from one-fifth to one tenth of what they brought when sold as export stems.

It is certainly conservative to estimate that the totality of fruit grown for local markets throughout the world, although almost three times as great in quantity, has less than one-half and perhaps not more than a third the value of that committed to export markets. It is probably safe to estimate the total retail value of the 1955 world's commercial banana crop at between $1.3 billion and $1.5 billion.

We are able to make a reasonably proximate estimate of the value in 1955 of world banana exports f.o.b. vessels at ports of embarkation. On the basis of our North American consumer dollar analysis that follows, it will be seen that about 27¢ out of each such dollar spent on bananas represents the return actually realized by producing countries. Hence, of the estimated $976 million sales at retail, $263 million can be assigned as the share of the producing countries from their banana exports.

4

Product Selection and Funding

If they are to promote genuine rural development, employment projects for rural women should be capable of becoming self-sustaining in the space of, say, three to five years. Although I do not want to belabor the obvious, there is little value in beginning a programme that is likely to collapse as soon as the original organizers or funding sources pull out. It is probably better to attempt nothing rather than to raise women's hopes of earning a living only to abandon them later on to failure.

Disillusionment, unfortunately, is the outcome of a number of welfare oriented training programmes that teach rural women handicrafts, sewing, or weaving. After perhaps a year's training and production in a workshop, the women are turned out on their own, only to find that they frequently cannot make a living from their work. Often they cannot afford to buy a loom or a sewing machine and are reduced to turning out handmade garments which cannot possibly compete in quality or quantity with those made by local tailors or manufacturers.

Many training programmes are really only sheltered workshops, where women spend their days sewing or embroidering on products for which there is no real market, their work being subsidized by donations from well-meaning women's organizations, voluntary associations, or international agencies. The women receive very low wages and little, if any, developmental training (for example, no functional education is offered) that could enable them to become truly self-reliant. Subsidies frequently do more harm than good. For example, one international agency distributed free sewing machines and cloth to women's groups in Bangladesh, but when the free supplies were discontinued, most groups were unable to survive. Indeed, their dependence on free materials prevented them from becoming competitive on the open market.

The issue of fair wages is crucial. An economically viable enterprise can pay wages high enough to act as a strong incentive for women to work. Skilled women workers should earn at least what men earn in agricultural day labour if their work is to acquire its proper value. Yet even this minimum requirement is unmet in many programmes, where skilled women earn the equivalent of only 20 or 25 cents a day by making handicrafts that are exported to European and American markets. A government welfare programme in India which encourages industries to employ women in small ancilliary workshops has been criticized on the grounds that it permits employers to pay lower wages to women workers while undercutting the unionization of male workers. The laudable goal of creating employment for women must not become a cover-up for the further exploitation of a cheap labour supply.

In this chapter, I propose some criteria for selecting appropriate products and for financing small-scale industries employing rural women. Clearly, market-oriented production is not possible in all situations, for the extreme seasonal or year-round isolation of many villages severely impedes their access to outlets. The best that can be achieved in many areas is to enable villagers to provide for their own basic needs through increased production of basic foodstuffs, clothing, and household and farming utensils. Such is the case in many villages of Bangladesh that are heavily flooded during the monsoons and distant from major markets. In Nepal, too, perhaps half the population lives in villages that can be reached only by several hours or days of foot travel over narrow mountain paths and bridges.

Where villages and towns are on major transportation routes—on roads, rails, or rivers—the possibilities are greatly expanded for orienting production to neighbouring urban markets or for export. It is toward these market-linked centres, and toward the goal of providing income-generating employment outside the home year round for young rural women, that the proposals in this chapter are directed. As noted previously, our interest lies in promoting labour-intensive, small-scale, rural industries with relatively low capital requirements and uncomplicated technologies. The question is, What type of production is best suited to the small, rural industrial model? As an overall strategy for encouraging modern small industries in developing countries, Staley and Morse urge policymakers to seek out projects that are:

1. Creative of real capital, in the form of physical improvements or human improvements;
2. High in labour intensity, so that a major portion of funds will go for labour or for materials produced by labour-intensive methods;
3. Likely to bring a fairly quick increase in production, thereby minimizing inflationary dangers; .
4. Capable of using many different types of labour, with or without heavy equipment;
5. Little dependent on materials or equipment requiring foreign exchange;
6. Widespread in location, capable of bringing jobs and increased productivity to needy parts of the country;
7. Capable of large-scale application, so as to make a real impact.

Staley and Morse also cite a number of conditions advantageous to the development of decentralized small industry:

1. Locational influences favouring factories processing a dispersed raw material (for example, butter or cheese); factories manufacturing products with local markets and relatively high transfer costs (for example, bottled

and canned soft drinks); and service industries with individualized requirements (for example, printing).

2. Process influences favouring separable manufacturing operations with a high degree of specialization; crafts or precision handiwork; and simple assembly, mixing, or finishing operations.
3. Market influences favouring differentiated products having low economies of scale (for example, ready-made garments); and industries serving small, total markets (for example, rice milling, glovemaking, making artificial flowers, and so forth).

In analyzing the role of small manufacturing in India's economic growth, Fisher suggests expanding small-scale hand industries for the domestic mass market, small-scale hand industries for mass markets abroad, and small-scale powered industry. Clearly, it makes no sense to promote hand industries that are not competitive with larger manufacturers or ones that are likely to be displaced by them in the future. But small producers can complement large producers. Artisans, for example, can be encouraged to adapt to changing conditions by withdrawing from activities that compete with factory production or are otherwise becoming obsolete.

By entering new lines—such as individualized installation, servicing, and repair of factory-made goods—that complement factory production and cater to new demands, they could continue to be self-supporting. A number of sectors can probably hold their own, even in competition with advanced industrial methods; for example, those in which being small carries certain advantages, or, at least, is not disadvantageous. The manufacture of furniture, shoes, clothing, ceramics, cigars, and baskets, and metalworking and food processing, as well as almost all service activities, including retailing, fall in this category. Small firms can also be created to cater to the needs of larger industries, for example, manufacturing or assembling components or carrying out particular processes.

Staley and Morse classify economic activities into oldline trades marked for retreat, such as ordinary handweaving, shoemaking, manufacturing of glass bangles, and so forth; old-line trades for modernization, including artistic handweaving, artistic metalworking, basketry, and jewelry making; and new-line trades for immediate development, including precision toolmaking, electrical wiring, and bicycle, automobile, and radio repair, among others. They heavily emphasize modern, factory-oriented service trades relating to installation and repair.

In this chapter, I will propose products particularly suited to the requirements of women workers that, at least initially, do not require extensive contact with the public as many service trades do. Our concern is with introducing small-scale industry that will fit within the prevailing cultural practices in South Asia, while at the same time creating conditions for the eventual breakdown of cultural constraints and the transformation of relations between the sexes.

The goal is also to promote the acceptance of women's employment by selecting activities that are not seen as taking jobs away from men. That is why the suggestions in this chapter derive primarily from women's work in the home. Although I noted Wajihuddin Ahmed's insistence on industries that are "least rural and least womanish," I would propose initially that we build on the prevailing division of labour, skills, and interests, with the object of upgrading these skills and modernizing production.

PRODUCT SELECTION

The basic criteria for selecting a product are the raw materials and skills currently available in the community. Villagers themselves, and especially potential workers, should actively share in the preliminary discussions and decisions. Building on the available and the familiar is probably preferable to introducing an entirely new product that is dependent on outside supplies and requires considerable job training. Recall that the papad cooperatives in India and, to some extent, the jute cooperatives in Bangladesh and the Indian milk cooperatives were especially suited in this respect.

The following proposals offer several possible sources for new employment:

1. Finding new uses for local resources such as tree barks, leaf fibers, fruit and vegetable dyes, grass fabrics, drugs and herbal medicines. KARIKA (Bangladesh Handicrafts Cooperative Federation), for example, sent a trainee to the Philippines to learn the technique of weaving washable fabrics from the fibers of pineapple and banana leaves
2. Finding out what people want or need that cannot be obtained regularly, or at all, in local markets, for example, soap, candles, and other household utensils or food products
3. Finding new products that will not duplicate products already made in the country. Or, if there are similar products already on the market, making sure that the new products will be better or cheaper
4. Exploring the possibilities for import substitutions. What could be made locally that is now imported (for example, clothing, appliances, or cosmetics)? Hirschman stresses the value of imports in creating a local demand for a product, but he acknowledges that it is sometimes difficult to shift to local substitutes once people have acquired a taste for the imported product
5. Establishing links with other industries in the area, as suppliers of component parts or as assemblers
6. Choosing an enterprise that will generate new demands and create new possibilities for products and markets, for example, prepared foodstuffs.

The variety of possibilities is endless if one uses some imagination and carefully explores potential markets. The rather obvious proposals which follow are suggestions only, for the selection of an appropriate product and technology will depend primarily on a cluster of socioeconomic conditions unique to every region and probably to every village.

Food Processing

Food processing includes a variety of treatments: fish and meat canning, salting, smoking, and drying; fruit and vegetable canning and drying; the bottling of fruit juices and fermented juices; the making of jams, jellies, syrups, chutneys, and pickles; the making of cheese, butter, ghee, and yoghurt; the preparation of snack foods such as papads or puffed rice; the processing of macaroni, spaghetti, or noodles of various types; the bottling of soda water; baking; the shelling and roasting of seeds and nuts, and so on. The local cooperative could also supply partially processed pulp or juices for larger manufacturers.

Fruit and vegetable preservation is uniquely suited to small-scale rural industry, although small- to medium-sized plants (that is, those with at least twenty employees and sales of over $20,000) generally hold some advantages over very small units by making possible the bulk purchase of fresh fruit or vegetables, more modern equipment, more storage space, and more effective marketing. A typical small unit in India in the late 1950s involved an initial investment and yearly output.

A report on fruit and vegetable preservation and canning suggested that the outlook for small-scale fruit and vegetable processing in India was moderately good with rising (although low) domestic consumption. As many as 70 percent of employees in the industry were seasonal workers employed only four or five months a year, however, and many worked in their own households.

Employing women in the food-processing industry has a number of advantages. First, local agricultural produce is utilized, some of which might go to waste when heavy seasonal harvests are sold in the market at low prices. The government of Nepal, for example, is planting fruit trees on hillsides in order to stop erosion. Frequently, there is too much fruit to market, and it falls to the ground unused.

Table: Initial Investment and Yearly Output of Four Typical Small-Scale Indian Industries (in dollars)

No. of employees	Initial investment	Output	Principal products
10	10,000	6,000	Fruit and squashes (fruit drinks)
27	82,000	74,000	Canned and bottled fruits and vegetables
30	43,000	50,000	Canned fruits and vegetables, mango chutney, and squashes
50	65,000	90,000	Jams, and mango and vegetable canning

Small-scale, dispersed processing plants could prevent such waste. Second, since food processing is typically women's work, the new industrial employment would not be seen as competitive with men's work. Third, food processing has important nutritional advantages by making available the surplus of one season for consumption during the rest of the year, when little fresh produce is grown. It also is appropriate to small-scale production, with intermediate technology, and at relatively low capital investment. Units of stainless steel and aluminum, with a daily capacity to produce 200 to 500 quarts per unit, can be manufactured to preserve fruits, vegetables, or fish.

Utilizing small steam generators, fired by any fuel, the workers require only simple training for their operation. Sun drying—a nutritious method of preservation that reduces problems of transporting goods in bulk—requires very little equipment and no power source unless it is necessary to substitute drying ovens during the rainy season. Additional investment is required for reusable glass containers or more expensive tin cans. Flexible units permit the industry to expand gradually in small segments in order to meet increasing demand without making heavy capital investment in the initial stages. And finally, processed foods appeal to a variety of local, urban, and export markets.

The basic drawbacks of food processing as an economic enterprise are its seasonal nature and its dependence on agricultural production, both of which are beyond the control of the cooperative. Prices may fluctuate drastically from year to year; a period of drought could throw everyone out of work. Both drawbacks could be controlled to some extent by diversifying agricultural production in the area and planning specifically for year-round use of equipment with a variety of fruits, vegetables, and fish. Some produce can be stored for processing at a later time.

In addition, the cooperative might well extend its activities to the actual production of some, or all, of its own raw materials, or establish links with other women's cooperatives that raise tree crops, such as mangoes, jackfruit, date or tal palms; vegetables; fish in tanks; poultry (for dried eggs or canned chicken); milch animals (for cheese, butter, ghee, yoghurt); or other goods in sufficient quantity to supply the needs of the food-processing industry over and above the immediate demand for fresh produce.

Local markets for preserved foods, especially fruit and vegetables, may be quite limited when they compete with cheaper fresh produce, although some out-of-season canned or dried fruits, fruit juices, and canned or dried vegetables, as well as products such as jams, syrups, and some snack foods should find local buyers. Local demand is also likely to decline in bad years when people have little money to spend.

In some rural areas villagers are beginning to grow a variety of vegetables, so that the pattern of consumption has not yet been set. The Bangladesh Rural Advancement Committee (BRAC) programme introduced carrots, cauliflower, squash, broccoli, peas, tomatoes, onions, garlic, and potatoes to the Sulla villagers for their own consumption, but the gardens produce only in the winter before the monsoon floods the area. The villagers have dried fish and dal to eat all year round, plus green cooking bananas and spinach. But neither the supply nor the demand yet exists for market-oriented food processing.

Institutional buyers such as hospitals, restaurants, the armed forces, and factory canteens can provide a major market for processed foods. Two canning factories near Peshawar, in Pakistan, which employ several hundred women each during the busy seasons, sell most of their fruit, squash, and canned and machine-dried vegetables to the armed forces. Registered cooperatives in India are eligible to sell through such major urban outlets as the Super Bazaar stores in Delhi. It is doubtful whether one cooperative could produce in sufficient quantity to establish a steady supply, but federations of cooperatives producing the same product under standardized conditions—such as the fifteen papad producers in Indiacould supply bulk orders with some consistency.

Small food-processing industries do have special requirements, namely, transportation (for example, papads are picked up once a day and milk twice a day in Gujarat); plentiful fresh water; good storage facilities, free from pests, mold, and other spoilage, and theft; hygienic working conditions; fuel for boiling or steaming produce for the bottling and canning processes; and high seasonal needs for credit or loans to purchase produce in bulk. It is also necessary to observe strict quality controls and a good deal of technical assistance and planning is required, both at the initial stages and in the everyday and seasonal scheduling of production. At the same time, however, food preservation should stimulate agricultural productivity, while simultaneously providing for some of the nutritional needs of the local community.

Related Processing of Agricultural Products

Although there are regions of South Asia where women are rarely seen in the fields either planting, weeding, or harvesting (in the rice fields of Bengal, for example), virtually everywhere women are responsible for processing the harvested grains for their family's consumption. Their tasks include threshing, sometimes boiling, drying, pounding, winnowing, cleaning, and grinding of rice, wheat, corn, various millets (small-seeded cereal grasses), and pulses (seeds of leguminous crops such as peas, beans, and lentils).

Oil is pressed from mustard or other seeds and nuts. They also dry, clean, and grind spices for everyday use and process nuts, such as the cashews of India and Bangladesh. In good weather women perform these tasks out-of-doors: in Bangladesh, they work in the centre of the *bari*, a small cluster of inward-facing households; in parts of India and Pakistan, it is done in courtyards surrounded by high mud walls; and in Nepal, by the doorsteps of their homes scattered along the mountain paths. Some tasks are seasonal, while others—such as grinding flour or spices on heavy stone slabs—are done almost every day.

Agricultural advances associated with the Green Revolution have added to women's (and men's) work in areas where irrigation now permits double- or triplecropping. Not only are the crops more frequent and more abundant, but the larger heads of the high-yield rice varieties require additional parboiling and are more difficult to dry and husk. Technological advances are beginning to lift some of these heavy burdens from women's shoulders. Rice and oil mills, for example, do the work faster, cheaper, and in much greater quantity than women at home can do with their primitive methods. Women in some areas have consequently been increasingly displaced from their productive roles by the new technology.

The displacement would be welcome if it simply relieved women from a heavy and thankless chore, but such is not entirely the case. Some village women earned money (or, more usually, a share of the produce) by pounding rice or pressing oil at home for sale to their neighbours or others. Yet the mills are run by men.

Rather than resisting the new technology, a more appropriate strategy would be to enable women to gain a monopoly over the new, as well as the old, processes, at least on the scale at which these functions are performed in small industries at the village or town level. The new technology need not be highly complex, labour displacing, or highly dependent on fuel. Rice processing offers a good example of time-consuming tasks that could be performed more efficiently by a group using intermediate-level technology.

Grain can be separated from the stalks in a pedal-driven thresher rather than by walking tethered bullocks round and round over the stalks or by hitting the stalks over a barrel. After threshing, the husks can be loosened by parboiling the rice in large metal cauldrons rather than in small earthenware pots, which sometimes are kept steaming all night over a low fire in order to supply only one or two days' food for the family. The rice can then be dried by a pedal-driven drying machine rather than by being spread out under the sun in the courtyard to dry.

Simple rice-husking machines could replace the traditional heavy wooden beam (called a *dekhi* in Bangla) which seesaws rhythmically with a push of the foot at one end, while the wooden spike at the other end pounds the small amount of grain that has been placed in a hollow at its base. One or two women pump the dekhi by foot, while another pushes fresh grain into the hollow and clears out the husked rice (trying not to get her hands caught under the spike). Women in one Bengali village report that they spend at least half a morning or afternoon twice a week pounding rice.

Winnowing, sieving, cleaning, and milling the rice into flour could also be performed more efficiently with better equipment. Unhusked rice can be stored in quantity, protected by its hard husks from pests, and processed as time permits and the market demands. A women's cooperative could not only process rice, wheat, corn, millet, pulses, and spices for village households in exchange for a cash fee or a portion of the produce, but could also purchase goods in bulk for processing and sale in local or more distant markets when prices rise.

Nor do the centres need to be limited to processing; they can also manufacture mixed cereals, high-protein baby foods, and animal and poultry feeds, the last from the waste products of the refining process. With adequate storage facilities, proper planning, and some diversification of products, there is no reason why production could not become a year-round activity, employing a significant number of rural women. At the same time, the production would relieve them of some of their most time-consuming tasks in the home.

5

Methods of Reducing Deterioration

A knowledge of deterioration factors and the way they act, including the rates of deterioration to a specific category of food, means that it is possible to list the ways of lowering or stopping the action and obtaining fruit and vegetable preservation.

In order to maintain their nutritional value and organoleptic properties and because of technical-economical considerations, not all the identified means against deterioration actually have practical applications for fruit and vegetable preservation.

TECHNICAL METHODS OF REDUCING FOOD DETERIORATION

These technical means can be summarised as follows:

Physical	Heating
	Cooling
	Lowering of water content Drying/dehydration. Concentration
	Sterilising filtration
	Irradiation
	Other physical means (high pressure, vacuum, inert gases)
Chemical	Salting
	Smoking
	Sugar addition

	Artificial acidification
	Ethyl alcohol addition
	Antiseptic substance action
Biochemical	Lactic fermentation (natural acidification)
	Alcoholic fermentation

This classification of methods of reducing deterioration presents some difficulties because their preservation effects are physical, physico-chemical, chemical and biochemical complex phenomena which rarely act in isolation. Normally they take place together or one after the other.

From the whole list of possible methods of reducing deterioration, over the years, some procedures for fruit and vegetable preservation have found practical application.

Procedures for fruit and vegetable preservation

Procedures	**Practical applications**
Fresh storage	Fruits, vegetables
Cold storage	Fruits, vegetables
Freezing	Fruits, vegetables
Drying/dehydration	Fruits, vegetables
Concentration	Fruit and vegetable juices
Chemical preservation	Fruit semi-processed
Preservation with sugar	Fruit products/preserves
Pasteurization	Fruit and vegetable juices
Sterilisation	Fruits, vegetables
Sterilising filtration	Fruit juices
Irradiation	Fruits, vegetables

These preservation procedures have two main characteristics as far as being applied to all food products is concerned:

- Some of them are applied only to one or some categories of foods; others can be used across the board and thus a wider application (cold storage, freezing, drying/dehydration, sterilisation, etc.);
- Some guarantee food preservation on their own while others require combination with other procedures,

either as principal or as auxiliary processes in order to assure preservation (for example smoking has to be preceded by salting).

Combined Preservation Procedures

In practice preservation procedures aim at avoiding microbiological and biochemical deterioration which are the principal forms of deterioration. Even with all recent progress achieved in this field, no single one of these technological procedures applied alone can be considered wholly satisfactory from a microbiological, physico-chemical and organoleptic point of view, even if to a great extent the food value is assured.

Thus, heat sterilisation cannot be applied in order to destroy all micro-organisms present in foods without inducing non desirable modifications. Preservation by dehydration/drying assures microbiological stability but has the drawback of undesirable modifications that appear during storage: vitamin losses, oxidation phenomena, etc.

Starting with these considerations, the actual tendency in food preservation is to study the application of combined preservation procedures, aiming at the realisation of maximum efficiency from a microbiological and biological point of view, with reduction to a minimum of organoleptical degradation and decrease in food value.

The principles of combined preservation procedures are:

- Avoid or reduce secondary (undesirable) effects in efficient procedures for microbiological preservation;
- Avoid qualitative degradation appearing during storage of products preserved by efficient procedures from a microbiological point of view;
- Increase microbiological efficiency of preservation procedures by supplementary means;
- Combine preservation procedures in order to obtain maximum efficiency from a microbiological point of view, by specific action on various types of micro-organisms present;

- Establish combined factors that act simultaneously on bacterial cells.

Research and applications in this direction were followed by microbiological and biochemical way, obtaining a serial of combination of preservation procedures with the possibility of application in industrial practice.

Fresh fruit and vegetable storage can be combined with:

- Storage in controlled atmosphere where carbon dioxide and oxygen levels are monitored, increasing concentration of CO2 and lowering that of oxygen according to fruit species. Excellent results were obtained for pomace fruit; in particular the storage period for apples has been extended. Application of this combined procedure requires airtight storage rooms.
- Storage in an environment containing ethylene oxide; this accelerates ripening in some fruit: tomatoes, bananas, mangoes, etc.

Cold storage can be combined with storage in an environment with added of carbon dioxide, sulphur dioxide, etc. according to the nature of product to be preserved.

Preservation by drying/dehydration can be combined with:- freezing: fresh fruit and vegetables are dehydrated up to the point where their weight is reduced by 50% and then they are preserved by freezing.

This procedure (freeze-drying) combines the advantages of drying (reduction of volume and weight) with those of freezing (maintaining vitamins and to a large extent organoleptic properties).

A significant advantage of this process is the short drying time in so far as it is not necessary to go beyond the inflexion point of the drying curve. The finished products after defreezing and rehydration/reconstitution are of a better quality compared with products obtained by dehydration alone.

- Cold storage of dried/dehydrated vegetables in order to maintain vitamin C; storage temperature can be varied with storage time and can be at -8° C for a storage time of more than one year, with a relative humidity of 70-75 %.
- Packaging under vacuum or in inert gases in order to avoid action of atmospheric oxygen;, mainly for products containing beta-carotene.
- Chemical preservation: a process used intensively for prunes and which has commercial applications is to rehydrate the dried product up to 35 % using a bath containing hot 2 % potassium sorbate solution. Another possible application of this combined procedure is the initial dehydration up to 35% moisture followed by immersion in same bath as explained above; this has the advantage of reducing drying time and producing minimum qualitative degradation. Both applications suppress the dehydrated products reconstitution (rehydration) step before consumption.
- Packaging in the presence of desiccants (calcium oxide, anhydrous calcium chloride, etc.) in order to reduce water vapour content in the package, especially for powdered products.

Preservation by concentration, carried out by evaporation, is combined with cold storage during warm season for tomato paste (when water content cannot be reduced under the limit needed to inhibit moulds and yeasts, e.g. a_w = 0.70...0.75).

Chemical preservation is combined with:

- Acidification of food medium (lowering pH);
- Using combined chemical preservatives.

Preservation by lactic fermentation (natural acidification) can be combined with cold storage for pickles in order to prolong storage time or shelf-life.

Preservation with sugar is combined with pasteurization for some preserves having a sugar content below 65%.

FRESH STORAGE

Fresh Fruit and Vegetable Storage

Once fruit is harvested, any natural resistance to the action of spoiling micro-organisms is lost. Changes in enzymatic systems of the fruit also occur on harvest which may also accelerate the activity of spoilage organisms.

Means that are commonly used to prevent spoilage of fruits must include:

- Care to prevent cutting or bruising of the fruit during picking or handling;
- Refrigeration to minimise growth of micro-organisms and reduce enzyme activity;
- Packaging or storage to control respiration rate and ripening;
- Use of preservatives to kill micro-organisms on the fruit.

A principal economic loss occurring during transportation and/or storage of produce such as fresh fruit is the degradation which occurs between the field and the ultimate destination due to the effect of respiration. Methods to reduce such degradation are as follows:

- Refrigerate the produce to reduce the rate of respiration;
- Vacuum cooling;
- Reduce the oxygen content of the environment in which the produce is kept to a value not above 5% of the atmosphere but above the value at which anaerobic respiration would begin. When the oxygen concentration is reduced within 60 minutes the deterioration is in practice negligible.

The following is a summary of some recent developments in post-harvest technology of fresh fruits and vegetables.

Harvest Maturity

This is particularly important with fruit for export. One recent innovation is the measurement of resonant frequency of the fruit which should enable the grading out of over mature and under-mature fruit before they are packed for export.

Harvest Method

Considerable research is continuing on mechanical harvesting of perishable crops with a view to minimising damage. In fruit trees, controlling their height by use of dwarfing rootstocks, pruning and growth regulating chemicals will lead to easier, cheaper more accurate harvesting.

Handling Systems

Field packing of various vegetables for export has been carried out for many years. In the last decade or so this has been applied, in selected cases, to a few tropical fruit types. Where this system can be practiced it has considerable economic advantages in saving the cost of building, labour and equipment and can result in lower levels of damage into crops.

Pre-cooling

Little innovation has occurred in crop pre-cooling over the last decade. However high velocity, high humidity forced air systems have continued to be developed and refined. These are suitable for all types of produce and are relatively simple to build and operate and, while not providing the speed of cooling of a vacuum or hydrocooler, have the flexibility to be used with almost all crops.

Chemicals

There is a very strong health lobby whose objective is to reduce the use of chemicals in agriculture and particularly during the post harvest period. Every year sees the prohibition of the use of commonly used post-harvest chemicals. New ways need to be developed to control post-harvest diseases, pest and sprouting.

Coatings

Slowing down the metabolism of fruit and vegetables by coating them with a material which affects their gaseous exchange is being tested and used commercially on a number of products.

Controlled Environment Transport

Recent innovations in this technique have produced great progress as a result of the development and miniaturisation of equipment to measure carbon dioxide and oxygen. Several companies now offer containers where the levels of these two gases can be controlled very precisely.

Water and Water Activity (a_w) in Foods

Micro-organisms in a healthy growing state may contain in excess of 80% water. They get this water from the food in which they grow. If the water is removed from the food it also will transfer out of the bacterial cell and multiplication will stop. Partial drying will be less effective than total drying, though for some micro-organisms partial drying may be quite sufficient to arrest bacterial growth and multiplication.

Bacteria and yeasts generally require more moisture than moulds, and so moulds often will be found growing on semi-dry foods where bacteria and yeasts find conditions unfavourable; example are moulds growing on partially dried fruits.

Slight differences in relative humidity in the environment in which the food is kept or in the food package can make great differences in the rate of micro-organism multiplication. Since micro-organisms can live in one part of a food that may differ in moisture and other physical and chemical conditions from the food just millimetres away, we must be concerned with conditions in the "microenvironment" of the micro-organisms. Thus it is common to refer to water conditions in terms of specific activity.

The term "water activity" is related to relative humidity. Relative humidity is defined as the ratio of the partial pressure of water vapour in the air to the vapour pressure of pure water at the same temperature. Relative humidity refers to the atmosphere surrounding a material or solution.

Water activity or aw is a property of solutions and is the ratio of vapour pressure of the solution compared with the vapour pressure of pure water at the same temperature. Under equilibrium conditions water activity equals:

$a_w = RH/100$

When we speak of moisture requirements of micro-organisms we really mean water activity in their immediate environment, whether this be in solution, in a particle of food or at a surface in contact with the atmosphere.

At the usual temperatures permitting microbial growth, most bacteria require a water activity in the range of about 0.90 to 1.00.

Some yeasts and moulds grow slowly at a water activity down to as low as about 0.65.

Qualitatively, water activity is a measure of unbound, free water in a system available to support biological and chemical reactions. Water activity, not absolute water content, is what bacteria, enzymes and chemical reactants encounter and is affected by at the micro-environmental level in food materials.

Two foods with the same water content can have very different a_w values depending upon the degree to which water is free or otherwise bound to food constituents. Fig. 5.2.1 is a representative water absorption isotherm for a given food at a given temperature. It shows the final moisture content the food will have when it reaches moisture equilibrium with atmospheres of different relative humidities.

Thus, this food, at the temperature for which this absorption isotherm was established, will ultimately attain a moisture content of 20% at 75% RH (relative humidity). If this food was previously dehydrated to below 20% moisture and placed in an atmosphere of 75% RH, it would absorb moisture until it reached 20%. Conversely, if this food was moistened to greater than 20% water and then placed at 75% RH, it would lose moisture until it reached the equilibrium value of 20%.

Under such conditions some foods may reach moisture equilibrium in the very short time of a few hours, others may require days or even weeks. When a food is in moisture equilibrium with its environment, then the a_w of the food will be quantitatively equal to the RH divided by 100.

Qualitatively, water activity is a measure of free or available water, to be distinguished from unavailable or bound water. These states of water also bear a relationship to the characteristic sigmoid shapes of water absorption isotherm curves of various foods.

Thus, according to theory, most of the water corresponding to the portion of the curve below its first inflection point is believed to be tightly bound water, often referred to as an adsorbed mono-molecular layer of water. Moisture corresponding to the region above this point and up to the curve's second inflection point is thought to exist largely as multi-molecular layers of water less tightly held to food constituent surfaces.

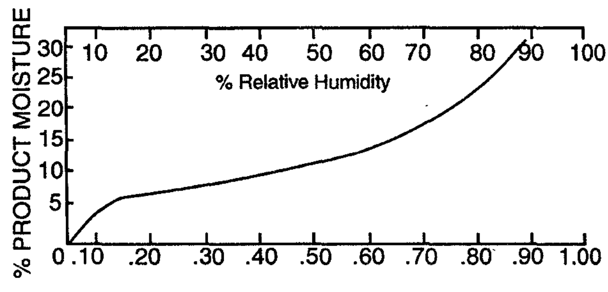

Fig. Water sorption isotherm

Beyond this second inflection point moisture generally is considered to be largely free water condensed in capillaries and interstices within the food. In this latter portion of the sorption isotherm curve small changes in moisture content result in great changes in a food's a_w. In Fig. given below are illustrated the moisture sorption isotherms for various dried fruits at 25°C.

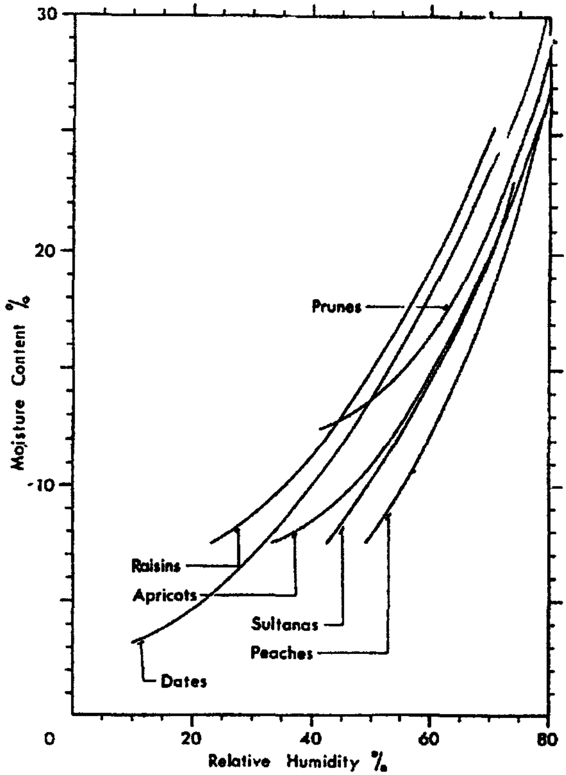

Fig. Moisture sorption isotherms for various dried fruits at 25°C

Preservation by Drying/Dehydration

The technique of drying is probably the oldest method of food preservation practiced by mankind. The removal of moisture prevents the growth and reproduction of microorganisms causing decay and minimises many of the moisture mediated deterioration reactions.

It brings about substantial reduction in weight and volume minimising packing, storage and transportation costs and enable storability of the product under ambient temperatures, features especially important for developing countries. The sharp rise in energy costs has promoted a dramatic upsurge in interest in drying world-wide over the last decade.

Heat and Mass Transfer

Dehydration involves the application of heat to vapourise water and some means of removing water vapour after its separation from the fruit/vegetable tissues. Hence it is a combined/simultaneous (heat and mass) transfer operation for which energy must be supplied.

A current of air is the most common medium for transferring heat to a drying tissue and convection is mainly involved.

The two important aspects of mass transfer are:

- The transfer of water to the surface of material being dried and
- The removal of water vapour from the surface.

In order to assure products of high quality at a reasonable cost, dehydration must occur fairly rapidly. Four main factors affect the rate and total drying time:

- The properties of the products, especially particle size and geometry;
- The geometrical arrangement of the products in relation to heat transfer medium (drying air);
- The physical properties of drying medium/ environment;
- The characteristics of the drying equipment.

It is generally observed with many products that the initial rate of drying is constant and then decreases, sometimes at two different rates. The drying curve is divided into the constant rate period and the falling rate period.

Surface Area

Generally the fruit and vegetables to be dehydrated are cut into small pieces or thin layers to speed heat and mass transfer. Subdivision speeds drying for two reasons:

- Large surface areas provide more surface in contact with the heating medium (air) and more surface from which moisture can escape;

- Smaller particles or thinner layers reduce the distance heat must travel to the centre of the food and reduce the distance through which moisture in the centre of the food must travel to reach the surface and escape.

Temperature

The greater the temperature difference between the heating medium and the food the greater will be the rate of heat transfer into the food, which provides the driving force for moisture removal. When the heating medium is air, temperature plays a second important role.

As water is driven from the food in the form of water vapour it must be carried away, or else the moisture will create a saturated atmosphere at the food's surface which will slow down the rate of subsequent water removal. The hotter the air the more moisture it will hold before becoming saturated.

Thus, high temperature air in the vicinity of the dehydrating food will take up the moisture being driven from the food to a greater extent than will cooler air. Obviously, a greater volume of air also can take up more moisture than a lesser volume of air.

Air Velocity

Not only will heated air take up more moisture than cool air, but air in motion will be still more effective. Air in motion, that is, high velocity air, in addition to taking up moisture will sweep it away from the drying food's surface, preventing the moisture from creating a saturated atmosphere which would slow down subsequent moisture removal. This is why clothes dry more rapidly on a windy day.

Some other phenomena influence the drying process and a few elements are summarised below.

Dryness of Air

When air is the drying medium of food, the drier the air the more rapid is the rate of drying. Dry air is capable of absorbing and holding moisture. Moist air is closer to saturation and so can absorb and hold less additional moisture than if it were dry. But the dryness of the air also determines how low a moisture content the food product can be dried to.

Atmospheric Pressure and Vacuum

If food is placed in a heated vacuum chamber the moisture can be removed from the food at a lower temperature than without a vacuum. Alternatively, for a given temperature, with or without vacuum, the rate of water removal from the food will be greater in the vacuum. Lower drying temperatures and shorter drying times are especially important in the case of heat-sensitive foods.

Evaporation and Temperature

As water evaporates from a surface it cools the surface. The cooling is largely the result of absorption by the water of the latent heat of phase change from liquid to gas.

In doing this the heat is taken from the drying air or the heating surface and from the hot food, and so the food piece or droplet is cooled.

Time and Temperature

Since all important methods of food dehydration employ heat, and food constituents are sensitive to heat, compromises must be made between maximum possible drying rate and maintenance of food quality.

As is the case in the use of heat for pasteurization and sterilisation, with few exceptions drying processes which employ high temperatures for short times do less damage to food than drying processes employing lower temperatures for longer times.

Thus, vegetable pieces dried in a properly designed oven in four hours would retain greater quality than the same products sun dried over two days.

Several drying processes will achieve dehydration in a matter of minutes or even less if the food is sufficiently subdivided.

Drying Techniques

Several types of dryers and drying methods, each better suited for a particular situation, are commercially used to remove moisture from a wide variety of food products including fruit and vegetables.

While sun drying of fruit crops is still practiced for certain fruit such as prunes, figs, apricots, grapes and dates, atmospheric dehydration processes are used for apples, prunes, and several vegetables; continuous processes as tunnel, belt trough, fluidised bed and foam-mat drying are mainly used for vegetables.

Spray drying is suitable for fruit juice concentrates and vacuum dehydration processes are useful for low moisture/ high sugar fruits like peaches, pears and apricots.

Factors on which the selection of a particular dryer/drying method depends include:

- Form of raw material and its properties;
- Desired physical form and characteristics of dried product;
- Necessary operating conditions;
- Operation costs.

There are three basic types of drying process:

- Sun drying and solar drying;
- Atmospheric drying including batch (kiln, tower and cabinet dryers) and continuous (tunnel, belt, belt-trough, fluidised bed, explosion puff, foam-mat, spray, drum and microwave);
- Sub-atmospheric dehydration (vacuum shelf/belt/drum and freeze dryers).

The scope has been expanded to include use of low temperature, low energy process like osmotic dehydration. As far dryers are concerned, one useful division of dryer types separates them into air convection dryers, drum or roller dryers, and vacuum dryers. Using this breakdown, Table given below indicates the applicability of the more common dryer types to liquid and solid type foods.

Table: Common dryer types used for liquid and solid foods

Dryer type	Usual food type
Air convection dryers	
kiln	pieces
cabinet, tray or pan	pieces, purées, liquids
tunnel	pieces
continuous conveyor belt	purées, liquids
belt trough	pieces
air lift	small pieces, granules
fluidized bed	small pieces, granules
spray	liquid, purées
Drum or roller dryers	
atmospheric	purées, liquids
vacuum	purées, liquids
Vacuum dryers	
vacuum shelf	pieces, purées, liquids
vacuum belt	purées, liquids
freeze dryers	pieces, liquids

Fruit and Vegetable Natural Drying — Sun and Solar Drying

Surplus production and specifically grown crops may be preserved by natural drying for use until the next crop can be grown and harvested. Natural dried products can also be transported cheaply for distribution to areas where there are permanent shortages of fruit and vegetables.

The methods of producing sun and solar dried fruit and vegetables described here are simple to carry out and inexpensive. They can be easily employed by grower, farmer, cooperative, etc.

The best time to preserve fruits and vegetables is when there is a surplus of the product and when it is difficult to transport fresh materials to other markets. This is especially true for crops which are very easily damaged in transport and which stay in good condition for a very short time.

Preservation extends the storage (shelf) life of perishable foods so that they can be available throughout the year despite their short harvesting season.

Sun and solar drying of fruits and vegetables is a cheap method of preservation because it uses the natural resource/ source of heat: sunlight. This method can be used on a commercial scale as well at the village level provided that the climate is hot, relatively dry and free of rainfall during and immediately after the normal harvesting period. The fresh crop should be of good quality and as ripe (mature) as it would need to be if it was going to be used fresh. Poor quality produce cannot be used for natural drying.

Dried fruit and vegetables have certain advantages over those preserved by other methods. They are lighter in weight than their corresponding fresh produce and, at the same time, they do not require refrigerated storage. However, if they are kept at high temperatures and have a high moisture content they will turn brown after relatively short periods of storage.

Different lots at various stages of maturity (ripeness) must NOT be mixed together; this would result in a poor dried product. Some varieties of fruit and vegetables are better for natural drying than other; they must be able to withstand natural drying without their texture becoming tough so that they are not difficult to reconstitute. Some varieties are unsuitable because they have irregular shape and there is a lot of wastage in trimming and cutting such varieties.

Damaged parts which have been attacked by insects, rodents, diseases, etc. and parts which have been discoloured or have a bad appearance or colour, must be removed. Before trimming and cutting, most fruit and vegetables must be washed in clean water. Onions are washed after they have been peeled.

Trimming includes the selection of the parts which are to be dried, cutting off and disposing of all unwanted material. After trimming, the greater part of the fruit and vegetables cut into even slices of about 3 to 7 mm thick or in halves/ quarters, etc.

It is very important to have all slices/parts in one drying lot of the same thickness/size; the actual thickness will depend on the kind of material. Uneven slices or different sizes dry at different rates and this result in a poor quality end product. Onions and root crops are sliced with a hand slicer or vegetable cutter; bananas, tomatoes and other vegetables or fruit are sliced with stainless-steel knives.

As a general rule plums, grapes, figs, dates are dried as whole fruits without cutting/slicing.

Some fruit and vegetables, in particular bananas, apples and potatoes, go brown very quickly when left in the air after peeling or slicing; this discolouration is due to an active enzyme called phenoloxidase. To prevent the slices from going brown they must be kept under water until drying can be started. Salt or sulphites in solution give better protection. However, whichever method is used, further processing should follow as soon as possible after cutting or slicing.

Blanching - exposing fruit and vegetable to hot or boiling water - as a pre-treatment before drying has the following advantages:

- It helps clean the material and reduce the amount of micro-organisms present on the surface;
- It preserves the natural colour in the dried products; for example, the carotenoid (orange and yellow) pigments dissolve in small intracellular oil drops during blanching and in this way they are protected from oxidative breakdown during drying;
- It shortens the soaking and/or cooking time during reconstitution.

During hot water blanching, some soluble constituents are leached out: water-soluble flavours, vitamins (vitamin C) and sugars. With potatoes this may be an advantage as leaching out of sugars makes the potatoes less prone to turning brown.

Blanching is a delicate processing step; time, temperature and the other conditions must be carefully monitored.

A suitable water-blanching method in traditional processing is as follows:

- The sliced material is placed on a square piece of clean cloth; the corners of the cloth are tied together;
- A stick is put through the tied corners of the cloth;
- The cloth is dipped into a pan containing boiling water and the stick rests across the top of the pan thus providing support for the cloth bag.

The average blanching time is 6 minutes. The start of blanching has to be timed from the moment the water starts to boil again after the cloth bag has been dipped into the pan. While the material is being blanched the cloth bag should be raised and lowered in the water so that the material is heated evenly.

When the blanching time is completed the cloth bag and its content should be dipped into cold water to prevent over-blanching. If products are over-blanched (boiled for too long) they will stick together on the drying trays and they are likely to have a poor flavour.

Green beans, carrots, okra, turnip and cabbage should always be blanched. The producer can choose whether or not potatoes need blanching. Blanching is not needed for onions, leeks, tomatoes and sweet peppers. Tomatoes are dipped into hot water for one minute when they need to be peeled but this is not blanching.

Use of Preservatives

Preservatives are used to improve the colour and keeping qualities of the final product for some fruits and vegetables. Preservatives include items such as sulphur dioxide, ascorbic acid, citric acid, salt and sugar and can either be simple or compound solutions.

Treatment with preservatives takes place after blanching or, when blanching is not needed, after slicing. In traditional, simple processing the method recommended is:

- Put enough preservative solution to cover the cloth bag into a container/pan;
- Dip the bag containing the product into the preservative solution for the amount of time specified;
- Remove the bag and put it on a clean tray while the liquid drains out. The liquid which drains out must not go back into the preservative solution because it would weaken the solution.

Care must be taken after each dip to refill the container to the original level with fresh preservative solution of correct strength. After five lots of material have been dipped, the remaining solution is thrown away; i.e. a fresh lot of preservative solution is needed for every 5 lots of material. The composition and strength of the preservative solution vary for different fruit and vegetables.

The strength of sulphur dioxide is expressed as "parts per million" (ppm). 1.5 grams of sodium metabisulphite in one litre of water gives 1000 ppm of sulphur dioxide. Details for solutions of different strengths are given in the following table.

Table: Dilutions of sodium metabisulphite with water to obtain "PM" of sulphur dioxide (SO2)

PPM SO_2	SODIUM METABISULPHITE	
	Grams per litre of water	Grams per 20 litre tin of water
1000	1.5	30.0
2000	3.0	60.0
3000	4.5	90.0
4000	6.0	120.0
5000	7.5	150.0
6000	9.0	180.0
7000	10.5	210.0

One level teaspoon of sodium metabisulphite = c. 5 g.

The preservative solutions in the fruit and vegetable pre-treatment can only be used in enamelled, plastic or stainless-steel containers; never use ordinary metal because solutions will corrode this type of container.

As a general rule, preservatives are not used for treating onions, garlic, leeks, chilies and herbs.

Osmotic Dehydration

In osmotic dehydration the prepared fresh material is soaked in a heavy (thick liquid sugar solution) and/or a strong salt solution and then the material is sun or solar dried. During osmotic treatment the material loses some of its moisture. The syrup or salt solution has a protective effect on colour, flavour and texture.

This protective effect remains throughout the drying process and makes it possible to produce dried products of high quality. This process makes little use of sulphur dioxide.

Sun Drying

The main problems for sun drying are dust, rain and cloudy weather. Therefore, drying areas should be dust-free and whenever there is a threat of a dust storm or rain, the drying trays should be stacked together and placed under cover.

In order to produce dust-free and hygienically clean products, fruit and vegetable material should be dried well above ground level so that they are not contaminated by dust, insects, livestock or people. All materials should be dried on trays designed for the purpose; the most common drying trays have wooden frames with a fitted base of nylon mosquito netting. Mesh made of woven grass can also be used. Metal netting must NOT be used because it discolours the product.

The trays should be placed on a framework at table height from the ground. This allows the air to circulate freely around the drying material and it also keeps the food product well away from dirt. Ideally the area should be exposed to wind and this speed up drying, but this can only be done if the wind is free of dust.

With 80 cm x 50 cm trays, the approximate load for a tray is 3 kg; the material should be spread in even layers. During the first part of the drying period, the material should be stirred and turned over at least once an hour.

This will help the material dry faster and more evenly, prevent it sticking together and improve the quality of the finished product. Products for sun drying should be prepared early in the day; this will ensure that the material enjoys the full effect of the sun during the early stages of drying.

At night the trays should be stacked in a ventilated room or covered with canvas. Plastic sheets should NEVER be used for covering individual trays during sun drying.

Dry or nearly dry products can be blown out of the tray by the wind. However, this can be protected by covering the loaded tray with an empty one; this also gives protection against insects and birds.

Shade Drying

Shade drying is carried out for products which can lose their colour and/or turn brown if put in direct sunlight. Products which have naturally vivid colours like herbs, green and red sweet peppers, chilies, green beans and okra give a more attractive end-product when they are dried in the shade.

The principles for the shade drying are the same as for sun drying. The material to be dried requires full air circulation. Therefore, shade drying is carried out under a roof or thatch which has open sides; it cannot be done either inside conventional buildings with side walls or in compounds sheltered from wind. Under dry conditions when there is a good circulation of air, shade drying takes little more time than is normally required for drying in full sunlight.

Identification of Suitable Designs of Solar Dryers for Different Applications

In the selection of appropriate solar dryers for commercial scale operation, it is imperative that economics be kept in view at all time. A total Energy System concept should be employed and due consideration be given to parasitic energy consumption.

The following features have been identified:

- Large scale dryers are more promising than small scale ones. However, small scale dryers should not be neglected.
- The dryer should be designed to maximise the utilisation factor of the capital investment, i.e. multi-products (fruit, vegetables and other raw material) and multi-use (e.g. drying and heating water for domestic use).
- In general, an auxiliary heat source should be provided to assure reliability, to handle peak loads and also to provide continuous drying during periods of no sunshine.
- Forced convection indirect dryers are preferred because they offer better control, more uniform drying and because of their high heat collection efficiency result in smaller collector area. However, parasitic power should be kept to a minimum.

Two dryer systems have been identified:

- A cabinet type dryer with natural convection for internal air circulation for the processing of dried fruit such as mango, banana, pineapple, apricot, pear, apple, etc. and also for potato chips and other vegetables;
- A greenhouse type dryer with forced air circulation.

Some of the barriers to the commercial development of solar dryers have been attributed to:

- Initial cost - poor farmers cannot afford them
- Durability - constant breakdown due to using low cost building materials
- Misuse - through lack of training and technical skills
- Dependability and reliability - during the wet season when drying is critical there is not enough solar energy available
- The wider use of Solar Drying Systems has been limited by other factors which are not necessarily of a

technical or technological nature. Among the most important are the lack of national policies directed to promoting the drying of produce at the production site, in order to reduce losses, improve quality and increase farmers' earnings.

Construction of Solar Dryers

In the case of simple natural convection dryers it may be more appropriate to build and operate a number of small units. Multiplicity allows diversity, since more than one crop can be dried at a time. A further advantage is that if one dryer is out of operation due to damage, drying can still continue at reduced capacity using the other dryers.

On the other hand, more sophisticated dryers, such as forced convection solar dryers, benefit from economies of scale due to the investment tied up in the fan and the source of heat.

Generally speaking, one large dryer will be more cost-effective than two smaller units. However, it should be taken into consideration that an oversized unit will be operating at less than full capacity, reducing any cost advantage. The drying area required will depend on local conditions, commodity and number of trays on each rack or trolley.

Construction Methods and Materials

Construction methods and available materials may vary considerably from location to location. It is not within the scope of this document to discuss individual, local circumstances. Some general guidelines regarding factors which must be considered can, however, be given:

— *Dimensions of standard materials:* Where possible, design should take account of the sizes of material locally available. For example, it would be poor design to specify the width of a corrugated iron collector as 1.1 m if the standard width of a corrugated iron sheet is 1 m.

Before finalising a design the commercial availability of materials must be ascertained.

— *Use of rural materials:* The cost of building of solar dryer can be minimised if the producer is able to use wood cut straight from the forest rather than prepared timber.

Careful design in the development stage of a dryer can often facilitate the use of cheaper materials. Difficulties caused by these materials are in joining pieces of the structure, in sealing the structure against air leaks, and in attaching the plastic sheet to the (wooden) frame. There is obvious scope for designs which use prepared timber for strategic points and unprepared at others.

Where the use of wood is necessary, remember to take environmental factors into consideration. For example, determine the effect of flash flooding or termites might be and take the appropriate preventive action.

— *Use of plastic sheets:* For many solar dryers, the clear plastic sheet used is the major capital cost to the farmer; therefore, the type of plastic chosen is important.

A choice must be made between a relatively cheap plastic such as ordinary polyethylene which will last, at best, for one season due to photo-degradation and wear and tear; and a more expensive, better quality plastic less prone to photo-degradation; or even glass or a rigid plastic.

Attaching plastic sheet to the framework structure, so as to minimise the likelihood of the plastic being torn is, perhaps, the most difficult part of building a dryer. Listed below are some general points which should be followed to prolong the useful lifetime of plastic sheet on a solar dryer:

- When attaching plastic sheet to the framework, care should be taken to stretch the plastic at the points of attachment, but the plastic should not be so loose that it will flap about in the wind;
- Rather than merely stapling or nailing the plastic directly to the framework, it is preferable to sandwich the plastic between the framework and a batten. This

may not be practical when unprepared wood or other materials are being used.

- No sharp edges should come in contact with the plastic sheet since these will initiate tears;
- Fold over the plastic at the point of attachment to the frame, so that there are two or more layers of plastic. This will help prevent tears;
- When fixing the sheet over the framework, sags and hollows in which water can collect should be avoided wherever possible;
- The dryer should be handled as carefully and as seldom as possible during operation and when not in use.

Technical Criteria

The following design factors must be established:

- The throughput of the dryer over the productive season; the size of batch to be dried;
- The drying period(s) under stated conditions;
- The initial and desired final moisture content of the commodity (if known);
- The drying characteristics of the commodity, such as maximum drying temperature, effect of sunlight upon the product quality, etc.;
- Climatic conditions during the drying season, i.e. sunlight intensity and duration; air temperature and humidity; wind speed (such data may be available from local meteorological stations);
- Availability and reliability of electrical power;
- The availability, quality, durability and price of potential construction materials such as:
  - Glazing materials: glass, plastic sheet or film;
  - Wood (prepared or unprepared);
  - Nails, screw, bolts, etc.;
  - Metal sheet, flat or corrugated angle iron;

  - Bricks (burnt or mud), concrete blocks, stones, cement, sand, etc.
  - Roofing thatch;
  - Metal mesh, wire netting, etc.
  - Mosquito netting, muslin, etc.
  - Bamboo or fibre weave;
  - Black paint, other blackening materials;
  - Insulation material; sawdust, etc.;
- The type of labour available to build and operate the dryer;
- The availability of clean water at the site for preparation of the commodity prior to drying.

In any one situation there may well be other technical factors that need to be considered.

Socio-economic Criteria

From the initial considerations, estimates of the capital costs of the dryer, the price of the commodity to be dried, and the likely selling price of the dried product will have been made. Other question that need to be considered are the following:

- Who will own the dryer?
- Is the dryer to be constructed by the end-user (with or without advice from extension agencies), local contractors, or other organisations?
- Who will operate and maintain it?
- How can the drying operation be incorporated into current practices?
- Are sources of finance from local authorities or extension agencies available, etc.?

Obviously there are many other socio-economic factors, particularly those of a local nature, which must be taken into account. It cannot be stressed too highly that if such factors are not taken into account and evaluated, then is every chance that an inappropriate dryer design may result. Equal emphasis must be placed on both technical and socio-economic factors.

a. Situations where solar dryer may be useful:
   - Where the cost of conventional energy is prohibitive and/or the supply is erratic, to supplement existing artificial drying systems and reduce fuel costs;
   - Where land is in short supply or expensive;
   - Where the quality of existing sun dried products can be improved upon;
   - Where the labour is in short supply;
   - Where is plenty of sunshine, but high humidity.

b. Situations where solar dryers may not be useful:
   - Where conventional energy sources are abundant and cheap;
   - Where large amounts of combustible by-products or waste materials are freely available;
   - Where there is insufficient sunshine;
   - Where is plenty of sunshine and arid conditions (sun drying may suffice);
   - Where the quality of sun dried products already made cannot be improved upon;
   - Where local operators are insufficiently trained;
   - Where the ramifications of introducing a solar dryer have not been completely thought out.

Sun/solar Drying Tray

The drying tray described requires seasoned timber 22.5 mm thick x 50 mm wide. A sun drying tray requires 6 metres of seasoned timber 22.5 mm thick x 50 mm wide.

Cut the timber into lengths of 900 mm long for the sides of the tray and 600 mm long for the ends - 4 pieces of each length will be needed. The ends of each piece are cut as shown in the drawing - this is to make flush fitting joints. Join the corners using small brass screws 20 mm long. To make extra strong joints use good quality wood glue as well as the screws.

The nylon mosquito netting or grass woven mesh can be fitted between the frames as shown in the bottom drawing.

Cut the mesh a little larger than the size of the frame. Using drawing pins, pin the mesh to the OUTSIDE edges of one of the frames - the mesh should be pulled tight as the pins are put in around the edges.

Lay the other frame on top and drill holes about 3 mm in diametre at the points marked X in the top drawing. Use nails that are a tight fit in the holes and tap gently into place leaving a portion standing above the frame.

Cut off the standing part to leave a piece about 12 mm long which is then bent over and tapped firmly down onto the frame. When the frame has been put together tightly, the drawing pins can be removed.

Preservation by Concentration

Foods are concentrated for many of the same reasons that they are dehydrated; concentration can be a form of preservation but this is true only for some foods. Concentration reduces weight and volume and results in immediate economic advantages.

Nearly all liquid foods which are dehydrated are concentrated before they are dried. This is because in the early stages of water removal, moisture can be more economically removed in highly efficient evaporators than in dehydration equipment. Further, increased viscosity from concentration often is needed to prevent liquids from running off drying surfaces or to facilitate foaming or puffing.

Foods are also concentrated because the concentrated forms have become desirable components of diet in their own right. Thus, fruit juices plus sugar with concentration becomes jelly. The more common concentrated fruit and vegetable products include items as fruit and vegetable juices and nectars, jams and jellies, tomato paste, many types of fruit purées used by bakers, candy makers and other food manufacturers.

Aspects of Preservation by Concentration

The level of water in virtually all concentrated foods is in itself more than enough to permit microbial growth. Yet while many concentrated foods such as non-acid fruit and vegetable purées may quickly undergo microbial spoilage unless additionally processed, such items as sugar syrups, jellies and jams are relatively "immune" to spoilage; the difference of course is in what is dissolved in the remaining water and what osmotic concentration is reached.

1. Cell walls
2. Trays on a car
3. Metal plat with burning sulphur
4. Hole for sulphur dioxide fumes
5. Exhaust hole

Courtesy of U.T.A. Industrie

1. Control and switch-board
2. Burner
3. Platform for burner
4. Frontal plate
5. Air flow regulating plate
6. Burner's cylinder
7. Air circulating fan
8. Air direction conveying plates
9. Cars rail
10. Tunnel "feeding" door: inlet of cars with fresh product
11. Tunnel "evacuating" door: outlet of cars with dry product
12. Cars pushing device
13. Cars with trays
14. Drying trays

Sugar and salt in concentrated solutions have high osmotic pressure. When these are sufficient to draw water from microbial cells or prevent normal diffusion of water into these cells, a preservative condition exists.

The critical concentration of sugar in water to prevent microbial growth will vary depending upon the type of micro-organisms and the presence of other food constituents, but usually 70% sucrose in solution will stop growth of all micro-organisms in foods. Less than this concentration may be effective but for short periods of time unless the foods contain acid or they are refrigerated.

Salt becomes a preservative when its concentration is increased and levels of about 18% to 25% in solution generally will prevent all growth of micro-organisms in foods. Except in the case of certain briny condiments, however, this level is rarely tolerated in foods.

Removal of water by concentration also increases the level of food acids in solution (particularly significant in concentrated fruit juices).

Reduced Weight and Volume by Concentration

While the preservation effects of food concentration are important, the main reason of most food concentration is to reduce food weight and bulk. Tomato pulp which is ground tomato minus the skins and seeds, has a solid content of only 6 % and so a 3.785 litre can would contain only 231 g of tomato solids.

Table: Specific gravity and solids. Tomato pulp and commercial tomato concentrates

Tomato Solids, %	Specific gravity at 68°F (20°C)	Dry Tomato Solids	
		per Gal. at 68°F, lb	per Litre at 20°C, g
6.0 Tomato pulp	1.025	0.51	61
10.8	1.045	0.94	113
12.0 Tomato purée	1.050	1.05	126
14.2	1.060	1.25	151
16.5	1.070	1.47	177

25.0	1.107	2.31	277
26.0	1.112	2.41	289
28.0 Tomato paste	1.120	2.61	314
30.0	1.129	2.82	339
32.0	1.138	3.03	364

Concentrated to 32% solids, the same can would contain 1.38 kg of tomato solids or six times the value of product. For a manufacturer needing tomato solids such a producer of soups, canned spaghetti or frozen pizza the saving from concentration are enormous in cans, transportation costs, warehousing costs and handling costs throughout his operation.

Methods of Concentration

a. Solar concentration. As in food dehydration, one of the simplest methods of evaporating water is with solar energy. A typical example of this method is production at farm level in developing countries of fruit pastes/leathers (such as apricot or plum pastes).

b. Open Kettles. Some foods can be satisfactorily concentrated in open kettles that are heated by steam. This is the case for jellies and jams, tomato juices and purées and for certain types of soups. High temperatures and long concentration times should be avoided in order to reduce or eliminate damage. It is also necessary to avoid thickening and burn-on of product to the kettle wall as these gradually lower the efficiency of heat transfer and slow the concentration process.

   However, when the process is under control, this type of evaporation is still highly recommended for small scale operations in developing countries. It is a quite widely used system, mainly for jellies, jams and marmalades.

c. Flash evaporators.

d. Thin-film Evaporators.

e. Vacuum evaporators. - It is common to construct several vacuumised vessels in series so that the product moves from one vacuum chamber to the next and thereby becomes progressively more concentrated in stages.

   With such an arrangement the successive stages are maintained at progressively higher degrees of vacuum, and the hot water vapour produced by the first stage is used to heat the second stage, the vapour from the second stage heats the third stage and so on. In this way maximum use of heat energy is made.

f. Freeze Concentration. This process has been known for many years and has been applied commercially to orange juice. However, high processing costs due largely to losses of juice occlude [unclear] to the ice crystals, have limited the number of installations to date.

g. Ultrafiltration and reverse Osmosis.

Changes from Concentration

Obviously concentration that exposes food to 100° C or higher temperatures for prolonged periods can cause major changes in organoleptic and nutritional properties. Cooked foods and darkening of colour are two of the more common heat induced results which must be kept under control during a well designed process with an efficient evaporator which is still "safe".

Microbial destruction is another type of change that may occur during concentration and will be largely dependent upon temperature. Concentration at a temperature of 100 °C or slightly above will kill many micro-organisms but cannot be depended on to destroy bacterial spores. When the food contains acid, such as fruit juices, the kill will be greater but again sterility is unlikely.

On the other hand, when concentration is done under vacuum many bacterial types not only survive the low temperatures but multiply in the concentrating equipment. It is therefore necessary to stop frequently and sanitise low temperature evaporators and where sterile concentrated foods are required, to resort to an additional preservation treatment.

Many chemicals will kill micro-organisms or stop their growth but most of these are not permitted in foods; chemicals that are permitted. Chemical food preservatives are those substances which are added in very low quantities (up to 0.2%) and which do not alter the organoleptic and physico-chemical properties of the foods at or only very little.

Preservation of food products containing chemical food preservatives is usually based on the combined or synergistic activity of several additives, intrinsic product parametres (e.g. composition, acidity, water activity) and extrinsic factors (e.g. processing temperature, storage atmosphere and temperature).

This approach minimises undesirable changes in product properties and reduces concentration of additives and extent of processing treatments.

The concept of combinations of preservatives and treatments to preserve foods is frequently called the hurdle or barrier concept. Combinations of additives and preservatives systems provide unlimited preservation alternatives for applications in food products to meet consumer demands for healthy and safe foods.

Chemical food preservatives are applied to foods as direct additives during processing, or develop by themselves during processes such as fermentation. Certain preservatives have been used either accidentally or intentionally for centuries, and include sodium chloride (common salt), sugar, acids, alcohols and components of smoke. In addition to preservation, these compounds contribute to the quality and identity of the products, and are applied through processing procedures such as salting, curing, fermentation and smoking.

Traditional chemical food preservatives and their use in fruit and vegetable processing technologies could be summarised as follows: common salt: brined vegetables; sugars (sucrose, glucose, fructose and syrups): foods preserved by high sugar concentrations: jellies, preserves, syrups, juice concentrates; interaction of sugar with other ingredients or processes such as drying and heating; indirect food preservation by sugar in products where fermentation is important (naturally acidified pickles and sauerkraut).

Acidulants and other preservatives formed in or added to fruit and vegetable products are as follows:

Lactic acid. This acid is the main product of many food fermentations; it is formed by microbial degradation of sugars in products such as sauerkraut and pickles. The acid produced in such fermentations decreases the pH to levels unfavourable for growth of spoilage organisms such as putrefactive anaerobes and butyric-acid-producing bacteria. Yeasts and moulds that can grow at such pH levels can be controlled by the inclusion of other preservatives such as sorbate and benzoate.

Acetic acid. Acetic acid is a general preservative inhibiting many species of bacteria, yeasts and to a lesser extent moulds. It is also a product of the lactic-acid fermentation, and its preservative action even at identical pH levels is greater than that of lactic acid. The main applications of vinegar (acetic acid) includes products such as pickles, sauces and ketchup.

Other acidulants

- Malic and tartaric (tartric) acids is used in some countries mainly to acidify and preserve fruit sugar preserves, jams, jellies, etc.
- Citric acid is the main acid found naturally in citrus fruits; it is widely used (in carbonated beverages) and as an acidifying agent of foods because of its unique flavour properties. It has an unlimited acceptable daily intake and is highly soluble in water. It is a less effective antimicrobial agent than other acids.
- Ascorbic acid or vitamin C, its isomer isoascorbic or erythorbic acid and their salts are highly soluble in water and safe to use in foods.

Commonly Used Lipophilic Acid Food Preservatives

Benzoic acid in the form of its sodium salt, constitutes one of the most common chemical food preservative. Sodium benzoate is a common preservative in acid or acidified foods such as fruit juices, syrups, jams and jellies, sauerkraut, pickles, preserves, fruit cocktails, etc. Yeasts are inhibited by benzoate to a greater extent than are moulds and bacteria.

Sorbic acid is generally considered non toxic and is metabolised; among other common food preservatives the WHO has set the highest acceptable daily intake (25 mg/kg body weight) for sorbic acid.

Sorbic acid and its salts are practically tasteless and odourless in foods, when used at reasonable levels (< 0.3 %) and their antimicrobial activity is generally adequate.

Sorbates are used for mould and yeast inhibition in a variety of foods including fruits and vegetables, fruit juices, pickles, sauerkraut, syrups, jellies, jams, preserves, high moisture dehydrated fruits, etc.

Potassium sorbate, a white, fluffy powder, is very soluble in water (over 50%) and when added to acid foods it is hydrolysed to the acid form. Sodium and calcium sorbates also have preservative activities but their application is limited compared to that for the potassium salt, which is employed because of its stability, general ease of preparation and water solubility.

Gaseous Chemical Food Preservatives

Sulphur dioxide and sulphites. Sulphur dioxide (SO_2) has been used for many centuries as a fumigant and especially as a wine preservative. It is a colourless, suffocating, pungent-smelling, non-flammable gas and is very soluble in cold water (85 g in 100 ml at 25°C).

Sulphur dioxide and its various sulphites dissolve in water, and at low pH levels yield sulphurous acid, bisulphite and sulphite ions. The various sulphite salts contain 50-68% active sulphur dioxide. A pH dependent equilibrium is formed in water and the proportion of SO_2 ions increases with decreasing pH values. At pH values less than 4.0 the antimicrobial activity reaches its maximum.

Sulphur dioxide is used as a gas or in the form of its sulphite, bisulphite and metabisulphite salts which are powders. The gaseous form is produced either by burning Sulphur or by its release from the compressed liquefied form.

Metabisulphite are more stable to oxidation than bisulphites, which in turn show greater stability than sulphites. The antimicrobial action of sulphur dioxide against yeasts, moulds and bacteria is selective, with some species being more resistant than others.

Sulphur dioxide and sulphites are used in the preservation of a variety of food products. In addition to wines these include dehydrated/dried fruits and vegetables, fruit juices, acid pickles, syrups, semi-processed fruit products, etc. In addition to its antimicrobial effects, sulphur dioxide is added to foods for its antioxidant and reducing properties, and to prevent enzymatic and non-enzymatic browning reactions.

Carbon dioxide (CO_2) is a colourless, odourless, non-combustible gas, acidic in odour and flavour. In commercial practice it is sold as a liquid under pressure (58 kg per cm^3) or solidified as dry ice.

Carbon dioxide is used as a solid (dry ice) in many countries as a means of low-temperature storage and transportation of food products. Beside keeping the temperature low, as it sublimes, the gaseous CO_2 inhibits growth of psychrotrophic micro-organisms and prevents spoilage of the food (fruits and vegetables, etc.).

Carbon dioxide is used as a direct additive in the storage of fruits and vegetables. In the controlled/modified environment storage of fruit and vegetables, the correct combination of O_2 and CO_2 delays respiration and ripening as well as retarding mould and yeast growth.

The final result is an extended storage of the products for transportation and for consumption during the off-season. The amount of CO_2 (5-10%) is determined by factors such as nature of product, variety, climate and extent of storage.

Chlorine. The various forms of chlorine constitute the most widely used chemical sanitiser in the food industry. These chlorine forms include chlorine (Cl_2), sodium hypochlorite (NaOCl), calcium hypochlorite ($Ca(OCl)_2$) and chlorine dioxide gas (ClO_2).

These compounds are used as water adjuncts in processes such as product washing, transport, and cooling of heat-sterilised cans; in sanitising solutions for equipment surfaces, etc.

Important applications of chlorine and its compounds include disinfection of drinking water and sanitation of food processing equipment.

General Rules for Chemical Preservation

Chemical food preservatives have to be used only at a dosage level which is needed for a normal preservation and not more. "Reconditioning" of chemical preserved food, e.g. a new addition of preservative in order to stop a microbiological deterioration already occurred is not recommended.

The use of chemical preservatives must be strictly limited to those substances which are recognised as being without harmful effects on human beings' health and are accepted by national and international standards and legislation.

Factors which Determine/Influence the Action of Chemical Food Preservatives

Factors related to the chemical preservatives:

a. Chemical composition;
b. Concentration.

Factors related to micro-organisms:

a. Micro-organism species; as a general rule it is possible to take the following facts as a basis:

- Sulphur dioxide and its derivatives can be considered as an "universal" preservative; they have an antiseptic action on bacteria as well as on yeasts and moulds;
- Benzoic acid and its derivatives have a preservative action which is stronger against bacteria than on yeasts and moulds;
- Sorbic acid acts on moulds and certain yeast species; in higher dosage levels it acts also on bacteria, except lactic and acetic ones;
- Formic acid is more active against yeasts and moulds and less on bacteria.

b. The initial number of micro-organisms in the treated product determines the efficiency of the chemical preservative.

The efficiency is less if the product has been contaminated because of preliminary careless hygienic treatment or an incipient alteration. Therefore, with a low initial number of micro-organisms in the product, the preservative dosage level could be reduced.

Specific factors related to the product to be preserved:

a. Product chemical composition;
b. Influence of the pH value of the product: the efficiency of the majority of chemical preservatives is higher at lower pH values, i.e. when the medium is more acidic.
c. Physical presentation and size which the product is sliced to: the chemical preservative's dispersion in food has an impact on its absorption and diffusion through cell membranes on micro-organisms and this determines the preservation effect.

Therefore, the smaller the slicing of the product, the higher the preservative action. Preservative dispersion is slowed down by viscous foods (concentrated fruit juices, etc.)

Miscellaneous factors

a. *Temperature:* chemical preservative dosage level will be established as a function of product temperature and characteristics of the micro-flora;

b. *Time:* at preservative dosage levels in employed in industrial practice, the time period needed in order to obtain a "chemical sterilisation" is a few weeks for benzoic acid and shorter for sulphurous acid.

Usual accepted chemical food preservatives are detailed in Table given below.

Table: Chemical Food Preservatives

Agent	Acceptable Daily intake (mg/Kg body weight)	Commonly used levels (%)
Lactic acid	No limit	No limit
Citric acid	No limit	No limit
Acetic acid	No limit	No limit
Sodium Diacetate	15	0.3-0.5
Sodium benzoate	5	0.03-0.2
Sodium propionate	10	0.1-0.3
Potassium sorbate	25	0.05-0.2
Methyl paraben	10	0.05-0.1
Sodium nitrite	0.2	0.01-0.02
Sulphur dioxide	0.7	0.005-0.2

For the purpose of this document, some food products in common usage are summarised as follows:

- Citric acid: fruit juices; jams; other sugar preserves;
- Acetic acid: vegetable pickles; other vegetable products;
- Sodium benzoate: vegetable pickles; preserves; jams; jellies; semi-processed products;
- Sodium propionate: fruits; vegetables;
- Potassium sorbate: fruits; vegetables; pickled products; jams, jellies;

- Methyl paraben: fruit products; pickles; preserves;
- Sulphur dioxide: fruit juices; dried/dehydrated fruits and vegetables; semi-processed products.

PRESERVATION OF VEGETABLES BY ACIDIFICATION

Food acidification is a means of preventing their deterioration in so far as a non-favourable medium for micro-organisms development is created. This acidification can be obtained by two ways: natural acidification and artificial acidification.

Natural Acidification

This is achieved by a predominant lactic fermentation which assures the preservation based on acidoceno-anabiosys principle; preservation by lactic fermentation is called also biochemical preservation. Throughout recorded history food has been preserved by fermentation. In spite of the introduction of modern preservation methods, lactic acid fermented vegetables still enjoy a great popularity, mainly because of their nutritional and gastronomic qualities.

The various preservation methods discussed thus far, based on the application of heat, removal of water, cold and other principles, all have the common objective of decreasing the number of living organisms in foods or at least holding them in check against further multiplication.

Fermentation processes for preservation purposes, in contrast, encourage the multiplication of micro-organisms and their metabolic activities in foods. But the organisms that are encouraged are from a select group and their metabolic activities and end products are highly desirable. The extent of this desirability is emphasised by a partial list of fermented fruits and vegetable products from various parts of the world.

There are some characteristic features in the production of fermented vegetables which will be pointed out below using cucumbers as an example. In the production of lactic acid fermented cucumbers, the raw material is put into a brine without previous heating. Through the effect of salt and oxygen deficiency the cucumber tissues gradually die. At the same time, the semi-permeability of the cell membranes is lost, whereby soluble cell components diffuse into the brine and serve as food substrate for the micro-organisms.

Under such specific conditions of the brine the lactic acid bacteria succeed in overcoming the accompanying micro-organisms and lactic acid as the main metabolic products is formed. Under favourable conditions (for example moderate salt in the brine, use of starter cultures) it takes at least 3 days until the critical pH value of 4.1 or less - desired for microbiological reasons - is reached.

Beside the typical taste, for the consumer a crisp texture is the most important quality criterion for fermented vegetables. Because there is no heating step before the fermentation, the indigenous plant enzymes in the fermenting materials are still present during the very first phase. After the destruction of the cell membranes they easily get to their active sites and under favourable conditions they can easily cause softening.

The environmental conditions act in a different manner on single enzymes or enzymes systems: some enzymes are strongly inhibited by salt, others are activated, and in the acid pH-region many enzymes are irreversibly inactivated. Beside indigenous enzymes also enzymes produced by micro-organisms can be responsible for the undesired soft products.

In technically advanced societies the major importance of fermented foods has come to be variety they add to the diet. However, in many less developed areas of the world, fermentation and natural drying are the major food preservation methods and as such are vital to survival of a large proportion of the world's current population.

Artificial acidification is carried out by adding acetic acid which is the only organic acid harmless for human health and stable in specific working conditions; in this case biological principles of the preservation are acidoanabiosys and, to a lesser extent, acidoabiosys.

Combined acidification is a preservation technology which involves as a preliminary processing step a weak lactic fermentation followed by acidification (vinegar addition). The two main classes of vegetables preserved by acidification are sauerkraut and pickles; the definitions of these products adapted from US Code of Federal Register are as follows.

Bulk sauerkraut. Bulk or barrelled sauerkraut is the product of characteristic acid flavour, obtained by the full fermentation, chiefly lactic, of properly prepared and shredded cabbage in the presence of 2-3% salt. On completion of fermentation, it contains not more than 1.5% of acid, expressed as lactic acid.

Canned sauerkraut. Canned (or packaged) sauerkraut, is prepared from clean, sound, well-matured heads of the cabbage plant (Brassica oleracea var. capitata L.) which have been properly trimmed and cut; to which salt is added and which is cured by natural fermentation. The product may or may not be packed with pickled peppers, pimientos, or tomatoes or contain other flavouring ingredients to give the product specific flavour characteristics. The product:

a. May be canned by processing sufficiently by heat to assure preservation in hermetically sealed containers; or
b. May be packaged in sealed containers and preserved with or without the addition of benzoate of soda or any other ingredient permissible under the provisions of Food and Drug Administration (FDA).

Pickles. "Pickles" means the product prepared entirely or predominantly from cucumbers (Cucumis sativus L.). Clean, sound ingredients are used which may or may not have been previously subjected to fermentation and curing in a salt brine (solution of sodium chloride, NaCl).

The prepared pickles are packed in a vinegar solution to which may be added salt and other vegetables, nutritive sweeteners, seasonings, flavourings, spices, and other ingredients permissible under FDA regulations. The product is packed in suitable containers and heat treated, or otherwise processed to assure preservation. Sauerkraut and pickle products can be preserved under the effect of natural or added acidity, followed by pasteurization when this acidification is not sufficient.

Sauerkraut is a very good source of vitamin C; the importance of this product should be emphasised in developing countries as a simple technology which can be applied mainly for consumption of the finished products in remote, isolated areas during the cold season. It is also a excellent technology to be learned to schools which have their own source of cabbage and cucumbers through school agricultural farms.

Sauerkraut and pickles are manufactured on an industrial scale in significant quantities world-wide. However, the basic technology is simple and could be applied at home, farm and community level after some explanation and training. The natural acidification preservation could be considered similar to sun/solar drying in terms of training and development.

Table: Some industrial fermentation processes in food industries

I. Lactic acid bacteria	
— cucumbers	dill pickles, sour pickles
— cabbage	sauerkraut
— turnips	sauerruben
— lettuce	lettuce kraut
— mixed vegetables, turnips, radish, cabbage	
— mixed Chinese vegetables, cabbage	Kimchi
— vegetables and milk	Tarhana
— vegetables and rice	Sajur asin
II. Lactic acid bacteria with other micro-organisms	
— with yeasts	Nukamiso pickles
— with moulds	tempeh, soy sauce
III. Acetic acid bacteria - wine, cider or any alcoholic and sugary or starchy products may be converted to vinegar	
IV. Yeasts	
— fruit	wine, vermouth

The principle of this technology is to add sugar in a quantity that is necessary to augment the osmotic pressure of the product's liquid phase at a level which will prevent microorganism development. From a practical point of view, however, it is usual to partially remove water (by boiling) from the product to be preserved, with the objective of obtaining a higher sugar concentration. In concentrations of 60% in the finished products, the sugar generally assures food preservation.

It is important to know the ratio between the total sugar quantity in the finished product and the total sugar concentration in the liquid phase because this determines, in practice, the sugar preserving action. The percent composition of a product preserved with sugar, for example marmalade, can be expressed as follows: $[i + S + s + n + w] = 100$;

i = insoluble substance;

s = sugar from fruits;

S = added sucrose;

n = soluble "non sugar"

w = water.

In this case, total sugar concentration, in the liquid phase, of the finished product is:

$$X = 100\ (S + s)/100 - (n + i)\ [\%]$$

Therefore, in the case of a standard marmalade with 55 % sugar added (calculated on the finished product basis), the real concentration in the liquid phase is for example:

$$X = 100\ (55 + 8)/100 - (5 + 3) = 68.5\%$$

In the food preservation with sugar, the water activity cannot be reduced below 0.845; this value is sufficient for bacteria and neosmophile yeast inhibition but does not prevent mould attack. For this reason, various means are used to avoid mould development:

- Finished product pasteurization (jams, jellies, etc.);
- Use of chemical preservatives in order to obtain the antiseptisation of the product surface.

It is very important from a practical point of view to avoid any product contamination after boiling and to assure an hygienic operation of the whole technological process (this will contribute to the prevention of product moulding or fermentation). Storage of the finished products in good conditions can only be achieved by ensuring the above level of water activity.

HEAT PRESERVATION/HEAT PROCESSING

Various Degrees of Preservation

There are various degrees of preservation by heating; a few terms have to be identified and understood.

a. Sterilisation.' By sterilisation we mean complete destruction of micro-organisms. Because of the resistance of certain bacterial spores to heat, this frequently means a treatment of at least 121° C (250° F) of wet heat for 15 minutes or its equivalent. It also means that every particle of the food must receive this heat treatment. If a can of food is to be sterilised, then immersing it into a 121° C pressure cooker or retort for the 15 minutes will not be sufficient because of relatively slow rate of heat transfer through the food in the can to the most distant point.

b. "Commercially sterile". Term describes the condition that exists in most of canned or bottled products manufactured under Good Manufacturing Practices procedures and methods; these products generally have a shelf-life of two years or more.

c. Pasteurized means a comparatively low order of heat treatment, generally at a temperature below the boiling point of water. The more general objective of pasteurization is to extend product shelf-life from a microbial and enzymatic point of view; this is the objective when fruit or vegetable juices and certain other foods are pasteurized.

   Pasteurization is frequently combined with another means of preservation - concentration, chemical, acidification, etc.

d. Blanching is a type of pasteurization usually applied to vegetables mainly to inactivate natural food enzymes. Depending on its severity, blanching will also destroy some microorganisms.

Determining Heat Treatment/Thermal Processing Steps

Since heat sufficient to destroy micro-organisms and food enzymes also usually has adverse effects on other properties of foods, in practice the minimum possible heat treatment should be used which can guarantee freedom from pathogens and toxins and give the desired storage life; these aims will determine the choice of heat treatment.

In order to safely preserve foods using heat treatment, the following must be known:

a. What time-temperature combination is required to inactivate the most heat resistant pathogens and spoilage organisms in one particular food?
b. What are the heat penetration characteristics in one particular food, including the can or container of choice if it is packaged?

Preservation processes must provide the heat treatment which will ensure that the remotest particle of food in a batch or within a container will reach a sufficient temperature, for a sufficient time, to inactivate both the most resistant pathogen and the most resistant spoilage organisms if it is to achieve sterility or "commercial sterility", and to inactivate the most heat resistant pathogen if pasteurization for public health purposes is the goal.

Different foods will support growth of different pathogens and different spoilage organisms so the target will vary depending upon the food to be heated.

Food acidity/pH value has a tremendous impact on the target in heat preservation/processing. Table given below lists various types of fruit and vegetables and their pH value, together with the heat processing requirements.

Table: Heat processing requirements — dependence on product acidity

Acidity class	pH value	Food item	Heat and processing requirements
Low acid	6.0	Peas, carrots, beets, potatoes, asparagus (240-250°F)	High temperature processing 116-121°C
	5.0	Tomato soup	
Medium acid	4.5	Tomatoes, pears, apricots, peaches	Boiling water processing 100°C (212°F)
Acid	3.7	Sauerkraut, apple,	
High acid	3.0	Pickles	

Sequence of Operations Employed in Heat Preservation of Foods (Fruit and Vegetables, etc.)

In a simplified manner, the main operations employed in heat preservation can be described as follows:

Food preparation	Preparation procedures will vary with the type of food. For fruit, washing, sorting, grading, peeling, cutting to size, pre-cooking and pulping operations may be employed.
Can/receptacle	This may be carried out manually or by using sophisticated filling machinery. The ratio of liquid to solid in the can must be carefully controlled and the can must not be overfilled. A headspace of 6-9 mm depth (6-8% of the container volume) above the level of food in the can is usual.
Vacuum production	This can be achieved by filling the heated product into the can, by heating the can and contents after filling, by evacuating the headspace gas in a vacuum chamber, or by injecting superheated steam into the headspace. In each case the can end is seamed on immediately afterwards.
Thermal processing	The filled sealed can must be heated to a high temperature for a sufficient length of time to ensure the destruction of spoilage micro-organisms. This is usually carried out in an

	autoclave or retort, in an environment of steam under pressure.
Cooling	The processed cans must be cooled in chlorinated water to a temperature of 37°C. At this temperature the heat remaining is sufficient to allow the water droplets on the can to evaporate before labelling and packing.
Labelling and packing	Labels are applied to the can body, and the cans are then packed into cases.

In principle, all these operations can also be carried out at the farm/community level using the appropriate small scale equipment, preferably only glass jars (e.g. no metal cans).

Technological principles of pasteurization

Physical and chemical factors which influence pasteurization process are the following:

a. Temperature and time;
b. Acidity of the products;
c. Air remaining in containers.

Pasteurization processes. In pasteurising certain acid juices for example, there are two categories of processes:

a. Low pasteurization where pasteurization time is in the order of minutes and related to the temperature used; two typical temperature/time combinations are as following:

   63° C to 65° C over 30 minutes

   or

   75° C over 8 to 10 minutes.

Pasteurization temperature and time will vary according to:

- Nature of product; initial degree of contamination;
- Pasteurized product storage conditions and shelf life required.

In this first category of pasteurization processes it is possible to define three phases:

- Heating to a fixed temperature;

- Maintaining this temperature over the established time period (= pasteurization time);
- Cooling the pasteurized products: natural (slow) or forced cooling.

b. Rapid, high or flash pasteurization is characterized by a pasteurization time in the order of seconds and temperatures of about 85° to 90° C or more, depending on holding time. Typical temperature/time combinations are as follows:

   88° C (190° F) for 1 minute;

   100° C for 12 seconds;

   121°C for 2 seconds.

While bacterial destruction is very nearly equivalent in low and in high pasteurization processes, the 121° C/2 seconds treatment give the best quality products in respect of flavour and vitamin retention. Such short holding times, however, require special equipment which is more difficult to design and generally is more expensive than the 63-65 ° C/30 minutes type of processing equipment.

In flash pasteurization the product is heated up rapidly to pasteurization temperature, maintained at this temperature for the required time, then rapidly cooled down to the temperature for filling, which will be performed in aseptic conditions in sterile receptacles. Taking into account the short time and rapid performance of this operation, flash pasteurization can only be achieved in continuous process, using heat exchangers.

Industrial applications of pasteurization process are mainly used as a means of preservation for fruits and vegetable juices and specially for tomato juice.

Thermopenetration

The thermopenetration problem is extremely important, especially in the case of the pasteurization of products packed in glass containers because it is the determining factor for the success of the whole operation.

During pasteurization it is necessary that a sufficient heat quantity is transferred through the receptacle walls; this is in order that the product temperature rises sufficiently to be lethal to micro-organisms throughout the product mass. The most suitable and practical method to speed up thermopenetration is the movement of receptacles during the pasteurization process.

Rapid rotation of receptacles around their axis is an efficient means to accelerate heat transfer, because this has the effect, among others of rapidly mixing the contents. The critical speed of for this movement is generally about 70 rotations per minute (RPM). This enables a more uniform heating of products, reducing heating time and organoleptic degradation.

Heating may precede or follow packaging. These principles of different temperature time combinations very largely determine the design parametres for heat preservation equipment and commercial practices.

The food processor will employ no less than that heat treatment which gives the necessary degree of micro-organism destruction. This is further ensured by periodic inspection by local sanitary authorities or by the importing countries sanitary services. However, the food processor also will want to use the mildest effective heat treatment to ensure highest food quality.

It is convenient to separate heat preservation practices into two broad categories: one involves heating of foods in their final containers, the other employs heat prior to packaging. The latter category includes methods that are inherently less damaging to food quality, where the food can be readily subdivided (such as liquids) for rapid heat exchange. However, these methods then require packaging under aseptic or nearly aseptic conditions to prevent or at least minimise recontamination.

On the other hand, heating within the package frequently is less costly and produces quite acceptable quality with the majority of foods and most of our present canned food supply is heated in the package. In practice, therefore, most of the canned food produced locally in developing countries should be heated within the package.

FOOD IRRADIATION

Food irradiation is one of the food processing technologies available to the food industry to control organisms that cause food-borne diseases and to reduce food losses due to spoilage and deterioration. Food irradiation technology offers some advantages over conventional processes. Each application should be evaluated on its own merit as to whether irradiation provides a technical and economical solution that is better than traditional processing methods.

Table: Possible Causes of Spoilage (Real or Aparent) in Canned Goods

Type of food: Acid and high acid foods (canned fruits)

Condition of can	Action to be taken to identify cause
Insufficient vacuum or headspace	Check vacuum and headspace in relation to storage temperature and altitude.
"Springer" or "flipper"	Cool can to 15°C and check if still domed. Check can for denting, if possible measure headspace volume change brought about by dents, by comparing can volume with volume of a sound can
Hydrogen swell	Check degree of detinning in can especially at the liquid level. Look for scratches or pinholes in lacquer or tin coating. Check if can is still domed on cooling to 15°C.
"Hard" or "soft swell"	Leaker spoilage. Check can for gross seam faults, perforation due to corrosion or damage to seams. Examine contents for signs of spoilage and can interior for detinning at air/product interface.

Applications

For products where irradiation is permitted, commercial applications depend on a number of factors including the demand for the benefits provided, competitiveness with alternative processes and the willingness of consumers to buy irradiated food products. There are a number of applications of food irradiation. For each application it is important to determine the optimum dosage range required to achieve the desired effect. Too high a dosage can produce undesirable changes in texture, colour and taste of foods.

Shelf-life Extension

Irradiation can extend the shelf-life of foods in a number of ways. By reducing the number of spoilage organisms (bacteria, mould, fungi), irradiation can lengthen the shelf life of fruits and vegetables.

Since ionising radiation interferes with cell division, it can be used as an alternative to chemicals to inhibit sprouting and thereby extend the shelf life of potatoes, onions and garlic. Exposure of fruits and vegetables to ionising radiation slows their rate of ripening. Strawberries, for example, have been found to be suitable for irradiation. Their shelf-life can be extended three-fold, from 5 to 15 days.

Disinfestation

Ionising radiation can also be used as an alternative to chemical fumigants for disinfestation of grains, spices, fruits and vegetables. Many countries prohibit the importation of products suspected of being contaminated with live insects to protect the importing country's agricultural base. With the banning of certain chemical fumigants, irradiation has the potential to facilitate the international shipment of food products.

Global Developments

In 1980, an FAD/IAEA/WHO Expert Committee reviewed in detail all the accumulated data on food irradiation from the past 40 years. The Expert Committee concluded that irradiation to an overall dose of 10 kGy (kilograys) presents no toxicological hazard and introduces no special nutritional or microbiological problems, thus establishing the wholesomeness of irradiated foods up to an overall average absorbed dose of 10 kGy.

Data were insufficient to formulate conclusions on applications of food irradiation above 10 kGy. Data on radiation chemistry, nutritional and microbiological aspects of food treated above 10 kGy is currently being compiled.

In 1983, the Codex Alimentarius Commission, an international group that develops global food standards for the FAO and the WHO, incorporated the 1980 Expert Committee's conclusions regarding the wholesomeness of irradiated foods into the Codex General Standard for Irradiated Foods. This proposed international standard was submitted to member countries to accept or to modify according to individual country needs. Currently most countries that allow food irradiation approve its use on a case-by-case basis.

The Codex Alimentarius Commission has also adopted a Recommended International Code of Practice for the Operation of Radiation Facilities for the Treatment of Foods. It is intended to serve as a guide for irradiator operators and government regulators.

International Trade

More than 30 countries have given clearances for the use of food irradiation to process some 40 food items and approximately 30 facilities world-wide treat food by irradiation processing. Approvals for additional items are being considered in many countries and many food irradiation facilities are being planned. It was anticipated in 1988 that by 1990 there could be approximately 50 commercial/demonstration irradiators in 25 countries.

Table given below shows commercial applications of food irradiation to fruits and vegetables by country.

Table: International Commercial Applications of Radiation for Fruit and Vegetables

Country	Location (application date)	Food Commodity
Argentina	Buenos Aires (1986)	Spinach
Belgium	Fleurus (1981)	Dehydrated vegetables
Brazil	Sao Paulo (1985)	Dehydrated vegetables
Chile	Santiago (1983)	Dehydrated vegetables onions, potatoes
China	Shanghai (1985	Potatoes
Cuba	Havana (1987)	Potatoes, onions
German Dem. Rep	Weideroda (1983)	Onions, garlic
	Spickendorf (1986)	Onions
Japan	Hokkaido (1973)	Potatoes
Korea	Seoul (1985	Garlic powder
Netherlands	Ede (1978)	Dehydrated vegetables
South Africa	Johannesburg (1981)	Dehydrated vegetables
	Tzaneen (1981)	Fruits, onions, potatoes
Thailand	Bangkok (1971)	Onions

6

Auxiliary Raw Materials

Auxiliary raw materials used in fruit and vegetable processing technologies play a major role in the determination of their physical and chemical characteristics, sensory properties and nutritive value.

WATER

Water is one of the essential factors in the activity of the processing centres; according to the final utilisation, water can be classified in three categories:

a. For technological utilisation (when it comes into direct contact with raw materials and enters in the finished product's composition),
b. For steam generators and
c. For receptacle cooling, washing of equipment and general hygiene.

Water for Technological Uses

Water coming into direct contact with the raw materials used for processing (washing, blanching, etc.) or that used as filling liquid of some canned products, must be of drinking water quality in terms of its physico-chemical and microbiological conditions.

More important even than fulfilling drinking water standards, water used for these purposes pests certain specific characteristics related to the technological step or the raw material treated during the processing.

When very hard water is used for blanching vegetables some pecto-calcium and pectomagnesium complexes are formed which starts the hardening of vegetable tissues. This process continues over the pasteurization of the finished product.

When fruit is processed in sugar syrup, the use of hard water for the syrup preparation could induce the formation of a pectin-sugar-acid gel facilitated by the medium pH and presence of calcium salts.

Soft water has negative consequences associated with mineral and hydrosoluble substances and losses during blanching of vegetables. For some specific products such as peeled tomatoes, green beans and fine texture fruit, the addition of calcium salts (chlorure, sulphate, etc.) is employed to correct for low texture.

The water hardness is an essential factor when used as filling liquid for canned products; ideally, the hardness of the water should be adapted to the raw material species used for canning. Thus a hardness of 3° is good for beans, 5° to 9° for green peas, green beans, and for fruit and vegetables with a tendency to disintegrate should use even harder water.

In the technological process of cucumber and gherkin preservation by natural acidification (lactic fermentation), water hardness has a paramount role. The literature maintains that as far as texture is concerned, the best results are obtained by using very hard water (about 30°); but since high magnesium and salt content has a negative effect on taste, in practice it is recommended that a water hardness of about 10° be used, which gives satisfactory results from both points of view.

Oxygen present in water can act as a corrosion factor in metal receptacles but this negative influence can be eliminated by preliminary boiling.

An important factor is pH. Water for canning must be neutral or slightly basic. Acid water plays a major role in corrosion which is evident both on receptacles and on iron or copper equipment, where changes of product colour will be induced. More dangerous is the attack on lead pipes or to the mix used for can sticking and this can render the product toxic. For these reasons an acid water must be neutralised before use.

Water for Steam Generators

Two main conditions must be fulfilled:

- Hardness has to be as low as possible, even zero, because precipitation of calcium salts can lead to the formation of encrustations ("crusts") in pipes and on equipment walls. For this reason, water treatment is practiced in the majority of installations;
- From a bacteriological point of view, the iron-bacteria must be eliminated with biological filters or oxidising substances. This is necessary in order to avoid iron hydroxide formed during equipment exploitation to deposit on the inner walls of the pipes.

The elimination of iron-bacteria is also of importance for the water used in processing steps.

Water for Receptacle Cooling and General Hygiene

This should be of drinking water standard.

Where this is not available in sufficient quantity, the use of industrial water is acceptable but only for cleaning of production rooms/workshops.

SWEETENERS

Sugar

Sugar is the conventional name applied to sucrose. Physically there is icing, granulated and lump sugar. In fruit and vegetable processing, sugar is used only in its granulated form; this quality must be in the form of uniform crystals, white, shining and completely soluble in water.

Concentration of various sugar solutions can be rapidly measured by refractometre reading or with areometres graduated in various ways: Brix, Baumé, etc. Sugar solubility in water is dependent upon temperature; for example, in order to obtain a saturated solution, one must dissolve 2040 g in one litre of water at 20° C and 4870 g at 100° C. Taking into account this temperature related solubility, in practice the majority of sugar solutions are prepared by heating the water. Water should be as soft as possible because the calcium salts can precipitate on boiling.

Corn syrup (liquid glucose)

Corn syrup is obtained industrially by acid or enzymatic starch hydrolysis, using as starting raw materials maize (corn) or potatoes. In fruit processing, mainly in the production of marmalades, it is possible to use corn syrup. The average composition of this corn syrup is of about 32-40% dextrose (glucose), about 40% dextrins and 18-20% moisture. Sweetening power is 50% compared with sucrose.

In a 10%-20% proportion with sucrose, addition of corn syrup has certain advantages:

a. It improves the shine and texture of marmalade;
b. It prevents "sugaring" defect and
c. It reduces the too sweet taste of finished products obtained with sugar alone.

SALT

Salt is used in order to give to the finished products a specifically salty taste and as a preserving substance. From a chemical point of view the term salt means sodium chloride but in practice the product is never in a pure state. The presence of a significant quantity of magnesium chloride increases the hygroscopicity, gives a bitter taste and can induce corrosion of receptacles.

Table: Physical Characteristics of Sugar Solutions

Specific weight	deg.Bé	Sugar in solution		Boiling temperature °C
		deg.Bx (K/100 g)	g/l	
1.144	18.5	33	377	101.1
1.149	19.0	34	391	101
1.154	19.6	35	404	101.2
1.159	20.1	36	417	101.3
1.164	20.7	37	430	101.3
1.169	21.2	38	444	101.4
1.174	21.8	39	457	101.4
1.179	22.3	40	470	101.5
1.185	22.9	41	486	101.5
1.190	23.4	42	500	101.6
1.195	23.9	43	513	101.6
1.200	24.5	44	527	101.7
1.206	25.0	45	543	101.7
1.211	25.6	46	557	101.8
1.216	26.1	47	571	101.8
1.222	26.6	48	586	101.9
1.227	27.2	49	600	101.9
1.233	27.7	50	616	102.0
1.238	28.2	51	630	102.1
1.244	28.8	52	646	102.2
1.249	29.3	53	660	102.3
1.255	29.8	54	677	102.4
1.261	30.4	55	693	102.5
1.267	30.9	56	709	102.6
1.272	31.4	57	723	102.7
1.278	31.9	58	740	102.8
1.284	32.5	59	757	102.9
1.290	33.0	60	774	103.0
1.296	33.5	61	790	103.2
1.302	34.0	62	807	103.5
1.308	34.5	63	824	103.7
1.314	35.1	64	840	103.9

1.320	35.6	65	857	104.2
1.326	36.1	66	874	104.6
1.332	36.6	67	891	105.0
1.338	37.1	68	909	105.5
1.345	37.6	69	928	106.0
1.351	38.1	70	945	106.5
1.357	38.6	71	962	106.8
1.364	39.1	72	981	107.1
1.370	39.6	73	999	107.4
1 376	40.1	74	1017	107.8
1.383	40.6	75	1037	108.2
1.389	41.1	76	1058	109.0
1.396	41.6	77	1076	110.0
1.402	42.1	78	1094	111.0
1.409	42.6	79	1113	112.0
1.414	43.1	80	1133	113.0

From a microbiological point of view, salt it is not a sterile product but on the contrary contains various micro-organisms, mainly halophil bacteria.

Salt solubility is only slightly influenced by temperature (0.360 kg/1 at 20° C and 0.390 kg/l at 100° C). Correspondence between specific weight and salt content of salt solutions at 15° C is shown in Table given below.

Table: Physical Characteristics of Salt Solutions

deg.Bé	Specific Weight	NaCl Content	
		g/100 g	g/l
1	1.007	1	10
2	1.014	2	20
3	1.022	3	30
4	1.029	4	41
5	1.037	5	52
6	1.045	6	63
7	1.052	7	74
8	1.060	8	85
9	1.067	9	96
10	1.075	10	107

11	1.083	11	119
12	1.091	12	131
13	1.100	13	143
14	1.108	14.2	158
15	1.116	15.5	173
16	1.125	16.7	188
17	1.134	18.0	204
18	1.142	19.0	217
19	1.152	20.0	230
20	1.162	21.2	246
21	1.171	22.4	262
22	1.180	23.6	278
23	1.190	24.8	295
24	1.200	26.0	312
24.5	1.204	26.4	318

Food Acids

Acetic Acid

Acetic acid is in use as solutions of various concentrations which are known under the generic name of vinegar. Vinegar can be obtained:

a. From wine, alcohol, cider, beer, etc. by fermentation;

b. By dilution of acetic acid obtained by dry wood distillation or by synthesis.

From a quality point of view, wine vinegar is preferred, as it has a more pleasant flavour. In order to improve taste, other vinegar types are usually flavoured with spices.

In addition to its spicing and flavouring role, vinegar is used and acts as a preservation agent for some vegetables: cucumbers, acidified vegetables, etc.

- Citric acid
- Tartric acid
- Lactic acid

Pectic Preparations

In fruit processing there many preparations and mixes known as "pectin" are used as liquid or powder extracts.

From a practical point of view, the pectic preparations are classified as:

- Strong pectins obtained from apples or citrus fruit peel; this category gives gels rich in sugar;
- Weak pectins which gives gels with low proportion of sugar or even without sugar but with the addition of calcium salts.

The fruit industry uses mainly strong pectins. These preparations are characterised, from a commercial point of view, by the capacity of gelification, expressed in degrees. The degree of gelification represents the quantity of sugar in grams able to be transformed in a standard gel (65% sugar and pH=3) by 1 g pectin.

Intensive Sweeteners

"Calorie-reduced" and "low-calorie foods are widely used and are cornering an increasing share of the market. Sweeteners are making an important contribution to the manufacture of sweet foods in these categories. They make it possible to manufacture sweet products without "sweet" being necessarily synonymous with "high-calorie".

Diabetics need to restrict their intake of sugar and various carbohydrates similar to sugar or avoid them altogether. Sweeteners enable diabetics to enjoy sweet tastes without changing their lifestyle. Sweeteners do not contribute to the development of tooth decay; they do not degrade in the mouth to form the acids which are responsible for caries. Thus sweeteners offer consumers a number of advantageous and favourable properties above and beyond merely reducing calories.

Sunett is the trade mark of Hoechst AG for its high intensity sweetener acesulfame K. As an ingredient, it can be used for sweetening all foods produced industrially or at home, or to produce tabletop sweeteners. Like all other sweeteners, Sunett tastes more intensely sweet than sugar; it is about 200 times sweeter than sugar compared with a dilute stock solution.

Synergism – Sunett is notable for its pronounced synergism with other sweeteners. The synergistic effect leads as quantitative synergism to an intensification of the overall sweetness and as qualitative synergism to an improved taste. The synergism results in a marked intensification of the sweet taste of the blends, which can amount to 30-50% at usual concentrations.

The favourable properties of Sunett, particularly its synergistic behaviour, can be used advantageously in the Sunett-Multi-Sweetener Concept. For high sweetness levels, blends of Sunett with other sweeteners, e.g. aspartame, are particularly favourable in many applications. The synergistic effect of the blend results in a taste that is particularly pleasant and rounded.

Alone or in blends with other sweeteners, Sunett is used mainly where only sweetness is important and no other properties of the foods are to be affected. This applies particularly to beverages (fruit syrups and juices, carbonated beverages, etc.).

In a number of food products, sweet carbohydrates do not only provide the sweet taste; they have other functions to fulfil; for example, they act as bulking or texturing agents and as preservatives by reducing the water activity. In these types of products, Sunett and other sweeteners cannot be used on their own. They must be combined with other substances which perform the required functions. These may be bulking agents or sugar substitutes (for example polyols: sorbitol, mannitol, xylitol). Sunett can be combined with both groups of substances.

Uses

In carbonated soft drinks blends of Sunett with other sweet-tasting substances are often recommended. Beverages formulated using the Sunett Multi-Sweetener Concept, i.e. blends of Sunett with other sweeteners, are usually preferred because of their particularly well balanced and rounded sweetness profile. The taste of these blends is often superiors to single sweeteners.

Sunett is compatible with sugar and other sweet-tasting carbohydrates, both technically and in terms of taste. It can therefore be used in the production of soft drinks with a reduced sugar content. Drinks based on fructose and Sunett are suitable for diabetics. Soft drinks with a reduced sugar content show an excellent taste quality when Sunett or Sunett blends are added to bring them up to the usual level of sweetness.

Fruit nectars and fruit juice drinks differ from most carbonated drinks in that they contain a noticeable amount of sweet carbohydrates provided by the fruit juice. The amount of carbohydrate may vary depending on the type of fruit and amount of juice used.

Amounts of up to 200 mg/l Sunett are often adequate as a single sweetener for the popular types of fruit nectars. With blends of Sunett and aspartame quantities in the order of 100150 mg/l Sunett and 50 mg/l aspartame or 60-70 mg/l of both Sunett and aspartame are sufficient.

Sunett offers such excellent stability that end products, such as drinks, show no reduction in sweetness performance during normal processing methods and storage periods. Sunett can withstand pasteurization, hot filling and aseptic filling without any loss of sweetness.

Jams and marmalades. Sugar contributes a great deal to the texture and stability of conventional jams and marmalades. For the production of sugar-free products either the sugar must be replaced by comparable amounts of sugar substitutes or some of the functions of the sugar must be taken only by other components, such as suitable gelling agents.

Sugar-free jams and marmalades containing sweeteners are more susceptible to microorganisms than sugar-containing products. The risk of spoilage due to yeast fermentation or moulding can be prevented by pasteurization. However, this is only feasible for small jars which will be quickly consumed once they are opened.

In all other cases, it is advisable to add 0.05-0.1% potassium sorbate as a preservative, wherever this is permitted under the relevant food regulations. For sugar-free jams and marmalades, concentrations in the range of 500-2000 mg Sunett/kg of the finished product are appropriate. It is advisable to add Sunett in the form of an aqueous stock solution towards the end of the boiling process. Care must be taken to ensure that Sunett is evenly dispersed throughout the whole batch.

Because of the excellent compatibility of Sunett with sugar alcohols, fruit jams and marmalades using these ingredients offer an outstanding taste.

Fruit preserves

Sunett can be used for the production of sugar-free or sugar-reduced fruit preserves. At the normal pH values for fruit preserves Sunett can be added even before pasteurization, as the sweetness is not impaired under the usual thermal treatment conditions. Sunett also withstands the usual storage periods without loss of sweetness.

NutraSweet(r) is the commercial name of aspartame (APM), a new sweetener from G.D. SEARLE & Co. which can be used in the most foods in order to give the same taste as sugar. NutraSweet is about 180 to 200 times sweeter than sucrose (sugar) and this value depends on pH, temperature and the type of flavour.

NutraSweet can be used as mentioned above in a mix with Sunett or alone in all sugar-free or calorie-reduced fruit jams, marmalades and preserves. Like other sweeteners, NutraSweet does not promote tooth decay.

International Regulatory Status

Both Sunett and NutraSweet are widely accepted by food laws in the majority of countries. The following are the main fruit products where Sunett is an accepted sweetener:

- Low-joule prepared jelly: max. 500 mg/kg;
- Canned fruit without added sugar: max. 500 mg/kg;
- Beverages including calorie-reduced fruit nectars: max. 600 mg/l;
- Calorie-reduced jams;
- Calorie-reduced and dietetic fruit compotes;
- Canned fruit and vegetables, fruit puree, jams and marmalades;
- Juices, nectars and juice based beverages;
- Jams, marmalades and related products: max. 300 mg/kg.

7

Packaging Materials

REQUIREMENTS AND FUNCTIONS OF FOOD CONTAINERS

The following are among the more important general requirements and functions of food packaging materials/containers:

a. They must be non-toxic and compatible with the specific foods;
b. Sanitary protection;
c. Moisture and fat protection;
d. Gas and odour protection;
e. Light protection;
f. Resistance to impact;
g. Transparency;
h. Tamperproofness;
i. Ease of opening;
j. Pouring features;
k. Reseal features;
l. Ease of disposal;
m. Size, shape, weight limitations;
n. Appearance, printability;
o. Low cost;
p. Special features.

PRIMARY AND SECONDARY CONTAINERS

The terms primary and secondary containers have been used. Some foods are provided with efficient primary containers by nature, such as nuts, oranges, eggs and the like. In packaging these, we generally need only a secondary outer box, wrap, or drum to hold units together and give gross protection.

Other foods such as milk, dried eggs and fruit concentrates often will be filled into primary containers such as plastic liners which are then packaged within protective cartons or drums. In this case the secondary container provided by the carton or drum greatly minimises the requirements that must be met by the primary container.

Except in special instances, secondary containers are not designed to be highly impervious to water vapour and other gases, especially at zones of sealing, dependence for this being placed upon the primary container. Since primary containers by definition are those which come in direct contact with the food, we will be far more concerned with them than with secondary containers.

Hermetic Closure

Two conditions of the greatest significance in packaging are hermetic and non-hermetic closure. The term hermetic means a container which is absolutely impermeable to gases and vapours throughout its entirety, including its seams.

Such a container, as long as it remains intact, will automatically be impervious to bacteria, yeasts, moulds, and dirt from dust and other sources since all of these agents are considerably larger than gas or water vapour molecules.

On the other hand, a container which prevents entry of micro-organisms, in many instances will be non-hermetic. A container that is hermetic not only will protect the product from moisture gain or loss, and from oxygen pickup from the atmosphere, but is essential for strict vacuum and pressure packaging.

The most common hermetic containers are rigid metal cans and glass bottles, although faulty closures can make them non-hermetic. With very rare exceptions flexible packages are not truly hermetic for one or more of the following reasons.

First, the thin flexible films, even when they do not contain minute pinholes, generally are not completely gas and water-vapour impermeable although the rates of gas and water vapour transfer may be exceptionally slow; second, the seals are generally good but imperfect; and third, even where film materials may be gas- and water-vapour-tight, such as certain gages of aluminium foil, flexing of packages and pouches leads to minute pinholes and crease holes.

Hermetic rigid aluminium containers can be readily formed without side seams or bottom end seams. The only seam then to make hermetic is the top end double seam, which may be closed on regular tin can sealing equipment.

Glass containers are hermetic provided the lids are tight. Lids will have inside rings of plastic or cork. Many glass containers are vacuum packed and the tightness of the cover will be augmented by the differential of atmospheric pressure pushing down the cover. Crimping of the covers, as in the case of pop bottle caps which operate against positive internal pressure, also can make a gas-tight hermetic seal. But bottles fail more often than cans in becoming non-hermetic.

Protection of Food by Packaging Materials

Important factors in selecting a packaging unit for food storage are presented in Fig. 7.1.

Figure: Factors for Selection a Packaging Material for Food Storage

Climatio Hazards	Biological Hazards
Atmospheric Humidity	Insects
Light (UV)	Bacteria & Moulds
Temperature	Mites
Rain	Rodents & Birds

	Product	
Handling	Chemical Composition	Types of Stores Customer Appeal Transport
Stacking		Price

Films and Foils; Plastics

Films and foils have different values for moisture and gas permeability, strength, elasticity, inflammability and resistance to insect penetration and many of these characteristics depend upon the film's thickness.

Important characteristics of the types of films and foils commonly used in food packaging are given in Table given below. For the most part such films are used in the construction of inner containers. Since they are non-rigid, their main functions are to contain the product and protect it from contact with air or water vapour. Their capacity to protect against mechanical damage is limited, particularly when thin films are considered.

Table: Properties of Packaging Films

Material	Properties
Paper	Strength; rigidity; opacity; printability.
Aluminium foil	Negligible permeability to water-vapour, gases and odours; grease proof, opacity and brilliant appearance; dimensional stability; dead folding characteristics.
Cellulose film (coated)	Strength; attractive appearance; low permeability to water vapour (depending on the type of coating used), gases, odours and greases; printability.
Polythene	Durability; heat-sealability; low permeability to water-vapour; good chemical resistance; good low-temperature performance.
Rubber hydrochloride	Heat-sealability; low permeability to water vapour, gases, odours and greases; chemical resistance.
Cellulose acetate	Strength; rigidity; glossy appearance; printability; dimensional stability.

Vinylidene chloride	Low permeability to water vapour, gases, copolymer odours and greases; chemical resistance; heat-sealability.
Polyvinyl chloride	Resistance to chemicals, oils and greases; heat-sealability.
Polyethylene terephtalate	Strength; durability; dimensional stability; low permeability to gases, odours and greases.

These materials can exist in many forms, depending upon such variables as identity and mixture of polymers, degree of polymerisation and molecular weight, spatial polymer orientation, use of plasticisers (softeners) and other chemicals, methods of forming such as casting, extrusion or calendering, etc.

One of the newer classes of plastic materials referred to as copolymers illustrate what can be done with mixtures of the basic units from which plastics are built. The term copolymer refers to a mixture of chemical species in the resin from which films and other forms can be made. The many variations possible make copolymers an important class of plastics to extend the range of useful food packaging applications.

Plastic Sheets

- Cellophane paper can be used for packing of dried products, mainly for dried fruit leathers.
- Polyethylene sheets have a variety of uses. They are flexible, transparent and have a perfect resistance to low temperatures and impermeability to water vapour. An important advantage is that these sheets can be easily heat-sealed. Utilisation is in forms of sheets and bags. It is a good packing material for primary protection of dehydrated products. If a good protection is needed to prevent flavour and gas losses, it will be necessary to combine polyethylene with other materials.

Receptacles and Packagings in Plastic Materials

In this class there are three categories:

a. Receptacles that can be heat treated: boxes, bottles and bags. Sterilisable bags used up to 120° C can be manufactured from same raw materials as described under plastic sheets and up to 100° C from cellophane. Polyethylene bags could be used to some extent for packing and pasteurization of sauerkraut.

b. Receptacles that are not heat treated during processing of fruit and vegetables, also divided in bags and boxes. Bags are the most used type of packing from plastic materials and they are manufactured from polyethylene or cellophane; an important utilisation is for dried/dehydrated fruits and vegetables.

c. special packagings - which can be contacted (Criovac type) by action of heat once the finished product is already inside the pack and the air is evacuated.

Laminates

Various flexible materials such as papers, plastic films, and thin metal foils have different properties with respect to water vapour transmission, oxygen permeability, light transmission, burst strength, pin holes and crease hole sensitivity, etc. and so multi-layers or laminates of these materials which combine the best features of each are used.

Commercial laminates containing up to as many as eight different layers are commonly custom designed for a particular product.

Laminations of different materials may be formed by various processes including bonding with a wet adhesive, dry bonding of layers with a thermoplastic adhesive, hot melt laminating where one or both layers exhibit thermoplastic properties, and special extrusion techniques. Such structured plastic films may be complete in themselves or be further bonded to papers or metal foils to produce more complex laminates.

GLASS CONTAINERS

As far as food packaging is concerned, glass is chemically inert, although the usual problems of corrosion and reactivity of metal closures will of course apply. The principal limitation of glass is its susceptibility to breakage, which may be from internal pressure, impact, or thermal shock, all of which can be greatly minimised by proper matching of the container to its intended use and intelligent handling practices. Here consultation with the manufacturer cannot be over-stressed.

The heavier a jar or bottle for a given volume capacity the less likely it is to break from internal pressure. The heavier jar, however, is more susceptible to both thermal shock and impact breakage. Greater thermal shock breakage of the heavier jar is due to wider temperature differences which cause uneven stress between the outer and inner surfaces of the thicker glass. Greater impact breakage susceptibility of the heavier jar is due to the lower resilience of its thicker wall.

Coatings of various types can markedly reduce each of these types of breakage. These coatings, commonly of special waxes and silicones, lubricate the outside of the glass. As a result, impact breakage is lessened by bottles and jars glancing off one another rather than sustaining direct hits when they are in contact in high speed filling lines.

Surface coating after annealing protects glass surfaces from many of the minute scratches appearing in normal handling after annealing ovens; surface coating also improves the high gloss appearance of glass containers and is said to decrease the noise from glass to glass contact at filling lines.

With regard to thermal shock, it is good practice to minimise temperature differences between the inside and outside of glass containers whenever possible. Some manufacturers will recommend that a temperature difference of 44° C (80° F) between the inside and the outside not be exceeded. This requires slow warming of bottles before use for a hot fill and partial cooling before such containers are placed under refrigeration.

Classification

Glass used for receptacles in fruit and vegetable processing is a carefully controlled mixture of sand, soda ash, limestone and other materials made molten by heating to about 1500° C (2800° F).

Main classes of glass receptacles are:

a. Jars which are resistant to heat treatments,
b. Jars, glasses, etc. for products not submitted to heat treatment (marmalades, acidified vegetables, etc.);
c. Glass bottles for pasteurized products (tomato juice, fruit juices, etc.) or not pasteurized (syrups) and
d. Receptacles with higher capacity (flasks, etc.)

Jars for Sterilised/Pasteurized Canned Products

These receptacles may replace metal cans, taking into considering both the advantages and disadvantages they present. Advantages are: they do not react to food content; they are transparent and can be manufactured in various shapes; they use cheap raw materials and are reusable. Disadvantages: heavier than metal can of same capacity; fragile; lower thermal conductance and a limited resistance to thermal shocks.

Receptacles in this category must assure a perfect hermeticity after their pasteurization/sterilisation and cooling and this has to be achieved by the use of metallic (or glass) caps and specific materials for tightness. Taking into account the receptacles' closure method, there are two categories of receptacles:

a. Glass jars with mechanical closure;
b. Glass jars with pneumatic closure;

Jars for Products without Heat Treatment

For marmalades, jellies and jams glass jars with non hermetic closures using metal, glass or rigid plastic caps are used; however for these products the receptacles mentioned above may also be used.

The use of jars with pneumatic closure presents the advantage that some products (e.g. marmalades, jams) can be filled hot and therefore sterile in receptacles. Pneumatic closing generally protects against negative air action which is in this case eliminated from receptacles.

Glass Bottles

These receptacles are widely used both for

a. Finished products which need pasteurization (ea. tomato juice, Knit juices, etc.) and for

b. Those which are preserved as such (ea. fruit syrups).

   Glass bottles in category a) are closed hermetically with metallic caps, provided with special materials for tightness. For glass bottles in category b) various corks, and aluminium caps with tightness materials may be used.

Glass Receptacles with High Capacity

In this category there are glass flasks with 3 and 10 litre capacity which can be hermetically closed by a SKO caps system and are resistant to product pasteurization (ea. tomato juice). As bigger receptacles it is possible to use glass demijohns with usual capacity of 25 and 50 litre; these receptacles are used for preservation of fruit juices by warm process. Closing is performed with flexible rubber hoods.

Paper Packaging

As primary containers few paper products are not treated, coated or laminated to improve their protective properties. Paper from wood pulp and reprocessed waste paper will be bleached and coated or impregnated with such materials as waxes, resins, lacquers, plastics, and laminations of aluminium to improve water vapour and gas impermeability, flexibility, tear resistance, burst strength, wet strength, grease resistance, sealability, appearance, printability, etc.

Paper Sheets

- Kraft paper is the brown unbleached heavy duty paper commonly used for bags and for wrapping; it is seldom used as a primary container;

- Parchment paper: acid treatment of paper pulp modifies the cellulose and gives water and oil resistance and considerable wet strength to this type of packaging material;
- Glassine-type papers are characterised by long wood pulp fibres which impart increased physical strength;
- Paper with plastic material sheets.

Receptacles from Paper or Cardboard

(paper = 8 to 150 g/m^2; cardboard = 150 to 450 g/m^2).

"Tin can"/Tinplate

The "tin can" is a container made of tinplate. Tinplate, a rigid and impervious material, consists of a thin sheet of low carbon steel coated on both sides with a very thin layer of tin. It can be produced by dipping sheets of mild steel in molten tin (hot-dipped tinplate) or by the electro-deposition of tin on the steel sheet (electrolytic tinplate). With the latter process it is possible to produce tinplate with a heavier coating of tin on one surface than the other (differentially coated).

Tin is not completely resistant to corrosion but its rate of reaction with many food materials is considerably slower than that of steel. The effectiveness of a tin coating depends on: a. Its thickness which may vary from about 0.5 to 2.0 µm (20 to 80 x 10(-6) in.); b. The uniformity of this thickness; c. The method of applying the tin which today primarily involves electrolytic plating; d. The composition of the underlying steel base plate; e. The type of food, and f. Other factors.

Some canned vegetables including tomato products actually owe their characteristics flavours to a small amount of dissolved tin, without which these products would have an unfamiliar taste. On the other hand, where tin reacts unfavourably with a particular food the tin itself may be lacquer coated.

The thickness of tinplate sheets may vary from 0.14 mm to 0.49 mm and is determined by weighing a sheet of known area and calculating the average thickness.

Tinplate sheets may be lacquered after fabrication to provide an internal or external coating to protect the metal surface from corrosion by the atmosphere or through reaction with the can contents.

They may also be printed by lithography to provide suitable instructions or information on containers fabricated from tinplate sheets (otherwise paper labels can be attached to the outer tinplate surface).

Under normal conditions the presence of the tin coating provides a considerable degree of electrochemical protection against corrosion, despite the fact that in both types of tinplate the tin coating is discontinuous and minute areas of steel base plate are exposed. With prolonged exposure to humid conditions, however, corrosion may become a serious problem.

The coatings not only protect the metal from corrosion by food constituents but also protect the foods from metal contamination, which can produce a host colour and flavour reactions depending upon the specific food.

Particularly common are dark coloured sulphides of iron and tin produced in low acid foods that liberate sulphur compounds when heat processed, and bleaching of red plant pigments in contact with unprotected steel, tin, and aluminium.

Table: General Types of can Coatings

Coating	Typical uses	Type
Fruit enamel	Dark coloured berries, cherries and other fruits requiring protection from metallic salts	Oleoresinous
C-enamel	Corn, peas and other sulphur-bearing products	Oleoresinous w. suspended zinc oxide
Citrus enamel	Citrus products and concentrates oleoresinous	Modified
Beverage can enamel	Vegetable juices; red fruit juices; highly corrosive fruits; non-carbonated	Two-coated w. resinous base coat beverages and vinyl top coat

8

Fruit Specific Preservation Technologies

FRUIT QUALITY

Fruit quality goes back to tree stock, growing practices and weather conditions. Closer to the shipper and processor, however, are the degrees of maturity and ripeness when picked and the method of picking or harvesting.

There is a distinction between maturity and ripeness of a fruit. Maturity is the condition when the fruit is ready to eat or if picked will become ready to eat after further ripening. Ripeness is that optimum condition when colour, flavour and texture have developed to their peak.

Some fruit is picked when it are mature but not yet ripe. This is especially true of very soft fruit like cherries and peaches, which when fully ripe are so soft as to be damaged by the act of picking itself. Further, since many types of fruit continue to ripen off the tree, unless they were to be processed quickly, some would become overripe before they could be utilised if picked at peak ripeness.

From a technological point of view, fruit characterisation by species and varieties is performed on the basis of physical as well chemical properties: shape, size, texture, flavour, colour/pigmentation, dry matter content (soluble solids content), pectic substances, acidity, vitamins, etc. These properties are directly correlated with fruit utilisation. Table given below shows which of the above mentioned properties have a major impact on the finished products obtained by fruit processing.

Table: Optimal Use of Fruits as a Function of their Properties

Processed Finished Products	Organoleptic (Sensory) Properties				Chemical Composition		
	Shape	Texture	Flavour	Taste	Acidity	Sugars	Pectic Sust.
Dried Fruits	+ +	+ +		+ +		+ +	
Fruit Juices			+ +	+ +	+ +		
Marmalade			+ +	+ +			+ +
Jams	+ +	+ +	+ +	+ +			
Jellies	+ +	+ +	+ +	+ +			+ +
Fruit Paste				+ +		+ +	

The proper time to pick fruit depends upon several factors; these include variety, location, weather, ease of removal from the tree (which change with time), and purpose to which the fruit will be put.

For example, oranges change with respect to both sugar and acid as they ripen on the tree; sugar increases and acid decreases. The ratio of sugar to acid determines the taste and acceptability of the fruit and the juice. For this reasons, in some countries there are laws that prohibit picking until a certain sugar-acid ratio has been reached.

In the case of much fruit to be canned, on the other hand, fruit is picked before it is fully ripe for eating since canning will further soften the fruit.

QUALITY MEASUREMENTS

Many quality measurements can be made before a fruit crop is picked in order to determine if proper maturity or degree of ripeness has developed. Colour may be measured with instruments or by comparing the colour of fruit on the tree with standard picture charts. Texture may be measured by compression by hand or by simple type of plungers.

As fruit mature on the tree its concentration of juice solids, which are mostly sugars, changes. The concentration of soluble solids in the juice can be estimated with a refractometre or a hydrometre. The refractometre measures the ability of a solution to bend or refract a light beam which is proportional to the solution's concentration. A hydrometre is a weighted spindle with a graduated neck which floats in the juice at a height related to the juice density.

The acid content of fruit changes with maturity and affects flavour. Acid concentration can be measured by a simple chemical titration on the fruit juice. But for many fruits the tartness and flavour are really affected by the ratio of sugar to acid.

Percentage of soluble solids, which are largely sugars, is generally expressed in degrees Brix, which relates specific gravity of a solution to an equivalent concentration of pure sucrose.

In describing the taste of tartness of several fruits and fruit juices, the term "sugar to acid ratio" or "Brix to acid ratio" are commonly used. The higher the Brix the greater the sugar concentration in the juice; the higher the "Brix to acid ratio" the sweeter and lees tart is the juice.

HARVESTING AND PREPROCESSING

Harvesting

The above and other measurements, plus experience, indicate when fruit is ready for harvesting and subsequent processing. A large amount of the harvesting of most fruit crops is still done by hand; this labour may represent about half of the cost of growing the fruit. Therefore, mechanical harvesting is currently one of the most active fields of research for the agricultural engineer, but also requires geneticists to breed fruit of nearly equal size, that matures uniformly and that is resistant to mechanical damage.

A correct manual harvesting includes some simple but essential rules:

- The fruit should be picked by hand and placed carefully in the harvesting basket; all future handling has to be performed carefully in order to avoid any mechanical damage;
- The harvesting basket and the hands of the harvester should be clean;
- The fruit should be picked when it is ready to be able to be processed into a quality product depending on the treatment which it will undergo.

It is worth emphasising the fact that the proximity of the processing centre to the source of supply for fresh raw materials presents major advantages; some are as follows:

- Possibility to pick at the best suitable moment;
- Reduction of losses by handling/transportation;
- Minimises raw material transport costs;
- Possibility to use simpler/cheaper receptacles for raw material transport.

Once it has left the tree, the organoleptic properties, nutritional value, safety and aesthetic appeal of the fruit deteriorates in varying degrees. The major causes of deterioration include the following:

a. Growth and activity of micro-organisms;
b. Activities of the natural food enzymes;
c. Insects, parasites and rodents;
d. Temperature, both heat and cold;
e. Moisture and dryness;
f. Air and in particular oxygen;
g. Light and
h. Time.

The rapidity with which foods spoil if proper measures are not taken is indicated in table given below.

Table: Useful Storage Life of Some Food Products

Food Products	Generalized Storage Life (Days) at 21°C (70°F)
Animal Flesh, Fish, Poultry	1-2
Dried, salted, smoked meat and fish	360 and more
Fruits	1-7
Dried Fruits	360 and more
Leafy Vegetables	1-2
Root Crops	7-20

Reception — Quality and Quantity

Fruit reception at the processing centre is performed mainly for following purposes:

- Checking of sanitary and freshness status;
- Control of varieties and fruit wholeness;
- Evaluation maturity degree;
- Collection of data about quantities received in connection to the source of supply: outside growers/ farmers, own farm.

Variety control is needed in order to identify that the fruit belongs to an accepted variety as not all are suitable for different technological processes. Fruit maturity degree is significant as industrial maturity is required for some processing/preservation methods while for others there is the need for an edible maturity when the fruit has full taste and flavour.

Special attention is given to size, appearance and uniformity of fruit to be processed, mainly in the form of fruit preserved with sugar using whole/half fruits ("with fruit pieces"). Some laboratory control is also needed, even if it not easy to precisely establish the technological qualities of fruit because of the absence of enough reliable rapid analytical methods able to show eventual deterioration.

The only reliable method for evaluating the quality is the combination of data obtained through organoleptic/taste controls and by simple analytical checks which are possible to perform in a small laboratory: percentage of soluble solids by refractometre, consistency/texture measured with simple penetrometres, etc.

Temporary Storage before Processing

This step has to be as short as possible in order to avoid flavour losses, texture modification, weight losses and other deterioration that can take place over this period.

Some basic rules for this step are as follows:

- Keep products in the shade, without any possible direct contact with sunlight;
- Avoid dust as much as possible;
- Avoid excessive heat;
- Avoid any possible contamination;
- Store in a place protected from possible attack by rodents, insects, etc.

Cold storage is always highly preferred to ambient temperature. For this reason a very good manufacturing practice is to use a cool room for each processing centre; this is very useful for small and medium processing units as well.

Table: Raw Material Control — Fresh Fruits and Vegetables at Reception

1.	Checks at each delivery/raw material lot
	Colour, Texture, Taste, Flavour, Appearance, Refractometric, extract, Number per kg, Variety, Sanitary evaluation
2.	Checks at each ten lots (for the same raw material)
	Density, Water content: oven method, Total sugars, reducing sugars, Total acidity
3.	Audits — every six months — on five different lots
	Ascorbic acid, Mineral substances, Tannic substances, Pectic substances.

The type of analysis for audits will be adapted to the specific fruits and vegetables that are received/processed. An excellent indication of a good temporary storage is the limited weight loss before processing, which has to be below 1.0%-1.2%.

Washing

Harvested fruit is washed to remove soil, micro-organisms and pesticide residues. Fruit washing is a mandatory processing step; it would be wise to eliminate spoiled fruit before washing in order to avoid the pollution of washing tools and/or equipment and the contamination of fruit during washing.

Washing efficiency can me gauged by the total number of micro-organisms present on fruit surface before and after washing - best result are when there is a six fold reduction. The water from the final wash should be free from moulds and yeast; a small quantity of bacteria is acceptable.

Fruit washing can be carried out by immersion, by spray/ showers or by combination of these two processes which is generally the best solution: pre-washing and washing.

Some usual practices in fruit washing are:

- Addition of detergents or 1.5% HCl solution in washing water to remove traces of insect-fungicides;
- Use of warm water (about 50°C) in the pre-washing phase;
- Higher water pressure in spray/shower washers.

Washing must be done before the fruit is cut in order to avoid losing high nutritive value soluble substances (vitamins, minerals, sugars, etc.).

Sorting

Fruit sorting covers two main separate processing operations:

a. Removal of damaged fruit and any foreign bodies (which might have been left behind after washing);
b. Qualitative sorting based on organoleptic criteria and maturity stage.

Mechanical sorting for size is usually not done at the preliminary stage. The most important initial sorting is for variety and maturity.

However, for some fruit and in special processing technologies it is advisable to proceed to a manual dimensional sorting (grading).

Trimming and Peeling (Skin Removal)

This processing step aims at removing the parts of the fruit which are either not edible or difficult to digest especially the skin.

Up to now the industrial peeling of fruit and vegetables was performed by three procedures:

a. Mechanically;
b. By using water steam;
c. Chemically; this method consists in treating fruit and vegetables by dipping them in a caustic soda solution at a temperature of 90 to 100° C; the concentration of this solution as well as the dipping or immersion time varying according to each specific case.

Cutting

This step is performed according to the specific requirements of the fruit processing technology.

Heat Blanching

Fruit is not usually heat blanched because of the damage from the heat and the associated sogginess and juice loss after thawing. Instead, chemicals are commonly used without heat to inactivate the oxidative enzymes or to act as antioxidants and they are combined with other treatments.

Ascorbic/Citric Acid Dip

Ascorbic acid or vitamin C minimises fruit oxidation primarily by acting as an antioxidant and itself becoming oxidised in preference to catechol-tannin compounds. Ascorbic acid is frequently used by being dissolved in water, sugar syrup or in citric acid solutions.

It has been found that increased acidity also helps retard oxidative colour changes and so ascorbic acid plus citric acid may be used together. Citric acid further reacts with (chelates) metal ions thus removing these catalysts of oxidation from the system.

Sulphur Dioxide Treatment

Sulphur dioxide may function in several ways:

- Sulphur dioxide is an enzyme poison against common oxidising enzymes;
- It also has antioxidant properties; i.e., it is an oxygen acceptor (as is ascorbic acid);
- Further SO_2 minimises non enzymatic Maillard type browning by reacting with aldehyde groups of sugars so that they are no longer free to combine with amino acids;
- Sulphur dioxide also interferes with microbial growth.

In many fruit processing pre-treatments two factors must be considered:

a. Sulphur dioxide must be given time to penetrate the fruit tissues;

b. SO_2 must not be used in excess because it has a characteristic unpleasant taste and odour, and international food laws limit the SO2 content of fruit products, especially of those which are consumer oriented (e.g. except semi-processed products oriented to further industrial utilisation).

Commonly a 0.25 % solution (except for semi-processed fruit products which are industry oriented and use a 6% solution) of SO_2 or its SO_2 equivalent in the form of solutions of sodium sulphite, sodium bisulphite or sodium/potassium metabisulphite are used.

Fruit slices are dipped in the solution for about two to three minutes and then removed so as not to absorb too much SO_2. Then the slices are allowed to stand for about one to two hours so that the SO_2 may penetrate throughout the tissues before processing. Sulphur dioxide is also used in fruit juice production to minimise oxidative changes where relatively low heat treatment is employed so as not to damage delicate juice flavour.

Dry sulphuring is the technological step where fruit is exposed to fumes of SO_2 from burning sulphur or from compressed gas cylinders; this treatment could be used in the preparation of fruits (and some vegetables) prior to drying/ dehydration.

Sugar Syrup

Sugar syrup addition is one of the oldest methods of minimising oxidation. It was used long before the causative reactions were understood and remains today a common practice for this purpose.

Sugar syrup minimises oxidation by coating the fruit and thereby preventing contact with atmospheric oxygen. Sugar syrup also offers some protection against loss of volatile fruit esters and it contributes sweet taste to otherwise tart fruits. It is common today to dissolve ascorbic acid and citric acid in the sugar syrup for added effect or to include sugar syrup after an SO_2 treatment.

Fresh Fruit Storage

Some fruit species and specially apples and pears can be stored in fresh state during cold season in some countries' climatic conditions. Fruit for fresh storage have to be autumn or winter varieties and be harvested before they are fully mature. This fruit also has to be sound and without any bruising; control and sorting by quality are mandatory operations.

Sorting has to be carried out according to size and weight and also by appearance; fruit which is not up to standard for storage will be used for semi-processed product manufacturing which will be submitted further to industrial processing. Harvested fruit has to be transported as soon as possible to storage areas. Leaving fruit in bulk in order to generate transpiration is a bad practice as this reduces storage time and accelerates maturation processes during storage. In order to store large quantities of fruit, silos have to be built.

FRUIT DRYING AND DEHYDRATION TECHNOLOGY

General technical data for fruit dehydration in tunnels are presented in Table given below.

Table: Technical Data for Fruit Dehydration in Tunnels

Fruits	Drying Conditions			Finished Product	
	Load kg/m²	Temperature °C	Time	Moisture %	Yield %
Plums	15	I. 40-50 II. 75-80	6 H 14 H	18-20	25-35
Apples (Rings)	10	75-55	5-6 H	20	10-12
Apricots (Halves)	10	70-60	10- 15	15-20	10-15
Cherries (w. stones)	10	55-70	6-8	12-15	25
Pears (Halves and quarters)	15	70-65	15-22	18-20	10-15
	15	70-60	10-15	15-20	10-15

For fruit with a high sugar content drying temperatures have to be lower at initial stage and then increase to the maximum acceptable; for fruit with lower sugar level the temperatures are applied in a reverse order.

Some pre-treatments of fruit and vegetables for sun/solar drying are described in table given above.

Table: Technical Data on some Osmotically Dehydrated Products

Fruit or vegetable	Type of cut	Treatment
Banana	5 mm slices	2 hours, 80% sugar 2000 ppm SO_2 at 70°C
Carrots	10 x 10 x 2 mm dices or 5 mm slices	4 hours, 60% sugar + 10% salt 4000 ppm SO_2
Mango, green	8 mm slices	2 hours, 25% salt 8000 ppm SO_2

Mango, ripe	8 mm slices	2 hours, 60% sugar 8000 ppm SO_2
Onions	2 mm slices	2 hours, 60% sugar + 10% salt 4000 ppm SO_2
Papaya	8 x 8 mm slices	4 hours, 80% sugar 2000 ppm SO_2 at 70°C
Strawberries	Whole	4 hours, 80% sugar 4000 ppm SO_2
Sweet peppers, red	6 mm dices	2 hours, 60 % sugar + 10 % salt 4000 ppm SO_2

Table: Moisture and Shipping Factors for some Dried/Dehydrated Fruits

Products	Form	Moisture, %
Apples	6 nun rings	20
Apricots	Caps	17-20
Banana	Cut pieces	15
Cherries	Whole	12-15
Figs	Whole	23
Guava	Quarters	6
Mango	15 mm pulp sheets	15
Peaches	Caps	15-20
Pears	Halves	23
Prunes	Whole	18-20
Raisins	Whole	17

The moisture contents listed are considered as the best from a technical, practical and commercial point of view for delivery to the market or for shipping and safe for the shelf life needed before buying/consumption by customers/ consumers. All instructions about packing, storage and transport must be followed in order to assure delivery of a safe and high quality product to the market.

Processing of Fruit Bars

The fruit bar processing method developed for FAO only involves a single major operation, which it drying the fruit pulp after mixing it with suitable ingredients. It can be used to produce mango, banana, guava or mixed fruit bars.

A dual-powered dryer, working by solar energy during the day and by electric or steam power at night and on rainy days, with cross-flow movement of air and controlled temperature (from 55° C at the beginning of processing to a high of 70° C), is well suited for dehydration of the pulp to the desired moisture level of 15 to 20%.

Main raw material quantities to prepare approximately 100 kg of fruit bars are as follows:

Type of fruit	Fruit required in kg	Pulp obtained in kg	Sugar required in kg	Yield (% of fresh fruit) approx.
Mango	720	360	33	14
Banana	600	360	30	17
Guava	406	325	60	25
Mango + banana	540 + 150	360	35	15
Papaya + banana	500 + 140	336	54	23

Mango fruit bar — Fully ripe mangoes are selected and washed in water at room temperature. The peeled fruit is cut into slices and passed through a helicoidal pulper to extract the pulp. The required amount of sugar to adjust the Brix (the unit measure for total solids in fruits) of the mixed pulp to 25 degrees Brix is then added.

Two grams of citric acid per kilogram of pulp (or 20 ml of lime or lemon juice) are added to inhibit possible growth of micro-organisms during drying. The mixture is then heated for two minutes at 80° C and partially cooled; the heat treatment serves to inactivate the enzymes and destroy the micro-organisms.

Potassium or sodium metabisulphite is added (two grams per kg of prepared mixture), so that the concentration of SO2 is 1000 ppm. The mixture is then transferred to stainless steel trays which have been previously smeared with glycerine (40 ml/m^2). Each tray must be loaded with 12.5 kg of mixture per square metre.

Drying could be carried out by a dual-powered dryer for a total of 26 hours:

a. 10 hours by solar energy at about 55° C and
b. 16 hours by electric or steam power at 70° C.

At the end of the drying operation, when moisture content is between 15 and 20%, the pieces of suitable shape and size are wrapped in cellophane paper, packed in cartons and stored at ambient air temperature. Pieces of unsuitable shape and size are further cut into small pieces and used to prepare, along with peanuts and cashews, a variety of "cocktail mixtures".

Banana fruit bar. - Banana varieties which give smooth pulp without serum separation must be used for this purpose. Ripe, suitable fruit is selected. The hand-peeled fruits are soaked in 0.3 per cent citric acid solution for about 10 minutes (lime or lemon juice can replace citric acid). The drained fruit are pulped to obtain smooth pulp.

The rest of the procedure is the same as in the case of the mango bar.

Guava Fruit Bar

A mixture of pink and yellow varieties is best suited for preparing the bar. The washed fruit is hand peeled and stem and blossom ends trimmed. The peeled fruit is cut into quarters which are passed through a helicoidal extractor to separate seeds and fibrous pieces (the holes in the stainless steel screen should be between 0.8 and 1.10 mm).

To get the maximum yield of pulp, the material is passed through the extractor twice. After adjusting the refractometric solids to 25 degrees Brix, the fruit bar can be prepared by following the same procedure as for mango pulp.

Mixed Fruit Bar

Mango and banana pulp, as well as papaya and banana pulp, can be mixed in a calculated ratio for preparing mixed fruit bars. The rest of the procedure is the same as in the case of pure mango pulp.

Packing and Storage

The dried pulp is removed from the dryer and cut into square pieces of 5 x 5 cm at a thickness of about 0.3 cm. These pieces, arranged in three layers make up blocks of about 0.9 cm thickness weighing between 25 and 28 grams. An unit pack consist of two such blocks and weights between 50 and 56 grams.

Each block is separately wrapped in cellophane and the unit pack is filled in a printed cellophane bag of size 15 x 8 cm. Two hundred unit packs are packed in a master carton of size 34 x 22 x 14 cm, with a net weight of about 10 kg. Shelf-life is about one year at room temperature.

Fruit Leathers

Fruit leathers are manufactured by drying/dehydration of fruit purées into leathery sheets. The leathers are eaten as confections or cooked as a sauce. They are made from a wide variety of fruits, the more common being apple, apricot, banana, cherry, blackcurrant, grape, peach, pear, pineapple, plum, raspberry, strawberry, kiwi fruit, mango and papaya.

A description of procedures for mango, banana, guava and mixed fruit bars is given in this document. Another product with good potential is ciku leather; ciku fruit is grown in Malaysia.

A standard process is carried out using ripe fruits which are washed, peeled, diced and the seeds removed. The fruits are blanched for 1 minute at 80° C and blended into puree in a food processor.

Ciku leather is prepared by mixing ciku puree with 10% sugar, 10% pre-gelatinous rice flour, 150 ppm sorbic acid an 500 ppm sodium metabisulphite (Na2H2SO4). The mixture is cooked on a water bath at 60° C and then made into sheets 1.8 mm thick on trays spread with glycerol to reduce stickiness.

This is then further dried in a forced-air dehydrator at 45° C for 3.5 hr or until the surface no longer feels sticky when touched with the fingers. The dried and cooled leathers are cut into 12 x 12 cm squares and wrapped in polypropylene (PP) of 0.1 mm thickness.

Osmotic Dehydration in Fruit and Vegetable Processing

Osmotic dehydration is a useful technique for the concentration of fruit and vegetables, realised by placing the solid food, whole or in pieces, in sugars or salts aqueous solutions of high osmotic pressure. It gives rise to at least two major simultaneous counter-current flows: a significant water flow out of the food into the solution and a transfer of solute from the solution into the food.

Process Variables

Main process variables are

a. Pre-treatments;
b. Temperature;
c. Nature and concentration of the dehydration solutions;
d. Agitation;
e. Additives.

In the light of the published literature, some general rules can be noted:

- Water loss and solid gain are mainly controlled by the raw material characteristics and are certainly influenced by the possible pre-treatments;
- It is usually not worthwhile to use osmotic dehydration for more than a 50% weight reduction because of the decrease in the osmosis rate over time. Water loss mainly occurs during the first 2 hr and the maximum solid gain within 30 min.;
- The rate of mass exchanges increases with temperature but above 45 ° C enzymatic browning and flavour deterioration begin to take place. High temperatures, i.e. over 60° C, modify the tissue characteristics so favouring impregnation phenomena and thus the solid gain;
- The best processing temperature depends on the food; mass exchanges are favoured by using high concentration solutions;

- Phénomena which modify the tissue permeability, such as over-ripeness, pre-treatments with chemicals (SO2), blanching or freezing, favour the solid gain compared to water loss because impregnation phenomena are enhanced;
- The kind of sugars utilised as osmotic substances strongly affects the kinetics of water removal, the solid gain and the equilibrium water content. Low molar mass saccharides (glucose, fructose, sorbitol, etc.) favour the sugar uptake;
- Addition of NaCl to osmotic solutions increases the driving force for drying.

Synergistic effects between sugar and salt have also been observed.

Applications

The effects of osmotic dehydration as a pre-treatment are mainly related to the improvement of some nutritional, organoleptic and functional properties of the product. As osmotic dehydration is effective at ambient temperature, heat damage to colour and flavour is minimised and the high concentration of the sugar surrounding fruit and vegetable pieces prevents discolouration.

Furthermore, through the selective enrichment in soluble solids high quality fruit and vegetables are obtained with functional properties "compatible" with different food systems. These effects are obtained with a reduced energy input over traditional drying process. The main energy-consuming step is the reconstitution of the diluted osmotic solution that could be obtained by concentration or by addition of sugar.

Drying

Air drying following osmotic dipping is commonly used in tropical countries for the production of so-called "semi-candied" dried fruits. The sugar uptake, owing to the protective action of the saccharides, limits or avoids the use of SO_2 and increases the stability of pigments during processing and subsequent storage period.

The organoleptic qualities of the end product could also be improved because some of the acids are removed from the fruit during the osmotic bath, so a blander and sweeter product than ordinary dried fruits is obtained. Owing to weight and volume reduction, loading of the dryer can be increased 2-3 times.

The combination of osmosis with solar drying has been put forward, mainly for tropical fruit. A 24 hour cycle has been suggested combining osmodehydration, performed during the night, with solar drying during the day. Two-three-fold increase in the throughput of typical solar dryers is feasible, while enhancing the nutritional and organoleptic quality of the fruits.

A two-step drying process, OSMOVAC, for producing low moisture fruit products was described. The osmotic step is performed with sucrose syrup 65-75 Brix until the weight reduction reaches 30-50%. By osmotic dehydration followed by vacuum drying puffy products with a crisp, honeycomb-like texture can be obtained at a cost comparatively lower than freeze-drying.

Commercial feasibility of the process on bananas has been studied, based on the results of a semi-pilot scale operation; the process scheme is reported in Figure 8.4.3. Osmotically dried bananas retained more puffiness and a crisper texture than simple vacuum dried ones, and the flavour lasted longer at ambient temperature. The combination of osmotic dehydration with freeze-drying has been proposed only at laboratory scale.

Appertisation

A combination of osmotic dehydration with appertisation has been proposed to improve canned fruit preserves. The feasibility of a process, called osmo-appertisation, to obtain high quality fruit in syrup, has been assessed on a pilot scale.

The key point of this technique is the pre-concentration of the fruit to about 20-40 Brix, that causes, together with the enhancement of the natural flavour, an increase of the resistance of the fruit to the following heat treatment, especially for colour and texture stability. The products obtained are stable up to 12 months at ambient temperature and show a higher organoleptic quality than canned preserved alternatives.

Furthermore, because of their higher specific weight and diminished volume, the filling capacity of jars or pouches is increased.

Freezing

The frozen fruit and vegetable industry uses much energy in order to freeze the large quantity of water present in fresh products. A reduction in moisture content of the material reduces refrigeration load during freezing.

Other advantages of partially concentrating fruits and vegetables prior to freezing include savings in packaging and distribution costs and achieving higher product quality because of the marked reduction of structural collapse and dripping during thawing.

The products obtained are termed "dehydro-frozen" and the concentration step is generally carried out through conventional air drying, the additional cost of which has to be taken into account. Osmotic dehydration could be used instead of air drying to obtain an energy saving or a quality improvement especially for fruit and vegetable sensitive to air drying.

Extraction of Juices

An osmotic pre-step before juice extraction was reported to give highly aromatic fruit or vegetable juice concentrates.

Further Developments

So far only applications on a pilot plant scale are reported in the literature. For further developments on a larger scale, theoretical and practical problems should be solved.

The industrial application of the process faces engineering problems related to the movement of great volumes of concentrated sugar solutions and to equipment for continuous operations. The use of highly concentrated sugar solutions creates two major problems.

The syrup's viscosity is so great that agitation is necessary in order to decrease the resistance to the mass transfer on the solution side. The difference in density between the solution (about 1.3 kg/litre) and fruit and vegetables (about 0.8 kg/litre), makes the product float.

Another important aspect, so far not investigated, is the microbiological safety of the process, which should be studied thoroughly before further industrial development.

Osmoappertisation in the Processing of Apricots

In order to obtain an alternative to the canned fruit preserves and to maintain a high quality of the fruits, a research has been carried out on the osmoappertisation of apricots, a "combined" technique that consists in the appertisation of the osmodehydrated apricots.

This technique could contributes also to the reduction of energy consumption, limits the cost of production and combines "convenience" (ready-to-eat, medium shelf-life) with many market outlets (retail, catering, bakery, confectionery, semi-finished products).

Osmoappertisation combines two unit operations: dehydration by osmosis and appertisation (packaging + pasteurization).

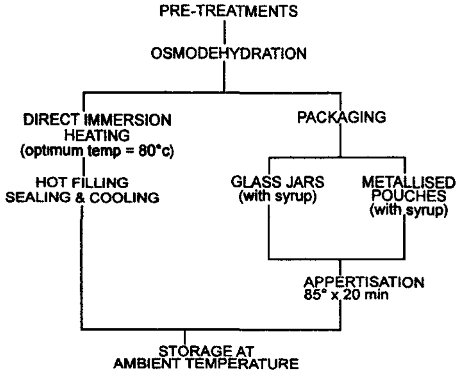

Figure: Osmoappertisation in the processing of apricots

Apricot Processing

a. Fresh apricot puree

After washing, cutting and removal of stones, apricot halves are dipped in 2% solution of sodium or potassium metabisulphite for 10 minutes. After draining, the resulting material is passed through a 0.045-in. screen pulper - finisher to produce a fresh apricot puree.

The fresh apricot puree obtained in this way could be further processed in different semiprocessed (i.e. chemically or otherwise preserved products) or finished fruit products (fruit leathers, fruit bars, jams, etc.).

b. Concentrated apricot pulp

Fresh apricot halves could also be steam blanched for 5 min., passed through a 0.045-in pulper - finisher and transformed in a purée with about 14 Brix depending on the fruit quality. This purée may be concentrated in steam jacketed kettles up to 20 Brix or in other adequate equipment (e.g. a stirred vacuum evaporator) up to 28°Brix.

As for fresh apricot purée, the concentrate may be further processed in various semiprocessed or finished fruit products as mentioned above and as will be described below.

c. Dried apricot leather

- From fresh fruit purée by drum drying. The fresh apricot purée at about 14 Brix could be dried to 12% moisture apricot sheets, using a double-drum dryer operating at 132 degrees C with a drum clearance of 0.008 in and speed of 45 sec per revolution.
- From fruit concentrate by drum drying. The concentrate could also be dried to 12% moisture fruit sheets by the same process as described above.

- From fresh fruit purée or from apricot concentrate by sun/solar drying or by dehydration.

a. *Trays:* For sun/solar drying or dehydration of fruit pulp, the trays must have a solid base in order to retain the liquid contents. They may be made of metal, timber or plastic. Stainless steel or plastic trays are most suitable because they are unaffected by acid fruit pulp; they are, however, expensive.

   A metal tray could be 75 x 50 cm in size and with side 5 cm high. The trays must keep level during drying; if the tray is not level the pulp will run to the lowest point, giving a layer of irregular depth which will dry unevenly. Any tray which is not made of stainless steel or plastic must be covered inside with a sheet of heavy gauge plastic film to protect the pulp from chemical or bacteriological contamination.

   Standard sun/solar trays as described can be used by covering them inside with a sheet of plastic film to create a solid base.

b. *Preparation before drying/dehydration*: Fresh apricot purée can be directly used for next processing steps. Fruit concentrate needs to be added to potassium metabisulphite to obtain a 0.3% concentration of SO2 in the material.

c. *Drying/dehydration*: The apricot/fruit purée or concentrate is poured into the trays to a depth of about 1.5 cm. When stainless steel or plastic trays are used they should be coated with a thin layer of glycerine to prevent sticking.

The pulp is then sun/solar dried or tunnel/cabinet dehydrated; moisture content in the dried product should not exceed 14% and the SO_2 content should not be less than 1500 pp. The dried product is wrapped in cellophane to prevent sticking, then put inside polythene bags and stored at best in tight fitting tins and sealed to prevent moisture transfer.

From fresh fruit purée or from apricot concentrate, with sugar addition, and then processed by sun/solar drying or by dehydration. In some countries preference is for finished products with added sugar; and this is also interesting from a point of view of energy consumption (concentration is partially achieved by sugar dry matter) and of shelf life. The overall content in SO_2 could also be reduced as sugar is a preservation agent, the product will be close to a fruit "paste".

Reconstitution Test for Dried/Dehydrated Products

In reconstitution water is added to the product which is restored to a condition similar to that when it was fresh. This enables the food product to be cooked as if the person was using fresh fruit or vegetable.

All vegetables are cooked but many of the dried fruits can be used for eating after they have been soaked in water. The following reconstitution test is used to find out the quality of the dried product.

Reconstitution test

1. Weigh out a sample of 35 grams from the bulked and packed final product of the previous day's production.
2. Put the sample into a small container (beaker) and add 275 ml of cold water (and 3.5 g salt).
3. Cover the container (with a watch-glass) and bring the water to the boil.
4. Boil GENTLY for 30 minutes.
5. Turn out the sample onto a white dish.
6. At least two people should then examine the sample for palatability, toughness, flavour and presence or absence of bad flavours. The testers should record their results independently.
7. The liquid left in the container should be examined for traces of sand/soil and other foreign matter.

This test can be used also to examine dried products after they have been stored for some time. Evaluation of rehydration ratio may be performed according to the following calculations.

Rehydration ratio. If weight of the dried sample is 10 g (Wd) and the weight of the sample after rehydration is 60 g (Wr), rehydration ratio is:

$$\frac{Wr}{Wd} = \frac{60}{10} = \frac{6}{1}, 6 \text{ to } 1$$

Rehydration coefficient. The weight of rehydrated sample is 60 g (Wr); the weight of dried sample is 10 g (Wd) and its moisture is 5% (Wu); raw material before drying had 87% water (A); rehydration coefficient is:

$$\frac{\dfrac{Wr}{Wd - Wu \times 100}}{100 - A} = \frac{60 \times (100-87)}{10 - [10 \times 0.05]} = \frac{780}{9.5} = 52.1.$$

A simpler test for eating quality can be carried out without weighing and measuring. The material is placed in a cooking pot with water (and a little salt). The pot is then covered and boiled as described above.

Except for a few products which are eaten in the dry state, most dried fruit and all dried vegetables are prepared by soaking and cooking. Often this preparation is carried out incorrectly and dried products get a bad reputation.

Good quality dried products, after cooking and if properly treated should be similar to cooked fresh produce. In order to get good results, the following methods are recommended:

Quick Method

Cold water, ten times the weight of the dry product, is added to the dried product. The container is covered, brought to the boil and simmered GENTLY until the product is tender. The cooking time may be 15 to 45 minutes after the boiling point has been reached.

Slow Method

This gives better results than the quick method. Cold water is added to the dry food and is left to soak for 1 to 2 hours before cooking. The product is then cooked in the same water as that in which it was soaked. The actual cooking time will probably be shorter than that for the quick method.

Other points to remember are:

- If too much water is added the cooked product will have little flavour. However, if too little water is added the product may dry and burn. This can be avoided by adding small quantities of water during cooking;
- Always cook with a lid on the container;
- Salt, if required, should be added when the cooking is almost complete;
- Partly used packages of dry products should be reclosed tightly or kept in containers with good fitting lids.

The composition of some dried fruits is seen in Table given below.

Table: Composition of Some Dried Fruits

Fruit	Moisture content %	Sugar as monosaccharides, %	Other carbohydrates	Vitamin C mg/ 100 g
Raisins	21.5	64	7	0.0
Dates	12.5	55	7	0.0
Prunes	20.0	45	15	0.0
Apricots	15.0	45	24	4.8
Peaches	15.5	55	14	8.0

Handling, Sorting, Packing and Storage of Dried and Dehydrated Fruit and Vegetables

It is not easy to assess when drying has been completed. In absence of instrumentation, the characteristics of the various products after drying/dehydration can only be assessed by experience. Although this cannot be conveyed adequately on paper, some general indications can be given.

Fruit Products

When a handful of fruit is squeezed tightly together in the hand and then released, the individual pieces should drop apart readily and no moisture be left behind on the hand. It should not be possible to separate the skin by rubbing unpeeled fruit and the fruit centre should no longer reveal any moist area. Banana should be leathery and not too tough to eat in their dry state.

Vegetable Products

Onions should be dried until they are crisp whereas tomatoes should be leathery. In general, the lower the moisture content, the better the keeping quality will be, but overdried products generally have an inferior quality. Also the loss in weight from excessive drying cannot be tolerated in a commercial operation designed to run profitably.

It is, however, essential to dry up to an optimum/safe moisture level, related to the type of the product and his designed shelf life, and to avoid running the risk of the products becoming spoiled due to excess water content. When drying is completed, the material should be sorted either on trays or on a table in order to remove pieces of poor quality and colour and any foreign matter.

Very fine material should be separated from the bulk of the material by using a sieve (12 or 16 mesh per inch). Bad quality products which show poor colour need to be removed from the bulk of finished product. After selection and grading, dried products should be packed immediately, preferably in polythene bags which must be folded and closed/tied tightly. However, plastic bags are easily damaged and therefore they must be packed into cartons or jute sacks before they are transported.

Deterioration of Dried Fruit During Storage

Dried fruit must be considered as a relatively perishable commodity in the same category as cereals, pulses and similar stored products. It is subject to deterioration resulting from mould growth, insect and mite infestation and physical and chemical changes.

Mould Growth

When the moisture content of dried fruit is allowed to exceed the maximum permissible level for safe storage then mould growth may occur. The moisture levels applicable to various types of fruit; and it can be seen that the safe moisture levels for dried fruit are much higher than those for other similar commodities.

At the present time, suitable field moisture metres for use with dried fruit are not readily available, and moisture determinations can only be satisfactorily carried out where laboratory facilities are available.

Various species of drought resisting fungi may develop on dried fruit when the moisture content is just above the safe level, and a number of osmophilic yeasts are quite commonly associated with spoilage in dried fruit.

Many of the yeasts bring about fermentation with the production of lactic acid or alcohol, and yeasts are frequently present in wart-like crystalline growths which occur in fruit which has become "sugared". In very moist fruit mucoraceous fungi may predominate and are visible as white fluffy growths on and within the fruit.

Mite Infestation

Severe mite infestations are often associated with the growth of osmophilic yeasts in fermenting dried fruit products. Many of these mites are unable to complete their development in the absence of yeast. They have been reported as occurring on dried fruit, and particularly figs and prunes in Mediterranean countries. Such infestations are difficult to eradicate and affect consumer acceptance of the contaminated products.

Insect Infestation

Insect infestations may begin in the field before harvest, may continue during bulk storage after drying, and unless measures are taken to prevent it, may occur in the finished packaged product during storage prior to distribution and consumption.

Regular treatments of the stack of dried fruit with a suitable insecticide will be necessary as a routine to combat light insect infestations. Pyrethrins synergised with piperonyl butoxide are commonly used as a surface spray or as an aerosol fog for this purpose. Heavy infestations will require that the fruit be fumigated.

Equipment for "Dry Sulphuring of Fruit before Dehydration/ Drying

SO_2 generator

1. SO_2 outlet pipe
2. Sulphur feeding door
3. Plate for sulphur burning
4. Small door
5. Burner for gas
6. Metallic sieve

Sulphuring installation

1. Exhaust pipe
2. SO_2 pipe
3. SO_2 generator
4. SO_2 distributor
5. SO_2 distribution pipes
6. Sulphuring cells
7. SO_2 flow regulator
8. Pipe for removing SO_2 from sulphuring cells
9. Electrical fan
10. Exhaust pipe for removing SO_2 from sulphuring installation
11. Hole for SO_2 coming from cells

Solar Dryer with Air Heater - Tunnel Type; Community or Business Level

I. Air heaters

1. Cover: Transparent 3 mm. plexiglass plate or plastic sheet

2. Absorber - bottom - corrugated black painted iron sheets - intermediary - black painted iron sieve
3. Insulation: none
4. Frames: metallic black painted corner/angle ironR

II. Drying tunnel or room

1. Cover: transparent plastic sheets
2. Frames: metallic black painted angle iron
3. Insulation: for back only on the outside
4. Back wall: wood plate, painted black on inside
5. Front wall: transparent plastic sheets
6. Side doors: - frames = wood
   — transparent plastic sheets
7. Dimensions of drying tunnel/room
   — L = 22 feet
   — W= 18 feet
   — H = 5 feet
8. One range of trolleys

III. Trays

1. Frames: wood, black painted
2. Bottom: nylon mesh or wood slats
3. Dimensions:
   — l = 3 feet
   — w = 2.4 feet

IV. Trolleys

1. Metal platform with wheels
2. Number of trays per trolley: 15
3. Distance between trays: 3"
4. Total height of trolley: 3 x 15 = 45 inch + 4 " (wheel) = 49 inch

V. Capacity calculation; number of trolleys and trays

1. Hypothesis: 300 kg fresh apricots received per day 2 days solar drying

2. Tunnel/dryer capacity: 2 x 300 = 600 kg fresh apricots
3. Number of trolleys and trays calculation:
   - number of trays/trolley = 15
   - kg fresh apricots per tray = 6 kg
   - kg fresh apricots per trolley: 6 x 15 = 90 kg
   - number of trolleys needed in drying room: 600: 90 = 7
   - number of trolleys in sulphuring cells = 2
   - number of trolleys in "wet preparation section" = 3
   - number of trolleys in dry section (after tunnel) = 2
   - total number of trolleys needed = 14
   - total number of trays needed: 14 x 15 = 200

VI. Sulphuring cell

1. Capacity: 2 trolleys
2. Dimensions: 1 = 5 feet; w = 3.5 feet; H = 55 inch
3. One sulphuring pipe inside the cell, diametre = 15 cm

VII. SO_2 generator: diametre = 45 cm; h = 70 cm

VIII. Air heater/heat collector

1. DIMENSIONS: L = 5 M; H = 30 CM; Hl = 15 CM; H2 = 20 CM
2. Bottom/corrugated black painted iron sheets
3. Intermediate heat absorber: iron black painted metallic plate/sieve with holes of about 3 cm in diametre fixation: at mid-distance between cover and bottom of the heat collector
4. Cover: transparent 3 mm Plexiglas plate (or transparent plastic sheets)

The calculation used in this dryer is based on a real situation in a developing country, within the framework of FAO projects; availability of building materials was confirmed.

For the orientation of the dryer geographical position of the available drying yard and local wind direction were taken into consideration.

Technology of Semi-processed Fruit Products

The semi-processed fruit products are manufactured in order to be delivered to industry processing centres (in the fruit producing country itself or in importing countries) where they will be further manufactured in consumer oriented finished products: jams, jellies, syrups, fruits in syrup, etc.

In the practice of semi-processed fruit products and for the purpose of this document the following categories are defined:

a. Fruit "pulps": semi-processed products, not refined, obtained by mechanical treatment (or, less often, by thermal treatment) of fruit followed by their preservation. Either whole fruit, halves or big pieces are used which enables easy identification of the species. "Pulps" can be classified in boiled or non boiled (raw).

b. Fruit "purées-marks": semi-processed products obtained by thermal and mechanical treatment or, very rare, raw and then refined, operations by which all nonedible parts (cores, peels, etc.) are removed. "Purées-marks" are classified in boiled (the more usual case) and non boiled (raw).

c. Semi-processed juices: products obtained by cold pressure or very rare by other treatments (diffusion, extraction, etc.) followed by the preservation.

Technical Processes for Preservation of Semi-processed Fruit Products

Preservation can be achieved by chemical means, by freezing or by pasteurization. The choice of preservation process for each individual case is a function of the semi-processed product type and the shelf life needed.

Chemical Preservation

In many countries, in practice, this is carried out with sulphur dioxide, sodium benzoate, formic acid and, on a small scale, with sorbic acid and sorbates.

Preservation with sulphur dioxide is a widespread process because of its advantages: universal antiseptic action and very economic application. The drawbacks of SO_2 are: SO_2 turn firms the texture of some fruit species (pomaces), desulphiting is not always complete and recolouring of red fruits is not always complete after desulphitation.

Practical preservation dosage levels with SO_2 for about 12 months is 0.18-0.20% SO_2 (with respect to the product to be preserved).

This level could be reduced to 0.09% SO_2 for 3 months and to 0.12% SO_2 for 6 months preservation. The preservation with sulphur dioxide is in use mainly for "pulps" and for "purées-marks".

Chemical preservation can be performed from a practical point of view by the utilisation of 6% SO_2 water solutions or by direct introduction of sulphur dioxide gas in the product (for "purées-marks"). The preparation of 6% SO_2 solutions is done by bubbling the gas from cylinders in cold water; from a 50 kg SO_2 compressed gas cylinder results 830 l of 6% SO_2 solution.

These SO_2 solutions have to be stored in cool places, in closed receptacles and with periodic concentration control/ check by titration or by density measurements approximate results.

Preservation with sodium benzoate has the following advantages: it does not firm up the texture and does not modify fruit colour. The disadvantages are: it is not a universal antiseptic, its action needs an acid medium and the removal is partial. Sodium benzoate is in use for "pulps" and for "purées-marks" but less for fruit juices.

Practical dosage level for 12 months preservation is 0.18-0.20 % sodium benzoate, depending on the product to be preserved. Sodium benzoate is used as a solution in warm water; the dissolution water level has to be at maximum 10% reported to semi-processed product weight.

Formic acid preservation is performed mainly for semi-processed fruit juices at a dosage level of 0.2 % pure formic acid (100%). Formic acid is an antiseptic effective against yeasts, does not influence colour of products and is easily removed by boiling.

Formic acid could be diluted with water in order to insure a homogeneous distribution in the product to be preserved; water has to be at maximum 5 % of the product weight. Because of a potential effect of pectic substance degradation, formic acid is less in use for "pulps" and "purées-marks" preservation.

Sorbic acid used as potassium sorbate (easily water soluble) can be used for preservation of fruit semi-processed products at a dosage level of 0. 1% maximum. Advantages of sorbates are: they are completely harmless and without any influence on the organoleptic properties of semi-processed fruit products.

Preservation by Pasteurization

As fruit has a low pH, preservation of semiprocessed fruit products could also be performed by pasteurization (heat treatment step at maximum temperature of 100°C), the length of this step varying with the size of the receptacles.

The advantages of this type of treatment are: hygienic process, which assure a long term preservation; the disadvantages are: need for air tight receptacles, and pectic substances could begin to deteriorate if the thermal treatment is too long.

Thermal preservation of fruit semi-processed products could also be done by a "selfpasteurization": very hot semi-processed products are filled into receptacles (e.g. metal cans) which are sealed and then inverted in order to sterilise the air which goes through the hot fruit mass.

Preservation by Freezing

This is done on an industrial scale in some countries and can be done with or without sugar addition. The advantages of this process are: absence of added substances; very good preservation of quality of fruit constituents (pectic substances, vitamins, etc.) and good preservation of organoleptic properties (flavour, taste, colour). Freezing is done at about -20 to -30° C and storage at -10 to -18° C.

Freezing is applied mainly to semi-processed fruit products aimed at very high quality and high cost finished products. Technological flow-sheet for semi-processed fruit "pulps": chemical preservation.

Sorting is needed in order to remove sub-standard fruit (with moulds, with diseases, etc.) and all foreign bodies.

Washing is obligatory in order to remove all impurities which cannot be eliminated at the processing step in finished products.

Coring and Cutting, mainly for pomace fruits, has as main objective a better utilisation of preservation "space" in receptacles and is not mandatory; this will be defined by customer/supplier agreements/standards. This operation is preferably performed by mechanical means.

Preservation is carried out with the 6% SO_2 solution which is added to the prepared fruits (placed in bulk in receptacles) in the quantity needed to obtain the preservation dosage level. For a better/homogeneous preservative distribution, the initial 6% SO_2 solution could be diluted with water; however, the diluted solution (which will be filled in receptacles) has to be at a dosage level of less than 10% of the semi-processed product weight.

For some soft fruit, especially strawberries, preservation is done with a mix of 6% SO_2 solution and calcium bisulphite solution (containing also 6% SO_2).

Preparation of calcium bisulphite solution is done by the introduction of 30 kg of CaO in 1 m^3 SO_2 solution and mixing up to clarification. The resulting solution is mixed with the initial 6% SO_2 solution, generally in a 1:1 ratio, but the ratio can be adapted to the fresh fruit texture. Firming of soft fruit texture by this treatment is based on the formation of calcium pectate with pectic substances from fruit tissues.

In the case of sodium benzoate, formic acid or potassium sorbate, the dosage levels to be used are as indicated above with the rule that it is not allowed to add more that 10% liquid in receptacles on the prepared fruits.

Preservation by pasteurization or "self-pasteurization" will need as additional steps: a) boiling with a minimum water addition (maximum 10%); b) filling of receptacles; c) hermetic closing followed by d) pasteurization or "self-pasteurization".

Some general technical data for the preparation of chemical preserved semi-processed fruit "pulps" are seen in Table given below.

Table: General Technical Processing Data for Semi-processed Fruit "Pulps"

Fruit species	Preliminary operations	Preservation means
Apples, pears, quinces	Sorting, washing, coring, cutting	Sulphur dioxide
Prunes, peaches, wax cherries, apricots	Sorting, washing, stone removal (pitting)	Sulphur dioxide or sodium benzoate
Cherries	Sorting, washing	Sulphur dioxide or sodium benzoate, sometimes with calcium bisulphite addition
Strawberries	Sorting, washing	Sulphur dioxide in mix with calcium bisulphite
Wild berries	Sorting, washing	Sulphur dioxide or sodium benzoate; in some cases with calcium bisulphite addition

Technological Flow-sheet for Semi-processed "Purée-marks"

The general technological flow-sheet includes the following operations:

Sorting and Washing are obligatory and are carried out in a similar manner as for "pulps".

Heat Treatment/Boiling is needed in order to soften the fruit tissues before refining. For some fruits as strawberry and wild berries, this step is not done and fruits are refined "raw" in order to preserve their flavour.

Pulping is performed with specific equipment - refiners or pulpers - which eliminate seeds, pits and other non edible parts (peels, cores, etc.).

Preservationis carried out by chemical means, by freezing or by pasteurization.

The general technical/processing data for the manufacture of "purée-marks" are seen in Table given below.

Table: General technical Processing Ddata for Semi-processed "Purées - marks"

Fruit species	Preliminary operations	Preservation means
Apples, pears, quinces	Sorting, washing, boiling, refining	Sulphur dioxide; in less frequent cases formic acid or sodium benzoate
Prunes, peaches, wax cherries, apricots,	Sorting, washing, boiling, refining	Sulphur dioxide, formic acid or sodium benzoate; cherries freezing with or without sugar; self-pasteurization
Strawberry, wild berries	Sorting, washing, refining	Chemical preservation, freezing or self pasteurization

1. Washing tank
2. Vertical transporter
3. Transport tubes
4. Regulating plates
5. Crushing machine
6. Grating machine
7. Preheating equipment
8. Pulper
9. Centrifugal pump

10. Finisher
11. Storage tank

From the storage tank 11, the product is transferred by pump to a mixing tank (mix with SO_2)

Table: Correlation between Density and Concentration for SO_2 Solutions

Density at 15°C	Concentration of solutions % SO_2
1.0168	3.00
1.0181	3.25
1.0194	3.50
1.0206	3.75
1.0221	4.00
1.0234	4.25
1.0248	4.50
1.0261	4.75
1.0275	5.00
1.0289	5.25
1.0302	5.50
1.0315	5.75
1.0340	6.25
1.0353	6.50
1.0365	6.75
1.0377	7.00

FRUIT SUGAR PRESERVES TECHNOLOGY; JAMS, JELLIES, MARMALADE, FRUIT PASTE

As a overall rule of thumb, a sugar concentration of about 60% in finished or processed fruit products generally insures their preservation. Preservation is not only determined by the osmotic pressure of sugar solutions but also by the water activity values in the liquid phase, which can be lowered by sugar addition; and by evaporation down to 0.848 aw; this value however does not protect products from mould and osmophile yeast attack.

Maximum saccharose concentration that can be achieved in the liquid phase of the product is 67.89%; however higher total sugar quantities (up to 70-72%) found in products are explained by an increased reducing sugar solubility resulting from saccharose inversion.

Jams

The preservation of fruit by jam making is a familiar process carried out on a small scale by housewives in many parts of the world. Factory jam making has become a highly complex operation, where strict quality control procedures are employed to ensure a uniform product, but the manufacturing operations employed are in essence the same as those employed in the house.

Fresh or pre-cooked fruit is boiled with a solution of cane or beet sugar until sufficient water has been evaporated to give a mixture which will set to a gel on cooling and which contains 32-34% water.

Gel formation is dependent on the presence in the fruit of the carbohydrate pectin, which at a pH of 3.2 - 3.4 and in the presence of a high concentration of sugar, has the property of forming a viscous semi-solid.

During jam boiling, all micro-organisms are destroyed within the product, and if it is filled hot into clean receptacles which are subsequently sealed, and then inverted so that the hot jam contacts the lid surface, spoilage by micro-organisms will not take place during storage.

The composition of jam made from stone fruit and berry fruit is shown in Table given below. About 30% of the vitamin C present in fresh fruit is destroyed during the jam-making process, but that which remains in the finished product is stable during storage.

The high moisture content of jam (equivalent to an equilibrium relative humidity of about 82%) makes it susceptible to mould damage once the receptacle has been opened and exposed from some time to the air. No problems of microbiological spoilage are likely to arise in the canned product during storage.

Table: Composition of Some Fruit Jams

Type of Jam	Moisture content %	Sugar (as invert sugar, %)	Vitamin C mg/ 100 g
Jam made from berry fruits: strawberry, raspberry, etc.	29.8	69.0	10 - 25
Jam made from stone fruits: apricot, peach, etc.	29.6	69.3	10 - 35

Marmalade

This sugar preserve is defined as "semisolid or gel-like product prepared from fruit ingredients together with one or more sweetening ingredients and may contains suitable food acids and food pectins; the ingredients are concentrated by cooking to such a point that the TSS - Total Soluble Solids - of the finished marmalade is not below 65%".

Fruit Paste

Fruit paste is a product obtained in the same way as special non-gelified fruit marmalade but with a lower water content - about 25% TSS in fruit paste. Lowering water content could be achieved by continuing boiling of the product or by drying the product by natural or artificial drying. An example of paste without sugar is the sun dried apricot or prune paste.

General Procedure for the Preparation of Jams, Jellies and Marmalade

a. Boil the pulp or the juice (with water when necessary)
b. Add the pectin
c. Boil for about 2 minutes to assure a complete dissolution
d. Add the sugar while keeping the batch boiling
e. Boil down quickly to desired Brix
f. Add the acid (usually citric acid) and remove the froth
g. Fill hot into the (previously cleaned) jars and close
h. Invert the jars for three minutes to pasteurize the cover

Basic Recipes

The following recipes must be considered only as guidelines because the composition of the fruit can vary; also the taste of the consumers varies concerning the consistency, the sweetness and acidity.

Before starting to make jam it is important to know the yield to settle the question on containers. The calculation is made as follows:

$$\frac{Total\ Soluble\ Solids\ content\ of\ all\ the\ raw ingredient}{Percentage\ of\ Total\ Soluble\ Solids\ in the\ final\ product} \times 100$$

In these basic recipes it is assumed that the fruits are poor in pectin content.

Recipe 1. Fruit: sugar = 50:50; desired Brix in the finished product is 68.

Soluble Solids:

10 kg of fruit at 10% TSS	1.000 kg
10 kg of sugar	10.000 kg
60 g of pectin (grade 200)	0.060 kg
55 g of citric acid	0.055 kg
	11.115 kg

$$Yield = \frac{11.115 \times 100}{68} = 16.4\ Kg$$

Recipe 2. Fruit: sugar = 45:55; desired Brix in the finished product is 68.

Soluble Solids:

d10 kg of fruit at 10% TSS	1.000 kg
2.5 litre of water	-
12.2 kg of sugar	12.200 kg
65 g of pectin grade 200	0.060 kg
60 g of citric acid	0.060 kg
	13.325 kg

$$Yield = \frac{13.325 \times 100}{68} = 19.6\ Kg$$

Recipe 3. Fruit: sugar = 40:60; desired Brix in the finished product is 68.

Soluble Solids:

d10 kg of fruit at 10% TSS	1.000 kg
3.3 litre of water	-
15 kg of sugar	15.000 kg
85 g of pectin grade 200	0.085 kg
80 g of citric acid	0.080 kg
	16.165 kg

$$Yield = \frac{16.165 \times 100}{68} = 23.8\ Kg$$

Various factors must be taken into account:

1. Size of the container: the quantity of pectin indicated in the recipes is valid for containers of 1 kg or less.

   If container capacity is between:

   Increase pectin by:

1 kg and 2.5 kg	5%
2.5 kg and 5.0 kg	10%
5.0 kg and 10.0 kg	20%
10.0 kg and 20.0 kg	30%

2. Finishing point: the quantity of pectin is given for a final Brix - Total Soluble Solids (TSS) of 68%.

If the final Brix is 66 increase the pectin by 5%

" " is 65 " " " by	10%
is 64 " " " by	15%
" " is 62 " " " by	20%
" " is 60 " " " by	30%

3. Acidic taste. If the product is too acid, replace the citric acid by tartaric acid (63% of the amount of citric acid).
4. Formation of clots: If batch clots, it is probably due to the pH being too low or the or TSS being too high; correct accordingly.
5. Formation of liquid at the surface: if liquid forms on the surface, it is probably due to too low a pH or too low pectin content.
6. Crystallisation:
   a. If liquid forms on the surfaces, then the pH is too low; reduce the acid content;
   b. If liquid does not form on the surface, then TSS or pH is too high.
7. Formation of mould: the TSS is probably below 68 deg. Brix. The filling may have been done at a low temperature. If the containers are large, wait until they are cold before closing.
8. Wrong batch: dilute the jam with water to 30% TSS; cook briefly. Add this diluted jam to a new batch but in a ratio not exceeding 10%.

Processing of Pineapple-papaya Jam

The fruit should be prepared as per previous instructions.

For pineapples, the ends are removed and discarded; the cores and outer parts of the fruits are also removed. The fruit cylinders obtained are pulped through a special extractor (Fitzpatrick communiting machine) equipped with a 0.40-in screen sieve; the pulp thus obtained is used for making jam.

The papaya are prepared by hand-peeling the fruit; the fruit is then halved and the seeds removed. It is then pulped in the communiting machine using a 0.40-in screen sieve.

When ginger root is used as flavouring, it is peeled and macerated in a Kenwood blender to a very fine consistency.

A typical formula for a pineapple-papaya jam (50:50 ratio) with ginger flavouring is given as follows:

Pineapple pulp	25.0
Papaya pulp	25.0 pounds
Cane sugar	50.0
Apple pectin (150 grade)	6.0 ounces
Citric acid	6.4
Fresh ground ginger	7.5

Processing is carried out in the following way:

The weighed fruit pulp is placed in a stainless steel steam-jacketed kettle and heated to about 110°F under constant stirring.

When the product reaches this temperature, the heat is turned off. The pectin (mixed in about ten times its weight with some of the weighed sugar), is then mixed into the fruit pulp, stirring constantly in order to prevent the pectin from clotting.

When the pectin has dissolved, the remainder of the sugar is added and dissolved completely in the mixture. The heat is then turned on and the jam mixture is stirred constantly until it starts boiling vigorously. During the remainder of the cooking, the product is stirred occasionally. Near the finishing point (approximately 221° F), the citric acid and the ginger (if it is used) are also added.

Determination of the finishing point is done by removing samples at intervals, cooling, and reading the soluble solids by means of a refractometre equipped with a Brix scale. After the jam reaches the proper Total Soluble Solids content, the heat is turned off and the surface scum/foam is removed.

The jam then is quickly put into receptacles which have been cleaned and sterilised with boiling in water for 30 minutes. The filling operation is done rapidly in order to prevent the temperature of the jam from falling below 190° F.

After filling, sterilised lids (boiled for 30 minutes in water) are placed on the receptacles and they are then sealed.

After this operation the receptacles are inverted for about 3 minutes to insure that the lids are sterilised. The receptacles are then placed upright. At this stage it is not necessary to do any further processing, therefore the receptacles are cooled in running cold water until they reach a temperature slightly above room temperature. They are then dried in air and labelled.

Evaluation of Finished Products

During production at medium/large scale, it is recommended that quality controls be performed during manufacturing. After ten weeks of storage at room temperature it is recommended that an examination of finished products be performed. The receptacles are opened and contents carefully emptied on to enamel trays without disturbing the formation of the jam.

The empty cans (if metal cans were used) are then inspected for signs of corrosion. Factors other than flavour include colour, appearance, syrup separation, firmness and spreading quality. For flavour, jam is tested on pieces of bread. Samples are taken for measurement of pH (with a glass electrode pH metre) and Total Soluble Solids (with a refractometre equipped with a Brix scale).

This evaluation enables to have a quality check during product shelf life and to obtain data needed for necessary improvements of future productions.

For pineapple-papaya jam, products made with 30% pineapple and 70% papaya with added ginger has the highest score for flavour. The use of plain tin cans causes corrosion problems which is not the case when acid resistant lacquer cans are used.

Pineapple Jam Making

1. Boil 40 lb. of pulp and 12 lb. of water.
2. Add 225 g of pectin to the batch while stirring rapidly.
3. Boil for about 90 sec to assure complete dissolution.
4. Add 60 lb. of sugar gradually if possible in several portions, while keeping the batch boiling.
5. Boil down quickly to 69 deg. Brix (223 deg. F).

6. Take off steam, remove foam.
7. Add 300 cc citric acid solution 50%.
8. Fill hot (180 deg. F).
9. Invert receptacles for 3 minutes.

Check each batch for Brix 68-70 deg.; acidity/pH = 3.2 +/- 0.2.

Evaluate: absence of defects; colour; flavour; consistency.

Various fruit:sugar ratios can be manufactured; some basic recipes are as follows:

	Ratio 50:50	Ratio 45:55	Ratio 40:60
Fruit	55 lb	49.5 lb	44 lb
Water	-	11 lb	13.2 lb
Sugar	55 lb	60.5 lb	66 lb
Pectin (150 grade)	225 g	237.5 g	250 g
Citric acid (50% sol.)		300 cc	320 cc 335 cc

Gelified Sugar Fruit Preserves

Technology of Fruit Jellies

Jellies are gelified products obtained by boiling fruit juices with sugar, with or without the addition of pectin and food acids. Jellies are usually manufactured from juices obtained from a single fruit species only, obtained by boiling in order to extract as much soluble pectin as possible.

Jellies have to be clear, shiny, transparent and with a colour specific to the fruit from which they are obtained. Once the product is removed from the glass receptacles where it was packed, jellies must keep their shape and gelification and not flow, without being sticky or of a too hard consistency.

Technological flow-sheet for jellies manufacturing covers two categories of operations: those to obtain gelifying juices and those related to the manufacturing of jelly itself.

a. Production of gelifying juices:

   Washing & Sorting are carried out in usual conditions;

   Cutting is applied eventually only to pomaces (apples, quinces) and are limited to cutting in halves or quarters;

Boiling is performed with water addition with 50-100% water, needed for pectin extraction. The boiling time is 30-60 min., it should not be longer so as to avoid pectin degradation; at the same time boiling must not be too violent.

Juice separation is carried out by a simple drain through metallic sieve or cloths; in these cases the yield is lower and the residue can be used for marmalade production. In bigger productions it juice separation by hydraulic press is preferred, yield being in these cases greater.

Juice clarification is strictly necessary in order to obtain clear jellies. This step can be achieved by sedimentation during 24 hours or by filtration.

b. Manufacturing of jellies:

Basic Recipe Seting is done starting with equal parts in weight of sugar and juice (for example 1000 g juice and 1000 g sugar). As final jelly has to contain about 60% added sugar, weight of finished product must be of about 1600 g, by evaporation of about 400 g water.

Boiling is carried out as following: juice is boiled up to removal of about half of the water that has to be evaporated, then the calculated sugar quantity is added gradually; the remainder of the water is evaporated until a concentration in soluble substances (refractometric extract) of 65-67% is reached, in which is incorporated also the sugar from juice.

During boiling it is necessary to remove foam/scum formed. Product acidity must be brought to about 1% (malic acid) corresponding to pH > 3. Any acid addition is performed always at the end of boiling.

For juices rich in pectin, gelification will occur without pectin addition. If at the trial boiling test the gelification has not occurred, because of pectin absence, in this case 1-2% powder pectin will be added by operating as indicated: pectin is mixed with 10-20 fold sugar quantity and is introduced directly in the partially evaporated juice and then boiling is conducted rapidly up to final point. Evaluation of final point is done not only by refractometry but also by gelifying test.

A rapid test for evaluation of juice pectin content is possible by mixing a small sample of juice with an equal volume of 96% alcohol; the apparition of a compact gelatinous precipitate indicates a sufficient pectin content for gelification.

Boiling of jellies is performed in small batches (25-75 kg) in order to avoid excessively long boiling time which brings about pectin degradation.

Cooling is optional and is carried out up to 85 deg. C, in double wall baths with water circulation.

Filling is performed at a temperature not below 85 deg. C in receptacles (glass jars, etc.), which must be maintained still about 24 hours to allow cooling and product gelification.

Receptacle closing is done after product gelification.

Usual jelly types are: quinces, strawberries, cherries, wild berries, alone or in mixes with apples.

Grading of Marmalades

Three categories can be defined:

- Fine marmalade, manufactured from one fruit;
- Superior marmalade, obtained from a mix of fruit in which 30% are "noble" species (cherries, strawberries, apricots, etc.) and 70% from other species;
- Marmalade from fruit mixes; apples, pears, plums, quinces, ungrafted apricots and wax cherries may be used, with the optional addition of "superior" fruit which was rejected at sorting but which was sound.

The content in total soluble substances (refractometric extract) of marmalades must be 64% minimum; the acidity must be between 0.5% and 1.8% expressed as malic acid.

Basic Recipe Setting For a normal composition - marmalade without pectin addition the following is a basic recipe:

100 kg semi-processed fruit product

(10% refractometric extract) .... 10 kg soluble substances

55 kg sugar .... 55 kg soluble substances

155 kg 65 kg soluble substances

55 kg water to be evaporated

100 kg marmalade with 65% refractometric extract

This marmalade satisfies many standards and at same time has a good shelf-life since it contains less than 35% water. Semi-processed fruit products must have a minimum 8% refractometric extract; in this case the recipe should use 125 kg of raw material, with 80 kg water to be evaporate.

The use of semi-processed fruit products with a low refractometric extract presents the following drawbacks:

a. Higher water quantity to be evaporated;
b. Longer boiling times with negative impact of pectin degradation;
c. Loss of flavour and
d. Lower equipment efficiency.

Pectin addition in marmalade manufacture produces the following advantages:

a. Improvement of gelification,
b. Economy in fruit;
c. Shorter boiling time; this maintains taste and flavour and produces higher equipment efficiency.

Pectin addition makes it possible to obtain the "fine" type of marmalade from "noble" fruits which do not contain enough pectin (cherries, peaches, apricots, etc.). In marmalades from fruit mixes, low pectin content can be compensated by addition of semi-processed fruit products which are rich in this component (for example apples).

When pectin is to be added, the above recipe should be modified as follows:

80 kg semi-processed fruit product

(10% refractometric extract) .... 8 kg soluble substances

55 kg sugar .... 55 kg soluble substances

10 kg pectic extract (10 % R.E.) .... 1 kg soluble substances

145 kg 64 kg soluble substances

45 kg water to be evaporated

100 kg marmalade with 64% refractometric extract

Pectin can be added as pectic extract with about 10% refractometric extract (R.E.) in the recommended proportion or in the form of a powder considered with 100% dry matter (e.g. 100% soluble substances) in a quantity of about 1%.

In some countries it is usual to add 5-12% of corn syrup (calculated to finished product weight) to replace the corresponding quantity of sugar (100 parts corn syrup can replace 80 parts sugar). Corn syrup has to be liquefied by heating before use. Corn syrup addition reduces the too sweet taste of marmalade, avoids sugar crystallisation and gives a special shine to finished products.

Marmalade manufacturing follows the technological line drawing in Fig. 8.6.1 and covers the following steps:

"MARK" Preparation can be achieved from fresh fruits (as indicated in the section related to semi-processed fruit products) or starting from chemical preserved semiprocessed fruit products: "marks" or "pulps". In the latter case, pulps will be processed in marks which then will be desulphitated.

Desulphitation is carried out by boiling at atmospheric pressure, under vacuum in specialised equipment or under pressure in special retorts built in acid-resistant material. In any case, the desulphitation must be carried out before sugar addition because sugar will bound to the sulphur dioxide. The desulphitation operation must be conducted so as to be, if possible, fully completed; the finished product must contain less than 0.005% free SO_2.

The technological flow for marmalade production is the following: fresh fruit after sorting on control belt (1) is washed in a washing machine (2) is brought to the continuous boiling equipment (3) then to the pulper (4); the semi-finished mark is passed on to the storage tank (6). Pulps are boiled and desulphited in continuous boiling equipment (3), then are brought to pulper (4) and to the storage tank (6).

Boiling aims at evaporating the required water quantity, to facilitate the formation of pectin-sugar-acid gel and to partially invert sugar (about 40% from total sugar). The boiling operation can be carried out in open kettles or in evaporators under vacuum.

In the latter case, the warm "mark" from storage tank (6) is aspirated in a concentrator (7) in a vacuum and submitted to a partial boiling up to removal of half of water quantity which needs to be evaporated; the calculated sugar quantity is then added by aspiration, keeping the boiling on.

After this the pectin extract or powder pectin which has previously been dissolved in warm water, is added; when the final concentration is reached, as indicated by refractometric control, the required quantity of acid is added. Sugar is added in proportion of 55% in finished product, pectic extract (10% refractometric extract) at a level of about 10-15% and the acid (citric, tartaric, lactic) in a quantity needed to obtain a finished product acidity of about 1%.

Boiling at atmospheric pressure affects not only the appearance but also the nutritional value of the products, mainly if these contain proteins, as some albuminoids coagulate even at 60°C.

Food products for which flavour is an essential property as for example fruit juices, etc., are also affected by the action of heat. Heat treatment has an impact on vitamin losses, mainly of vitamin C, in the presence of oxygen as is the case at concentration in open vessels.

Sugars are generally less damaged by heat at temperatures below 100° C; as the boiling point is increasing above 100° C, a risk of partial sugar caramelization exists. In the study of heat effects on products submitted to concentration operation, it is necessary to take into account not only the evaporation surface temperature but also the distribution of the temperature in the whole liquid mass.

The length of the heating period also has a major influence because in many cases it is preferable to concentrate the liquid at a relatively high temperature in a short time avoiding the drawbacks of lower temperatures acting during a long time.

In order to maintain the food value and organoleptic properties, it is necessary that concentration take place at a low temperature which can be achieved by concentration under partial vacuum, taking into account that boiling point decreases when the residual pressure decreases, respectively with the increase of vacuum degree.

Advantage of concentration under partial vacuum are the following:

- Lowering of boiling point;
- The total time needed for concentration of food products under a residual pressure of about 200 mm Hg is about half as compared to the that of concentration by boiling at atmospheric pressure;
- By lowering the concentration temperature and time, organoleptic properties and of nutritional value are maintained better particularly as far as the vitamins are concerned;
- When products are concentrated in a vacuum, it is possible to recover volatile aromatic substances by using adequate installations.

Technical procedures of concentration by vaporisation can be classified in:

a. Concentration at atmospheric pressure: continuous or discontinuous;

b. Concentration under partial vacuum: discontinuous (in vacuum equipment with simple or multiple effect) or continuous (in vacuum installations with continuous action or in thin film vaporisation installations).

Even if open kettle equipment is less expensive than evaporators in a vacuum, it is necessary to take into account that boiling under vacuum has the following advantages:

a. Low boiling temperature (60-70° C), depending the degree of the vacuum; this give the fruit better taste and flavour-keeping qualities;
b. Easy feeding with raw and auxiliary materials;
c. Shorter boiling time;
d. Better working conditions (vapour elimination in condensed water and not in open air).

There are small size evaporators under vacuum which can be well suited to the needs of medium size operations in developing countries.

Cooling of marmalade to about 50-60°C can even be done in a vacuum evaporator by closing the heating steam and maintaining vacuum degree or by discharge in storage tanks (8).

Filling in receptacles (boxes, jars, glasses, etc.) is done preferably with filling machines (9) followed by labelling(10). Small packages can be closed warm or after complete cooling; big packages (boxes, etc.) must be closed only after cooling, e.g. 24 hours after processing.

STORAGE of marmalade must be done in dry rooms (air relative humidity at about 75%), well ventilated, medium cool places (temperature 10-20 degrees C), disinfected and away from direct sunlight and heat. These measures are necessary because marmalade is a hydroscopic product and, by water absorption, favourable conditions for mould development are created.

Technology of Special Fruit Jams

Special fruit jams are products similar to marmalades but in which fruit partially keep their shape (whole, halves, etc.).

Special fruit jams are obtained by boiling fruit with sugar, with or without pectin addition, with acid addition followed by n concentration by evaporation.

Special fruit jams present a pronounced gelification at their cooling and can be considered as fruits included in a pectin-sugar-acid gel.

High quality special fruit jams are obtained only from fresh fruit or possibly frozen and from only one fruit species.

Special fruit jams are classified in:

a. Non-pasteurized (min. 68% refractometric extract) and
b. Pasteurized (min. 65% refractometric extract); minimum acidity, expressed in malic acid, is 0.5%.

Basic Recipe Seting is done taking into account following elements: - maintenance, as much as possible, of fruit shape, because this is specific to these finished products;

- Added sugar, in relation to finished product, must be at 60-65%; this high percentage is needed in order to obtain a rapid and strong gelification and to facilitate conservation of fruit shape;
- A satisfactory gelification cannot generally be obtained without pectin addition, at a level of 1-2%, or respectively 10-20% pectic extract (10% refractometric extract);
- Partial (about 40%) inversion of added sugar is necessary.

The basic recipe is: 80 kg fruit + 100 kg sugar + 1.6-2.0 kg pectin powder and 1 kg citric or tartric acid; this will yield about 165 kg of special fruit jam with 60% added sugar; water quantity to be evaporated is about 18 kg. If the finished product has to contain 65 % added sugar, the boiling has to be continued up to evaporation of about 30 kg water, the resulting finished product quantity will be about 153 kg.

Technological flow sheet for manufacturing of special fruit jams is as follows:

Fruit Preparation: sorting, washing, peeling and coring (for apples, pears, quinces), or removal of quetches and stones/

pits (for plums, peaches, apricots, cherries) or of short tails (for strawberries and wild berries). Pomace fruits are then cut in slices or quarters.

Boiling with sugar is the most important operation in production of special fruit jams and has as objective to evaporate water until gel formation and partial inversion of sugar. Boiling has to be conducted in such a way as to avoid fruit disintegration, but fruits must be well penetrated with sugar.

By boiling an equilibrium is reached, by osmosis, between sugar solution and cellular juice. The initial concentration gap between sugar syrup and cellular juice is very high and if the equilibration process is forced, juice comes out of cells and fruit loses its shape and may even disintegrate.

The boiling process accelerates the equilibration, intensity of which increases with temperature and boiling time.

Pectin addition shortens boiling and thus delays the equilibration; for this reason there are different methods for special fruit jams preparation:

- Maintaining fruit in sugar, at ambient temperature, over 8-24 hours; fruit to sugar ratio is that indicated in recipe. After this sugar impregnation, fruits and resulting sugar syrup are brought together to boil; toward the end of boiling, pectin, dissolved in warm water, and necessary acid quantity are added.
- Preparation of a very concentrated sugar syrup (at least 75%), in which fruit is introduced in order to be boiled. The rest of the operations are similar to those described in the previous method.
  - Soft fruit (strawberries, wild berries) can be mixed with sugar directly in evaporating open kettles, without added water and then heated gradually up to boiling, which is continued as in previous method.

Boiling is preferably carried out in small open kettles (50-100 kg) in order to avoid too long a boiling and fruit disintegration.

Gelification corresponds generally to the reaching of a concentration of 65% soluble extract, respectively 68% refractometric extract. Practical test for gelification is done as for jellies and marmalades.

Cooling is a technological step strictly necessary in order to avoid fruit rising to the surface in preservation receptacles. Cooling is done in a double bottomed water bath in which water circulates at about 80° C.

Filling of receptacles (jars, boxes, glasses, etc.) is carried out and it is necessary to assure at this stage that the finished product is homogeneous (equal quantities of fruits and gel).

Pasteurization is only applied to special fruit jams with 65 % refractometric extract packed in jars or boxes and is performed at about 100° C for about 20 min.

Gelification is carried out during product cooling and intensifies during storage.

Storage must follow the same conditions as for marmalades.

Non Eelified Sugar Fruit Preserves

Technology of Fruit Jams

Fruit jams are products obtained by boiling of fruits (whole, halves, etc.) with sugar syrup until the reaching a viscous consistency. Jams can be defined as fruits included in a concentrated syrup.

Jams are only prepared from fresh fruits; the usual product range covers the following species: strawberries, cherries, apricots, wild berries, peaches, plums, raisins, quinces, rose petals, etc.; manufacturing of jams from fruit mixes is not an accepted practice. Standards indicate that fruit jams have to conform with following conditions:

- Fruit or fruit pieces content 45-55%;
- Soluble substances, refractometric degree min. 72%;
- Acidity (expressed in malic acid) min. 0.7%.

Basic Recipe Setting is presented below as an indication:

100 kg fruits

150 kg sugar

250 kg

35 kg water to be evaporated

215 kg jam at about 72% refractometric extract

Fruit preparation is similar to special fruit jams with the difference that stone/seed removal is mandatory for all species.

Boiling Fruits with Sugar can be achieved by the same three methods described above for special fruit jams. By boiling a sugar content equilibration is foreseen and the operation must be conducted in such a way that texture, flavour and colour of fruits be preserved. Foam/scum has to be removed during boiling.

Generally boiling in concentrated sugar syrup (at least 75%) after a previous diffusion during 2-4 hours is in practical use. Boiling must to be carried out in small portions (about 15 kg) in order to avoid fruit disintegration.

For some fruit species, boiling has to be conducted in many phases/steps with "stops" to enable sugar diffusion. At the end of boiling, vanillin at a ratio of 125 g for 100 kg jam may be added for some fruits (white cherries, raisins, etc.). At the same time, it is also possible to add citric or tartric acid in order to avoid the "sugaring" defect.

Cooling of jams, necessary in order to avoid fruit rising to the surface, is carried out as for special fruit jams.

Filling of receptacles and Storage for jams are performed in same way as for special fruit jams.

Technology of Special non Gelified Fruit Marmalades

Special non gelified fruit marmalades are products resulting from fruit without stones or seeds, sieved or squashed, concentrated by boiling, without sugar added and non gelified. Their consistency results from a low water content (about 35%) and a high percentage of insoluble substances (5-10%). Sugar the from fruits acts as a preserving agent.

Plum special non gelified fruit n armalade is the product representative of this category. Other fruit is used very rarely, because they have a reduced sugar content as compared to plums; though there are some countries producing special non gelified fruit marmalade from pears or sweet apples.

For plums, the finished product in this category must contain minimum 55-60% soluble substances (refractometric extract), rising up to 70% for a high quality product.

Basoc Reco[e Settomg for plums is done in relation with sugar content of fruits; when this is higher, the product quality is better and the yield is higher. Thus, if plums with 18% refractometric extract are used, 300-350 kg of fruits are needed for 100 kg finished product.

At the same time, concentration of sugar by boiling, also increases by three fold acidity and astringency of this special plum non gelified marmalade; for this reason it is recommended to use only sweet and completely mature plums.

Washing is performed in usual conditions.

Pre-Boiling of fruits can be carried out in water or vapour, preferably with continuous running and has as its objective the softening of tissues.

De-Stoning is performed in a pulper.

Boiling of the sieved mass is done in double bottom open kettles with a big evaporation surface or in vacuum evaporators.

Boiling in open kettles enables production of a more tasty slightly caramelized, product; boiling in vacuum evaporators has the technological advantages indicated in marmalade production.

At the end of boiling and once of necessary concentration is reached, the product is poured directly into receptacles (drums, etc.) and left to cool in order to form a hard surface layer (crust).

Storage of well closed receptacles is carried out as for marmalade.

Special non gelified fruit marmalade can also be prepared from chemically preserved semi-processed fruit products, but the quality is lower than that obtained from fresh fruits.

Sometimes dried prunes in a mix with preserved semi-processed products can be used for plum special non gelified marmalade preparation.

In some countries plum finished products in this category are sweetened by the addition of maximum 30% sugar, calculated in relation to the finished product.

Technology of Fruit Pastes

These products are obtained in a similar way to marmalades and special non gelified marmalades, but have a lower water content (about 25%). Reduction of water content can be achieved by continuing the boiling of the product or by natural or artificial drying.

A typical example of fruit paste without sugar added is the apricot paste - "pistil", etc. which is a concentrated special non gelified fruit marmalade poured in thin layers and sun dried. An example of fruit paste with sugar added is quince paste which is a marmalade concentrated by evaporation. Sugar content must be 65%; soluble substances content, 7075 % refractometric extract and acidity at least 0.5% expressed as malic acid. Packing is done usually in polyethylene sheets and then in boxes or tins; storage conditions are similar to those for marmalade.

Technology of Fruit Syrups

Fruit syrups are products obtained by dissolving sugar in juices obtained from direct pressing of fruits. Sugar dissolving can be done at room temperature or by heating.

Syrups have to contain 68% soluble substances (refractometric extract) and minimum 1 g/100 ml malic acid. Up to a maximum 10% of sugar can be replaced by corn syrup. Syrups must be manufactured from the juice of only one fruit species.

Juice preparation is carried out at room temperature as described above.

Sugar dissolving in fruit juice can be performed by one of the following methods:

a. Boiling in open kettles, done by using the basic recipe:

   350-400 kg fruit juice; 650-660 kg sugar; max. 10 kg citric or tartric acid.

   The juice is brought to boiling and the sugar is dissolved; the total time has to be as short as possible in order to avoid flavour loss and a too high sugar inversion degree (optimum inversion degree is 40%). Acid is added preferably towards the end of boiling.

   During all boiling processes it is necessary to remove foam/scum. In order to avoid caramelization, the syrup has to be cooled rapidly, and this can be carried out in baths with double bottoms through which are circulated water.

   One alternative to this method is to boil syrup in closed vessels to avoid flavour losses.

b. Boiling in a vacuum. The basic recipe is the same as above. Sugar and fruit juice are mixed previously in a pre-heating kettle and then transported to vacuum equipment.

   Boiling is performed at 50°C and at the end the temperature is raised slowly up to 65-70°C. The syrup can be cooled directly in vacuum equipment by closing the steam inlet and by increasing the vacuum. In this boiling method it is possible to incorporate a flavour recuperation device.

c. A continuous process for syrup preparation can be carried out by dissolving components with heat while passing them through a horizontal cylinder with a screw inside.

   In the methods where sugar is dissolved by heat, it is also possible to use chemically preserved juices.

In this case it is necessary to first perform the desulphitation of juices preserved with SO_2. This can be performed by boiling juice with optional water addition (and before any sugar addition). High quality syrups are obtained however from fresh juices.

d. Sugar can also be dissolved at room temperature by using continuous flow percolators. These are similar to those used for salt solution preparation in vegetable canning processes. The juice goes over a sugar layer and is concentrated progressively until saturation (about 65 %). The syrup is then passed through a filtration section in the bottom of the percolator.

Syrup filtration is needed in order to clarify crystals; the filtration of syrup is done in warm conditions through cloth.

Filling of syrup in bottles is done in aseptic conditions as much as possible in order to avoid syrup infection with osmophile yeasts.

Syrup preservation is assured by the high sugar content with respect to a low water activity [unclear].

Storage takes place in well ventilated storage rooms; avoiding sunlight at 10-15°C.

The usual product range is: strawberries, cherries, wild berries, citrus fruits.

Technology of "Fruit in Syrup" Products

This type of product is represented by fruit (whole, halves or pieces) covered by a sugar solution and preserved by pasteurization. In these products sugar does not have a preservation effect but only a sweetening role.

Technological general flow-sheet covers the following steps:

Sorting is necessary in order to choose mature fruit, whole, unblemished, undamaged and with a specific texture. Fruit of good quality but with a texture not compatible with this type of finished product are used for the production of semi-processed products, marmalades, etc. This step is done manually on a sorting belt.

Washing is performed in equipment with fan and sprays.

Cleaning covers removal of leaves, etc., skin removal by one of the described methods for some fruits and coring/pitting for others.

Cutting is applied only to pomace fruits and is performed preferably by mechanical means.

Preliminary Heat Treatment depends very much upon the fruit types and can be as different as a light blanching up to a real boiling; this step is aimed toward softening of tissues for hard fruits, elimination of waxy pruin layer (plums, etc.) or enzyme inactivation for pomace fruits.

This treatment has to be reduced to the minimum necessary in order to avoid sugar losses. Some fruit (for example apricots, black cherries, grapes, etc.) does not undergo preliminary heat treatment.

Cooling is carried out in water (as cold as possible) and should not be too long to avoid soluble substances loss.

Receptacle filling Fruit is introduced manually or sometimes mechanically (filling tables, etc.) in receptacles and then sugar syrup is added.

Sugar syrup preparation is performed by dissolving crystal sugar in hot water (90100° C). After the sugar has been dissolved, the syrup is boiled briefly; removal of impurities and coagulated substances is then performed by foaming/ scumming. An addition of about 0.3% citric acid helps syrup clarification, followed by filtration through cloth.

Preheating/Emptying of open receptacles has as its objective to eliminate air from fruit tissues and this step is largely replaced today by receptacle closing under vacuum. Preheating may be done in steam or in water in such a way that syrup temperature reaches 8090°C and is maintained for 10-15 min.

Hermetic sealing is performed according to the type of receptacle and of cover/cap.

Pasteurization is carried out at 100°C and may be performed in continuous installations or in normal water baths. In some countries fruits in syrup are pasteurized at 80-90°C; this contributes to a greater flavour retention.

Cooling should be intensive in order to avoid discolourations and colour modifications and to reduce corrosion in metal cans.

Refractometric extract is to be measured 30 days after manufacturing. In order to establish exact concentration of sugar syrup to be added in each individual case it is possible to use the following formula:

$$C = 1.5 \times [(2 \times E) - F]$$

C = added syrup concentration;

E = refractometric extract needed in finished products, according to Table 8.6.3.

F = fruit refractometric extract.

Hot syrup is put into receptacles with a minimum temperature of 80°C in order to enable a corresponding vacuum after cooling.

It is possible to add in the syrup 0.3-0.5% citric or tartaric acid for fruit with a low acidity. Adding ascorbic acid in proportion of 0.8% assures colour maintenance and taste improvement based on its reducing action.

Avoidance of excessively soft texture in finished products may be achieved for soft fruit (strawberries, apricots, etc.) by dipping fruit in a solution of calcium chloride (5% $CaCl_2$ in water).

Finished product defects and production "accidents" for "Fruit in syrup" and the means of preventing them

- Change of colour in red fruit (red cherries, plums, etc.) to violet; to avoid this it is necessary to use glass jars or varnished/lacquered tinplate;
- Colour change to red for pears and quinces (pink shade) could arise in products which are over-pasteurized and insufficiently cooled;

- Change of colour of whole peaches peeled by chemical means is due to an incomplete inactivation of oxidative enzymes; to avoid this it is necessary to boil fruit after chemical peeling followed by washing with 0.5% citric or tartric acid solutions or by adding ascorbic acid in syrup;
- Softening of strawberries tissues can be prevented by a pre-treatment with warm syrup and also by addition of calcium salt.

Some technical data for processing are seen in Table given below.

Table: Technical Data for "Fruits in Syrup"

Type of fruit/ product RE** at name	Size/shape	Minimum fruit (in syrup), content, %	Soluble substances 20°C, minimum
Apricots	Halves	55	25
Strawberries	Whole	47	25
Cherries	Whole	53	22
Quinces	Slices, 30 mm	50	26
Apples	Halves or quarters	47	25
Pears	Halves or quarters	57	22
Plums	Whole	45	25
Melon	Pieces	55	26
Wax cherries	Whole	53	27
Wild cherries	Whole	47	27
Pineapple	Slices	55	26
Mangos	Pieces	50	25
Papaya	Pieces	55	27
Fruit mixes	According to the conditions indicated above, for each fruit	50	25

Fruit Juice Technologies

Fruit juices are products for direct consumption and are obtained by the extraction of cellular juice from fruit, this operation can be done by pressing or by diffusion.

For the purpose of this document, the technology of fruit juice processing will cover two finished product categories:

- juices without pulp ("clarified" or "not clarified");
- juices with pulp ("nectars").

We will also define as

a. "natural juices" products obtained from one fruit; and
b. "mixed juices" products obtained from the mix of two or three juices from different fruit species or by adding sugar.

Juices obtained by removal of a major part of their water content by vacuum evaporation or fractional freezing will be defined as "concentrated juices".

Technological Steps for Processing of Fruit Juices without Pulp

Fruit juices must be prepared from sound, mature fruit only. Soft fruit varieties such as grapes, tomatoes and peaches should only be transported in clean boxes which are free from mould and bits of rotten fruit.

Washing: fruit must be thoroughly washed. Generally, fruit will be submitted to a pre-washing before sorting and a washing step just after sorting.

Sorting: removal of partially or completely decayed fruit is the most important operation in the preparation of fruit for production of first quality fruit juices; sorting is carried out on moving inspection belts or sorting tables.

Crushing/Grinding/Disinteration Step is applied in different ways and depends on fruit types:

Crushing for grapes and berries;

Grinding for apples, pears;

Disintegration for tomatoes, peaches, mangoes, apricots.

This processing step will need specific equipment which differs from one type of operation to another.

Enzyme Treatment of crushed fruit mass is applied to some fruits by adding 2-8% pectolitic enzymes at about 50° C for 30 minutes.

This optional step has the following advantages: extraction yield will be improved, the juice colour is better fixed and finished product taste is improved.

However, for fruit which is naturally rich in pectic substances, this treatment makes the resulting "exhausted" material useless for industrial pectin production.

Heating of crushed fruit mass before juice extraction is an optional step used for some fruit in order to facilitate pressing and colour fixing; at same time, protein coagulation takes place.

Pressing to extract juice.

Diffusion is an alternative step for juice extraction and can be carried out discontinuously or in batteries at water temperature of about 80-85 ° C.

Juice clarifying can be performed by centrifugation or by enzyme treatment. Centrifugation achieves a separation of particles in suspension in the juice and can be considered as a pre-clarifying step. This operation is carried out in centrifugal separators with a speed of 6000 to 6500 RPM.

Enzyme clarifying is based on pectic substance hydrolysis; this will decrease the juices' viscosity and facilitate their filtration. The treatment is the addition of pectolitic enzyme preparations in a quantity of 0.5 to 2 g/l and will last 2 to 6 hours at room temperature, or less than 2 hours at 50° C, a temperature that must not be exceeded.

The control of this operation is done by checking the decrease in juice viscosity. Sometimes, the enzyme clarifying is completed with the step called "sticking" by the addition of 5-8 g/hl of food grade gelatine which generates a flocculation of particles in suspension by the action of tannins.

Filtration of clarified juice can be carried out with kieselgur and bentonite as filtration additive in press-filters (equipment).

De-Tartarisationis applied only to raisin juice and is aimed to eliminate potassium bitartrate from solution. This step can be performed by the addition of 1% calcium lactate or 0.4% calcium carbonate.

Pasteurization of juice can be done for temporary preservation (pre-pasteurization) and in this case this operation is carried out with continuous equipment (heat exchangers, etc.); warm juice is stored in drums or large size receptacles (20-30 kg). Pasteurization conditions are at 75°C in continuous stream.

Pasteurization of bottled juice is then carried out just before delivery to the market; this is performed in water baths at 75° C until the point where the juice reaches 68° C. In cases when the final pasteurization is done without pre-pasteurization and temporary storage, modern methods use a rapid pasteurization followed by aseptic filling in receptacles.

Rapid pasteurization conditions are as follows: temperature about 80° C, over 10-60 sec., followed by cooling; all operations are carried out in continuous stream.

Preservation under CO_2 pressure may be done at a concentration of 1.5% CO_2 under a pressure of 7 kg/cm^2. At the distribution step, proceed at CO_2 decompression and the juice is then submitted to a sterilising filtration and aseptic filling in receptacles.

Preservation by freezing is carried out at about -30° C, after a preliminary de-aeration; storage is at -15 to -20° C.

Production of concentrated juices by evaporation is performed under vacuum (less than 100 mm Hg residual pressure) up to a concentration of 65-70% total sugar which assures preservation without further pasteurization. Modern evaporation installations recover flavours from juices which are then reincorporated in concentrated juices.

Additional operations for juice manufacturing are the vacuum de-aeration and mixing with other fruit juices or with sugar. For the production of non clarified juices the centrifugation is the only specific step, enzyme clarifying and subsequent filtration being eliminated. The optimum sugar/acid ratio for the majority of fruit, mainly for pomaces, is 10/1 to 15/1.

Fruit which is rich in carotenoids (apricots, peaches, etc.) is only processed as juices with pulp ("nectars").

Technological Flow-sheet for Fruit Juices with Pulp ("Nectars")

This process is divided at industrial scale in two categories of operations:

a. Processing for obtaining juices;
b. Juice conditioning for preservation.

a. Operations in the first category are differ according to the type of fruit which to be processed.

Pomaces (apples, pears) are washed and sorted and then crushed in a colloid mill; fruit purée is then passed through a screw type heating equipment where direct steam is used as a source of heat. Warm fruit mass is treated in a pulper with a 2 mm screen and then through an extractor similar with the equipment used for tomato juice.

Stone fruits (apricots, peaches, cherries, etc.) after washing and sorting are submitted to steam in a continuous heater, then the warm fruit mass is passed through a pulper and then an extractor (as mentioned above). Berries (strawberry, wild berries, etc.) are washed, sorted and then crushed, preheated and then introduced in extractor.

In order to avoid browning and undesirable taste modifications it is usual to add about 0.05% ascorbic acid.

b. Second category type of operations are similar for all fruit species. Partial elimination of cellulose is achieved with a continuous centrifugal separator; the resulting juice is then processed in order to adjust sugar and acid content for viscosity.

Sugar (about 8-10%) is added as a syrup (in water or in the juice of same fruit obtained by pressure). Acidity is adjusted with citric or tartaric acid. The adjusted juice is then deaerated under vacuum at about 40° C. This step aims at avoiding oxidative reactions and vitamin C loss reduction.

An important subsequent step is an intensive homogenisation (under pressure at 150-180 A) in order to obtain particles with dimensions below 100. The homogenised juice obtained is then continuously pasteurized in plate heat exchanger equipment at a temperature of about 130° C, cooled down to about 90° C and aseptically packed in receptacles.

The principal characteristics of fruit "nectars" are uniformity and stability of the content provided by the advanced disintegration of fruits. Stability can be obtained by increasing product viscosity by adding pectin for fruit which is deficient in this component. In order to avoid "separation", intensive homogenisation is carried out as described above.

Fruit "nectars" contain all the important components of the original fruit and to a large extent maintain their taste and flavour. The sugar/acidity (as citric acid) ratio is to a large extent determined by the type of fruit and the correction applied; for example, this ratio is 30 for apricots, 40 for peaches, 160 for pears, etc.

BANANA AND PLANTAIN PROCESSING TECHNOLOGIES

Traditional Processing

Products: Uses and Dietary Significance

Most of the world's bananas are eaten either raw, in the ripe state, or as a cooked vegetable, and only a very small proportion are processed in order to obtain a storable product. This is true both at a traditional village level with both dessert and cooking bananas and when considering the international trade in dessert bananas.

In general, preserved products do not contribute significantly to the diet; however, in some localised areas the products are important in periods when food are scarce. Probably the most widespread and important product is flour preparation from unripe banana and plantains by sun-drying.

In Uganda, dried slices known as "mutere" are prepared for storage from green bananas, the dried slices being either used directly for cooking or after grinding into a flour. "Mutere" is used chiefly as a famine reserve and does not feature largely in the diet under normal conditions.

In Gabon, plantains are sometimes made into dried slices which can be stored and used on long journeys, and plantains are used in Cameroon to prepare dried pieces which are stored and ground as needed into flour for use in cooking a paste known as "fufu". Dried green banana slices are also used in parts of South and Central America and West Indies for preparing flour.

The other nutritionally important product is beer which is a major product in Uganda, Rwanda and Burundi where green banana utilisation is particularly high.

Preservation Methods and Processes

Drying

Both ripe and unripe bananas and plantains are normally peeled and sliced before drying, although banana figs are sometimes prepared from whole ripe fruit. Sun drying is the most widespread technique where the climate is suitable but drying in ovens or over fires is also practiced. In west Africa, plantains are often soaked and sometimes parboiled before drying. The slices of unripe fruit are normally spread out on bamboo frameworks; or a cemented area; or on a mat; or on a swept-bare patch of earth; or on a roof; or sometimes on stones outcrops or sheets of corrugated iron.

Oven-drying of ripe bananas is practiced in Polynesia as a mean of preserving the fruits, which are then wrapped in leaves and bound tightly to store until needed. In East Africa a method has been reported that involves drying the peeled bananas on a frame placed over a fire for 24 hr before drying in the sun, to accelerate the process.

Product Stability and Storage Problems

There is little experimental data on the storage life of the traditionally made banana and plantain products.

Potential for Scaling up of Traditional Processes to Industrial Level

Many banana products are now produced on an industrial scale, including the traditional banana figs and flour, and the processing techniques are described below. One of the main problems encountered has been the susceptibility of banana products to flavour deterioration and discolouration and in the past many products reaching the market have been of poor quality.

A great deal of research has been directed to overcoming these problems, although however good the resultant products are they cannot compare in flavour and other characteristics with the fresh banana fruit. Indeed, an important constraint on the large-scale development of banana processing is the lack of demand for banana products since the fresh fruit is available throughout the year in most parts of the tropical world.

The production of beer from banana and plantains has not been scaled up to an industrial level, and while an important product in localised areas of tropical Africa, the market is rapidly declining in favour of European-type brews produced locally.

Industrial Processing

Products and Uses

The main commercial products made from bananas are canned or frozen purée, dried figs, banana powder, flour, flakes, chips (crisps), canned slices and jams. Banana products can be divided roughly into two types - those for direct consumption, such as figs, and those for use in food manufacturing industry, for example purées and powder.

Banana figs, or fingers as they are sometimes known, are usually whole, peeled fruit carefully dried so as to retain their shape, although sometimes the fruit is sliced or halved to facilitate drying. Banana and plantain chips (crisps) are thinly sliced pieces of fruit fried in oil and eaten as a snack like potato chips (crisps).

The main use of canned slices is in tropical fruit salads. Banana flakes are used as a flavouring or in breakfast cereals. Banana purée find use mainly in the production of baby foods. Banana flour is said to be highly digestible and is used in baby and invalid foods, but can also be used in the preparation of bread and beverages. Banana powder is used chiefly in the baking industry for the preparation and fillings for cakes and biscuits and is also used for invalid and baby foods.

Processing Technology

In general, to obtain a good-quality product from ripe-bananas the fruit is harvested green and ripened artificially under controlled conditions at the processing factory. After ripening, the banana hands are washed to remove dirt and any spray residues, and peeled. Peeling is almost always done by hand using stainless steel knives, although a mechanical peeler for ripe bananas has been developed, capable of peeling 450 Kg of fruit per hour (Banana Bulletin, 1974).

The peeling of unripe bananas and plantains is facilitated by immersing the fruit in hot water. For example, immersion in water at 70-75 ° C for 5 min. has been suggested as an aid for peeling green bananas for flour production, while the peeling of green bananas for freezing has been facilitated by immersion in water at 93° C for 30 min.

Banana Figs

Fully ripe fruits with a sugar content of about 19.5% are used and are treated with sulphurous acid after peeling, then dried as soon as possible afterwards. Various drying systems have been described using temperatures between 50 and 82° C for 10 to 24 hr to give a moisture content ranging from 8 to 18% and a yield of dried figs of 12 to 17% of the fresh banana on the stem.

One factory in Australia uses a solar heat collector on the roof to augment the heat used for drying bananas. Bananas can also be dried by osmotic dehydration, using a technique which involves drawing water from 1/4-in. thick banana by placing them in a sugar solution of 67 to 70 deg. Brix for 8 to

10 hr. followed by vacuum-drying at 65 to 70° C, at a vacuum of 10 mm Hg for 5 hr. The moisture content of the final products is 2.5% or less, much lower than that achieved by other methods.

Banana Puree

Banana purée is obtained by pulping peeled, ripe bananas and then preserving the pulp by one of three methods: canning aseptically, acidification followed by normal canning, or quick-freezing. The bulk of the world's purée is processed by the aseptic canning technique. Peeled, ripe fruits are conveyed to a pump which forces them through a plate with 1/4-in. holes, then onto a homogeniser, followed by a centrifugal de-aerator, and into a receiving tank with 29in. vacuum, where the removal of air helps prevent discolouration by oxidation.

The purée is then passed through a series of scraped surface heat exchangers where it is sterilised by steam, partially cooled, and finally brought to filling temperature. The sterilised purée is then packed aseptically into steam-sterilised cans which are closed in a steam atmosphere.

Banana Slices

Several methods for canning of banana slices in syrup are used. Best-quality slices are obtained from fruit at an early stage of ripeness. The slices are processed in a syrup of 25 deg. Brix with pH about 4.2, and in some processes calcium chloride (0.2%) or calcium lactate (0.5%) are added as firming agents.

A method for producing an intermediate-moisture banana product for sale in flexible laminate pouches has been developed. Banana slices are blanched and equilibrated in a solution containing glycerol (42.5%), sucrose (14.85%), potassium sorbate (0.45%), and potassium metabisulphite (0.2%) at 90 deg. C for 3 min. to give a moisture content of 30.2%.

Banana Powder

In the manufacture of banana powder, fully ripe banana pulp is converted into a paste by passing through a chopper followed by a colloid mill. A 1 or 2 % sodium metabisulphite solution is added to improve the colour of the final product. Spray- or drum-drying may be used, the latter being favoured as all the solids are recovered.

A typical spray dryer can produce 70 kg powder per hour to give yields of 8 to 11% of the fresh fruit, while drum-drying gives a final yield of about 13% of the fresh fruit. In the latter method the moisture content is reduced to 8 to 12 % and then further decreased to 2 % by drying in a tunnel or cabinet dryer at 60° C.

Banana Flour

Production of flour has been carried out by peeling and slicing green fruit, exposure to sulphur dioxide gas, then drying in a counter-current tunnel dryer for 7 to 8 hr. with an inlet temperature of 75° C and outlet temperature of 45° C, to a moisture content of 8%, and finally milling.

Banana Chips (Crisps)

Typically, unripe peeled bananas are thinly sliced, immersed in a sodium or potassium metabisulphite solution, fried in hydrogenated oil at 180 to 200° C, and dusted with salt and an antioxidant.

Alternatively, slices may be dried before frying and the antioxidant and salt added with the oil. Similar processes for producing plantain chips have been developed.

Banana Beverages

In a typical process, peeled ripe fruit is cut into pieces, blanched for 2 min. in steam, pulped and pectolytic enzyme added at a concentration of 2 g enzyme per 1 kg pulp, then held at 60 to 65° C and 2.7 to 5.5 pH for 30 min.

In a simpler method, lime is used to eliminate the pectin. Calcium oxide (0.5%) is added to the pulp and after standing for 15 min. this is neutralised giving a yield of up to 88% of a clear, attractive juice. In another process banana pulp is acidified, and steam-blanched in a 28-in Hg vacuum which ensures disintegration and enzyme inactivation. The pulp is then conveyed to a screw press, the resulting purée diluted in the ratio 1:3 with water, and the pH adjusted by further addition of citric acid to 4.2 to 4.3, which yields an attractive drink when this is centrifuged and sweetened.

Jam

A small amount of jam is made commercially by boiling equal quantities of fruit and sugar together with water and lemon juice, lime juice or citric acid, until setting point is reached.

Product Stability and Spoilage Problems

All dried banana products are very hydroscopic and susceptible to flavour deterioration and discolouration, but this can be overcome to some extent by storing in moisture-proof containers and sulphiting the fruit before drying to inactivate the oxidases.

The dried products are also liable to attack by insects and moulds if not stored in dry conditions, although disinfestation after drying by heating for 1 hr to 80° C or by fumigation with methyl bromide ensures protection against attack. Banana powder is said to be stored for up to a year commercially and flakes have been stored in vacuum-sealed cans with no deterioration in moisture, colour or flavour for 12 months.

Banana chips tend to have a poor storage life and to become soft and rancid. However, chips treated with an antioxidant have been stored satisfactorily at room temperature in hermetically sealed containers up to 6 months with no development of rancidity.

Quality Control Methods

In general a good quality product is obtained if fruit is harvested at the correct stage of maturity and, where appropriate, ripened under controlled conditions. For example, in the case of banana figs, the fruit should be fully mature (sugar content of 19.5% or above) or the final. Alternatively, slices may be dried before frying and the antioxidant and salt added with the oil. Similar processes for producing plantain chips have been developed.

Banana Beverages

In a typical process, peeled ripe fruit is cut into pieces, blanched for 2 min. in steam, pulped and pectolytic enzyme added at a concentration of 2 g enzyme per 1 kg pulp, then held at 60 to 65° C and 2.7 to 5.5 pH for 30 min.

In a simpler method, lime is used to eliminate the pectin. Calcium oxide (0.5%) is added to the pulp and after standing for 15 min. this is neutralised giving a yield of up to 88% of a clear, attractive juice. In another process banana pulp is acidified, and steam-blanched in a 28-in Hg vacuum which ensures disintegration and enzyme inactivation. The pulp is then conveyed to a screw press, the resulting purée diluted in the ratio 1:3 with water, and the pH adjusted by further addition of citric acid to 4.2 to 4.3, which yields an attractive drink when this is centrifuged and sweetened.

Jam

A small amount of jam is made commercially by boiling equal quantities of fruit and sugar together with water and lemon juice, lime juice or citric acid, until setting point is reached.

Product Stability and Spoilage Problems

All dried banana products are very hydroscopic and susceptible to flavour deterioration and discolouration, but this can be overcome to some extent by storing in moisture-proof containers and sulphiting the fruit before drying to inactivate the oxidases.

The dried products are also liable to attack by insects and moulds if not stored in dry conditions, although disinfestation after drying by heating for 1 hr to 80° C or by fumigation with methyl bromide ensures protection against attack. Banana powder is said to be stored for up to a year commercially and flakes have been stored in vacuum-sealed cans with no deterioration in moisture, colour or flavour for 12 months.

Banana chips tend to have a poor storage life and to become soft and rancid. However, chips treated with an antioxidant have been stored satisfactorily at room temperature in hermetically sealed containers up to 6 months with no development of rancidity.

Quality Control Methods

In general a good quality product is obtained if fruit is harvested at the correct stage of maturity and, where appropriate, ripened under controlled conditions. For example, in the case of banana figs, the fruit should be fully mature (sugar content of 19.5% or above) or the final product is liable to be tough and lacking in flavour. However, if over-ripe fruit is used, the figs tend to be sticky and dark in colour, so the fruit must be fully yellow but still firm.

For banana flour, which is prepared from unripe bananas, the fruit is harvested at three-quarters the full-ripe stage and is processed within 24 hr. prior to the onset of ripening. If less mature fruit is used, the flour tastes slightly astringent and bitter due to the tannin content. Bananas harvested between 85 and 95 days after the emergence of the inflorescence, with a pulp-to-peel ratio of about 1.7, were considered to be most suitable for the deep-fat frying.

Other criteria suggested for assessing maturity were beta-carotene and reducing sugar content, both of which increase with increasing maturity and pH which decreases as the fruit ripens, and these should be, respectively, about 2000 μg/100 g, less than 1.5% and 5.8 or above. Browning was found to occur if the sugar content was higher than 1.5%. The determination of crude fat in processed chips is also considered to be a necessary quality control measure. It is important to remove all impurities prior to processing of products, and this is done by washing to remove dirt and spray residues and control on the processing line so that substandard fruit can be removed.

Preparation Methods for Fresh Bananas and Plantains

The main ways of preparing fresh bananas for consumption are boiling or steaming, roasting or baking and frying. Boiling followed by pounding into "fufu" is also widely adopted in certain areas of the tropics.

Boiling or Steaming

Plantains and bananas are often prepared simply by boiling in water, either in their peel or after peeling, and either ripe or unripe; if unripe, the fruit is scraped thoroughly after peeling to remove all traces of fibrous material. The boiled fruit is eaten alone or more usually accompanied by a sauce. This preparation technique is widely used in West Africa.

Roasting or Baking

Unpeeled or peeled fruit, either ripe or unripe, is roasted simply by placing in the ashes of a fire or in an oven. This method is widely used in West Africa, East Africa and the South Pacific islands. For example, ripe plantains are placed unpeeled in an oven and when partly brown and tender, removed and peeled, then replaced in the oven and roasted evenly.

Frying

Ripe or unripe plantains or bananas are often peeled, sliced and cooked in oil, particularly in West Africa and in parts of South America and the West Indies. Similar products are also made in East Africa. Typically, ripe plantains are peeled, cut into slices or split lengthways, and fried in palm oil or with groundnut oil, the pieces being served either hot with a sauce or with fried eggs, or cold as a snack.

Pounding

Pounding is a process, used particularly in West Africa, for preparing most perishable staple food crops including plantains, cassava, yams and cocoyams to obtain a paste or dough known as "fufu" (also spelled "foofoo", "foutou", "foufou"). The plantains are peeled or boiled and peeled after boiling and pounded in a wooden mortar, the resulting paste normally being eaten with soup or a spiced sauce of meat and vegetables, but sometimes after wrapping in leaves and steaming.

MANGO AND GUAVA PROCESSING TECHNOLOGIES

Mango Processing Technologies

Mangoes are processed at two stages of maturity. Green fruit is used to make chutney, pickles, curries and dehydrated products. The green fruit should be freshly picked from the tree. Fruit that is bruised, damaged, or that has prematurely fallen to the ground should not be used. Ripe mangoes are processed as canned and frozen slices, purée, juices, nectar and various dried products. Mangoes are processed into many other products for home use and by cottage industry.

The mango processing presents many problems as far as industrialization and market expansion is concerned. The trees are alternate bearing and the fruit has a short storage life; these factors make it difficult to process the crop in a continuous and regular way. The large number of varieties with their various attributes and deficiencies affects the quality and uniformity of processed products.

The lack of simple, reliable methods for determining the stage of maturity of varieties for processing also affects the quality of the finished products. Many of the processed products require peeled or peeled and sliced fruit. The lack of mechanised equipment for the peeling of ripe mangoes is a serious bottleneck for increasing the production of these products.

A significant problem in developing mechanised equipment is the large number of varieties available and their different sizes and shapes. The cost of processed mango products is also too expensive for the general population in the areas where most mangoes are grown. There is, however, a considerable export potential to developed countries but in these countries the processed mango products must compete with established processed fruits of high quality and relatively low cost.

Green Mango Processing

Pickles

The optimum stage of maturity should be determined for each variety used to make pickles. There are two classifications of pickles - salt pickles and oil pickles. They are processed from whole and sliced fruit with and without stones. Salt is used in most pickles.

The many kinds of pickles vary mainly in the proportions and kinds of spices used in their preparation. One basic recipe for the study of the preparation and storage of pickles in oil is as follows:

Mango pieces	250 g	**Tumeric powder**	2 to 4 g
Salt	60 g	**Fenugreek seeds**	2 to 4 g
Mustard powder	30 g	**Bengal gram seeds**	2 to 4 g
Chili powder	20 g	**Gingelly oil**	20 to 30 g

The ingredients are mixed together and filled into wide-mouthed bottles of 0.5 kg capacity. Three days later the contents are thoroughly mixed and refilled into the bottles. Extra oil is added to form a 1-2 cm layer over the pickles.

Chutney

The product is prepared from peeled, sliced or grated unripe or semi-ripe fruit by cooking the shredded fruit with salt over medium heat for 5 to 7 minutes, mixed and then sugar, spices and vinegar are added. Cook over moderate heat until the product resembles a thick purée, add remaining ingredients and simmer another 5 min. Cool and preserve in sterilised jars.

Spices usually include cumin seeds, ground cloves, cinnamon, chili powder, ginger and nutmeg. Other ingredients such as dried fruits, onions, garlic and nuts may be added.

Drying/dehydration. immature fruit is peeled and sliced for sun-drying. The dried mango slices can be powdered to make a product called amchoo. The use of blanching, sulphuring and mechanical dehydration gives a product with better colour, nutrition, storability and fewer microbiological problems.

Ripe Mango Processing

Puree

Mangoes are processed into purée for re-manufacturing into products such as nectar, juice, squash, jam, jelly and dehydrated products. The purée can be preserved by chemical means, or frozen, or canned and stored in barrels. This allows a supply of raw materials during the remainder of the year when fresh mangoes are not available.

It also provides a more economical means of storage compared with the cost of storing the finished products, except for those which are dehydrated, and provides for more orderly processing during peak availability of fresh mangoes.

Mangoes can be processed into purée from whole or peeled fruit. Because of the time and cost of peeling, this step is best avoided but with some varieties it may be necessary to avoid off-flavours which may be present in the skin. The most common way of removing the skin is hand-peeling with knives but this is time-consuming and expensive. Steam and lyepeeling have been accomplished for some varieties.

Several methods have been devised to remove the pulp from the fresh ripe mangoes without hand-peeling. A simplified method is as follows: the whole mangoes were exposed to atmospheric steam for 2 to 2 1/2 min in a loosely covered chamber, then transferred to a stainless steel tank.

The steam-softened skins allowed the fruit to be pulped by a power stirrer fitted with a saw-toothed propeller blade mounted 12.7 to 15.2 cm below a regular propeller blade. The pulp is removed from the seeds by a continuous centrifuge designed for use in passion fruit extraction. The pulp material is then passed through a paddle pulper fitted with a 0.084 cm screen to remove fibre and small pieces of pulp.

Mango purée can be frozen, canned or stored in barrels for later processing. In all these cases, heating is necessary to preserve the quality of the mango purée. In one process, purée is pumped through a plate heat exchanger and heated to 90°C for 1 min and cooled to 35° C before being filled into 30 lb tins with polyethylene liners and frozen at -23.50 C.

In an other process, pulp is acidified to pH 3.5, pasteurized at 90°C, and hot-filled into 6 kg high-density bulk polyethylene containers that have been previously sterilised with boiling water. The containers are then sealed and cooled in water. This makes it possible to avoid the high cost of cans.

Wooden barrels may be used to store mango pulp in the manufacture of jams and squashes. The pulp is acidified with 0.5 to 1.0% citric acid, heated to boiling, cooled, and SO2 is added at a level of 1000 to 1500 ppm in the pulp. The pulp is then filled into barrels for future use.

Slices

Mango slices can be preserved by canning or freezing, and recent studies have shown the feasibility of pasteurized-refrigerated and dehydro-canned slices. The quality of the processed product in all of these procedures will be dependent upon selection of a suitable variety along with good processing procedures. Thermal process canning of mango slices in syrup is the most widely used preservation method.

Beverages

The commercial beverages are juice, nectar and squash. Mango nectar and juice contain mango purée, sugar, water and citric acid in various proportions depending on local taste, government standards of identity, pH control, and fruit composition of the variety used. Mango squash in addition to the above may contain SO2 or sodium benzoate as a preservative. Other food grade additives such as ascorbic acid, food colouring, or thickeners may be used in mango beverages.

A short description of finished products found in literature is as follows:

- Mango juice: prepared by mixing equal quantities of pulp (purée) and water together and adjusting the total soluble solids (TSS) and acidity to taste (12 to 15% TSS and 0.4 to 0.5% acidity as citric acid);

- Mango nectar containing 25% purée can be prepared using the following procedure.

	Brix of puree		
Nectar components	15°	17°	20°
Purée	100	100	100
Sugar	45	43	40
Water	255	257	260

Commercial processing conditions may require the use of a preservative.

The pH is adjusted to approximately 3.5 by adding citric acid as a 50% solution.

The time of heat processing will vary with filling temperature, can size and viscosity of the juice or nectar.

Mango squash may be prepared according to flow-sheet described below; the finished product may contain 25% juice, 45% TSS and 1.2 to 1.5% acidity and may be preserved with sulphur dioxide (350ppm) or sodium benzoate (1000 ppm) in glass bottles.

Mango squash simplified flow-sheet.

Ingredients

Mango pulp	900	900
Sugar	900	1100
Citric acid	18	15
Water	900	900

Mangoes are washed, stored, peeled with stainless steel knives. The pulp is prepared by using a pulper with fine sieve (0.025-in); Sugar is mixed with water and citric acid = syrup; The pulp is added to the syrup and mixed well; The mixture is strained trough cloth; The squash is heated at 85° C and bottles are filled and closed.

For additional heat treatment bottles may need to be maintained at a product temperature of 80°C for 30 minutes if the product is to be processed without preservatives. The bottles are then left to cool in water and stored at room temperature.

Two negative points must be avoided: presence of air bubbles (which is a source of quick deterioration) and separation of squash solids (giving an undesirable appearance). The means to avoid these two phenomena are described in the fruit juices section.

A type of "squash type" beverage may also be manufactured with '/a pulp + '/a water + i/a sugar and pH adjusted to 3.7 by addition of citric acid. Using different sieve sizes affects the quality and reduces air bubbles to a certain extent but homogenisation and de-aeration of purée or squash seem to be important in order to avoid separation and air bubbles. The squash quality is evaluated on the basis of the following characteristics: pH, titrable acidity, soluble solids, ascorbic acid (by 2,6 dichlorophenol indophenol method), specific gravity.

Dried/Dehydrated

Ripe mangoes are dried in the form of pieces, powders, and flakes. Drying procedures such as sun-drying, tunnel dehydration, vacuum-drying, osmotic dehydration may be used. Packaged and stored properly, dried mango products are stable and nutritious.

One described process involves as pre-treatment dipping mango slices for 18 hr (ratio 1:1) in a solution containing 40° Brix sugar, 3000 ppm SO_2, 0.2% ascorbic acid and 1% citric acid; this method is described as producing the best dehydrated product. Drying is described using an electric cabinet through flow dryer operated at 60° C. The product showed no browning after 1 year of storage.

Drum-drying of mango purée is described as an efficient, economical process for producing dried mango powder and flakes. Its major drawback is that the severity of heat preprocessing can produce undesirable cooked flavours and aromas in the dried product. The drum-dried products are also extremely hydroscopic and the use of in-package desiccant is recommended during storage.

Canning

This preservation technology is described in various technological flow-sheets in this bulletin. Mango bar or "fruit leather" is presented in various flow-sheets.

Guava Processing Technologies

Guava Puree

Guava purée is used in the manufacture of guava nectar, various juice drink blends and in the preparation of guava jam. The washed sound fruit is first passed through a chopper or slicer to break up the fruit and this material is fed into a pulper. The pulper will remove the seeds and fibrous pieces of tissue and force the reminder of the product through a perforated stainless steel screen. The holes in the screen should be between 0.033 and 0.045 in. The machine should be fed at a constant rate to ensure efficient operation.

The puréed material coming from the pulper is next passed through a finisher. The finisher is equipped with a screen containing holes of approximately 0.020 in. The finisher will remove the stone cells from the fruit and provide the optimum consistency to the product.

Perhaps the best way to preserve the guava purée is by freezing and the material passing through the finisher can be packaged and frozen with no further treatment. It is not necessary to heat the product to inactivate enzymes or for other purposes. The material can be frozen in a number of types of cartons and cans; however, a fibre box with a plastic bag inside is commonly used and is probably the less expensive.

It is also possible to can and heat process the guava purée and this can be accomplished by heating the purée to 195° F in an open double bottom kettle, filling into cans, closing the cans, inverting the cans for a few seconds, followed by cooling. Cans should be cooled rapidly to approximately 100° F before they are cased and stacked into warehouses.

Guava Juice and Concentrate

Guava juice can be used in the manufacture of a clear guava jelly or in various drinks. A clear juice may be prepared from guava purée that is depectinised enzymatically. About 0.1% pectin-degrading enzyme is mixed into the purée at room temperature; heating of the product at approximately 120° F will greatly speed the action of the enzyme. After 1 hr. clear juice is separated from the red pulp by centrifuging or by pressing in a hydraulic juice press. A batch-type or continuous-flow centrifuge can be used on the depectinised purée with no further treatment.

The clear juice after centrifuge or after press (and subsequent filtration) can be preserved by freezing or by pasteurization in hermetically sealed cans. For shipment to overseas markets it may be advantageous to concentrate either the purée or the juice.

RECENT TRENDS IN FRUIT AND VEGETABLE PROCESSING

New Products

The number and variety of fruit and vegetable products available to the consumer has increased substantially in recent years. The fruit and vegetable industry has undoubtedly benefited from the increased recognition and emphasis on the importance of these products in a healthy diet.

Traditional processing and preservation technologies such as heating, freezing and drying together with the more recent commercial introduction of chilling continue to provide the consumer with increased choice. This has been achieved by new heating (e.g. UHT, microwave, ohmic) and freezing (e.g. cryogenic) techniques combined with new packaging materials and technologies (e.g. aseptic, modified atmosphere packaging).

The overall trend in new fruit and vegetable products is "added value", thus providing increased convenience to the consumer by having much greater variety of ready prepared fruit and vegetable products. These may comprise complete meals or individual components. The suitability of products and packages for microwave re-heating has been an important factor with respect to added convenience.

Fruit and vegetable product trends

Heat processed products

1. Canned fruits and vegetables
   - Combination of vegetables in sauces and vegetable recipe dishes. Exotic fruits.
2. Glass packed fruits and vegetables
   - "Condiverde"/"antipasti" products based on vegetables in oil.
   - High quality fruit packs.
3. Retortable plastics
   - Basic vegetables or vegetable meals
   - Fruit in jelly
4. Aseptic cartons
   - Ready made jelly
5. Rosti meals
   - Potato based products in retort pouches
6. Fruit juices
   - New combinations of juices and freshly squeezed products
7. Crisps
   - Thick and crunch skin-on crisps. Kettle or pan fried chips. Lower fat crisps.

Table: Numbers of New Fruit and Vegetable Products

	1990	1991	1992 Jan-June
Frozen vegetable products	66	95	21
Chilled vegetable products	76	81	78
Heat processed vegetables	51	60	38
Heat processed fruits	13	14	5
Fruit juices and drinks	73	83	46
Potato crisps	32	33	16

New product development in the fruit and vegetable sector is most important in meeting the continued challenge of providing the consumer with choice and high quality products.

A Fresh Look at Dried Fruit

New fruit varieties and advance in drying technologies are putting a fresh twist on dried fruit applications. Fruits that have been introduced to the drying process include cranberries, blueberries, cherries, apples, raspberries and strawberries - not to mention the traditional mainstays of raisins, dates, apricots, peaches, prunes and figs.

Perceived as a "value-added" ingredient, dried fruit adds flavour, colour, texture and diversity with little alteration to an existing formula. The growing interest in ethnic cuisines in U.S.A. and the change to a more healthy way of eating, has also moved dried fruit considerably closer to the mainstream.

Found primarily in the baking industry, dried fruit is coming into its own in various food products, including entrees, side dishes and condiments. Compotes, chutneys, rice and grain dishes, stuffings, sauces, breads, muffins, cookies, deserts, cereals and snacks are all food categories encompassing dried fruit.

Since some dried fruit is sugar infused (osmotic drying), food processors can decrease the amount of sugar in formula - this is especially the case in baked products. Processors are making adjustments in moisture content of the dried fruit so that a varied range is available for different applications. An added bonus is dried fruits' shelf stability (a shelf life of at least 12 months). Dried fruit is more widely available in different forms, including whole dried, cut, diced and powders.

Citric Acid and its Use in Fruit and Vegetable Processing

Citric acid may be considered as "Nature's acidulant". It is found in the tissues of almost all plants and animals, as well as many yeasts and moulds. Commercially citric acid is manufactured under controlled fermentation conditions that produce citric acid as a metabolic intermediate from naturally-occurring yeasts, moulds and nutrients. The recovery process of citric acid is through crystallization from aqueous solutions.

Citric acid is widely used in carbonated and still beverages, to impart a fresh-fruit "tanginess". Citric acid provides uniform acidity, and its light fruity character blends well and enhances fruit juices, resulting in improved palatability. The amount of citric acid used depends on the particular desired flavour (e.g., High-acid: lemonade; Medium-acid: orange, punch, cherry; Low-acid: strawberry, black cherry, grape).

Sodium citrate is often added to beverages to mellow the tart taste of high acid concentrations. It provides a cool, distinctive smooth taste and masks any bitter aftertaste of artificial sweeteners. In addition, it serves as a buffer to stabilise the pH at the desired level. The high water solubility of citric acid (181 g/100 ml) makes it an ideal additive for fountain fruit syrups and beverages concentrates as a flavour enhancer and microbial growth inhibitor (preferably at pH < 4.6).

In processed fruits and vegetables, citric acid performs the following functions:

a. It reduces heat-processing requirements by lowering pH: inhibition of microbial growth is a function of pH and heat treatment. Higher heat exposure and lower pH result in greater inhibition. Thus the use of citric acid to bring pH below 4.6 can reduce the heating requirements. In canned vegetables, citric acid usage is greatest in tomatoes, onions and pimentos. For tomato packs, the National Canners Association recommends a pH of 4.1 to 4.3. In general, 0. 1% citric acid will reduce the pH of canned tomatoes by 0.2 pH units

b. Optimise flavour: citric acid is added to canned fruits to provide for adequate tartness. Recommended usage level is generally less then 0.15%.

c. Supplement antioxidant poter tial: citric acid is used in conjunction with antioxidants such as ascorbic and erythorbic acids, to inhibit colour and flavour deterioration caused by metal-catalysed enzymatic oxidation. Recommended usage levels are generally 0.1% to 0.3% with the antioxidant at 100 to 200 ppm.

d. Inactivate undesirable enzymes: oxidative browning in most fruits and vegetables is catalysed by the naturally present polyphenol oxidase. The enzymatic activity is strongly dependent on pH.

   Addition of citric acid to reduce pH below 3 will result in inactivation of this enzyme and prevention of browning reactions.

Cherry and Apricot Oils are Safe for Food Use

The oils obtained by cold pressing the kernels of the cherry (Prunus cerasus) and the apricot (Prunus armeniaca) have been declared acceptable for food use by the UK Ministry of Agriculture, Fisheries & Food's Advisory Committee on Novel Foods and Processes (ACNFP) by June 1993.

In its assessments of the safety in use of the cherry and apricot kernel oils, the ACNFP consider specifications that included data on fatty acid composition, the presence of natural antioxidants and the content of cyanide, mycotoxins and heavy metals.

The Committee says that it gave particular consideration to the possible presence in the oils of the cyanogenic glucoside amygdalin, from which cyanide is released by enzymic action when the kernels of cherry and apricot are crushed. Amygdalin was found to be absent from the cherry and apricot kernel oils.

The ACNFP is satisfied that there are no food safety reasons why the use of cherry and apricot kernel should not be acceptable provided there is compliance with the specifications shown in Table given below.

Table: Specification of Purity for Cherry and Apricot Kernel Oils as Determined by UK ACNFP

	Cherry	Apricot
Contaminants limits:		
Heavy metals (total)	0.5 mg/kg	0.5 mg/kg
Aflatoxins (total)	4.0 g/kg	4.0 g/kg
Cyanide	0.15 mg/kg	0.15 mg/kg
Pesticide residues	0.01 mg/kg	0.01 mg/kg
Tocopherols:		
Alpha/delta/gamma (mg/kg)	356-886	569-899

The oils are obtained by the mechanical mincing and cold pressing of kernels extracted from cleaned cherry or apricot stones. After filtering, the oils are stored and are to be sold in a raw, unrefined state.

The cherry and apricot kernel oils are high unsaturated and are expected to be used as speciality oils for salad dressings, baking and shallow frying applications.

The Use of Fruit Juices in Confectionery Products

During the last decade, the concept of fruit juices has gained immensely on consumer popularity. The majority of new non-alcoholic and alcoholic fruit drink products were a combination of syrups, fruit juices and flavours.

The confectionery industry followed suit and new products incorporated fruit juices as part of their confectionery formulations and processes. Fruit juice concentrates of high solids are often used instead of normal or single-fold juices.

Juice concentrates are made of pure fruit juices. The process starts with pressing fruits and obtaining pure fruit juice; this is stabilised by heat treatment which inactivates enzymes and micro-organisms.

The next processing step is concentration under vacuum up to 40-65° Brix or 4-7 fold. The concentrates are then blended for standardisation and stored.

These fruit juice concentrates are often further stabilised by the addition of sodium benzoate and potassium sorbate and are usually stored away from light and are refrigerated or frozen.

Depectinised fruit juices are also used to prevent foaming in confectionery processes and are essential for use in clear beverage products. Fruit juice concentrates which are depectinised, and have added preservatives are called stabilised, clarified, fruit juice concentrates.

Fruit juices are used in confectionery products in conjunction with natural and artificial flavours which provides intense flavour impact and are cost-effective for a confectionery product.

The traditional concern in using fruit juice concentrates in confectionery applications has been the effect of the natural acids on the finished product, particularly the formation of invert sugar during processing.

This is a logical concern since concentrates contain differing amounts and types of acids. For example: apple, cherry, strawberry and other berries contain primarily malic acid. Grapes mainly contain tartaric acid. Cranberry is high in quinic acid. Citrus fruits and pineapple contain differing amounts of citric acid. The concentrates, when used, are normally buffered to a pH of 5-7 with sodium hydroxide.

In formulating products with fruit juice concentrates, the solids of the concentrate are considered as mostly reducing sugars and a reduction in corn syrup is made to compensate for equivalent amount of reducing sugar being added in the concentrate.

The exact replacement can be determined by measuring the D.E. of the concentrate to be added. In formulations when small amounts of concentrate are used (less than 1%), no adjustment is made since the reducing sugar contribution of the concentrate is not significant.

Fruit juice concentrates can also be used to provide a source of natural colour, in particular red colour. Grape, raspberry, cherry, strawberry and cranberry concentrates in small amounts are very effective in colouring cream centres.

The inclusion of fruit juices in confectionery products is now left up to the imagination of the manufacturer. These products must, of course, hold up to the standards of flavour integrity, and product excellence, during the shelf-life of these products.

9

Vegetable Specific Processing Technologies

VEGETABLES VARIETIES

Vegetable processors must appreciate the substantial differences that varieties of a given vegetable will possess. In addition to variety and genetic strain differences with respect to weather, insect and disease resistance, varieties of a given vegetable will differ in size, shape, time of maturity, and resistance to physical damage.

Varietal differences then further extend into warehouse storage stability, and suitability for such processing methods as canning, freezing, pickling or drying. A variety of peas that is suitable for canning may be quite unsatisfactory for freezing and varieties of potatoes that are preferred for freezing may be less satisfactory for drying or potato chip manufacture.

This should be expected since different varieties of a given vegetable will vary somewhat in chemical composition, cellular structure and biological activity of their enzyme system.

HARVESTING AND PRE-PROCESSING

When vegetables are maturing in the field they are changing from day to day. There is a time when the vegetable will be at peak quality from the stand-point of colour, texture and flavour. This peak quality is quick in passing and may last only a day. Harvesting and processing of several vegetables, including tomatoes, corn and peas are rigidly scheduled to capture this peak quality.

After the vegetable is harvested it may quickly pass beyond the peak quality condition. This is independent of microbiological spoilage; these main deteriorations are related to:

a. Loss of sugars due to their consumption during respiration or their conversion to starch; losses are slower under refrigeration but there is still a great change in vegetable sweetness and freshness of flavour within 2 or 3 days;

b. Production of heat when large stockpiles of vegetables are transported or held prior to processing.

At room temperature some vegetables will liberate heat at a rate of 127,000 kJ/ton/day; this is enough for each ton of vegetables to melt 363 kg of ice per day. Since the heat further deteriorates the vegetables and speeds micro-organisms growth, the harvested vegetables must be cooled if not processed immediately.

But cooling only slows down the rate of deterioration, it does not prevent it, and vegetables differ in their resistance to cold storage. Each vegetable has its optimum cold storage temperature which may be between about 0-100 C (32-500 F).

c. The continual loss of water by harvested vegetables due to transpiration, respiration and physical drying of cut surfaces results in wilting of leafy vegetables, loss of plumpness of fleshy vegetables and loss of weight of both.

Moisture loss cannot be completely and effectively prevented by hermetic packaging. This was tried with plastic bags for fresh vegetables in supermarkets but the bags became moisture fogged, and deterioration of certain vegetables was accelerated because of buildup of CO_2 and decrease of oxygen in the package. It therefore is common to perforate such bags to prevent these defects as well as to minimise high humidity in the package which would encourage microbial growth.

Shippers of fresh vegetables and vegetable processors, whether they can, freeze, dehydrate, or manufacture soups or ketchup, appreciate the instability and perishability of vegetables and so do everything they can to minimise delays in processing of the fresh product. In many processing plants it is common practice to process vegetables immediately as they are received from the field.

To ensure a steady supply of top quality produce during the harvesting period the large food processors will employ trained field men; they will advise on growing practices and on spacing of plantings so that vegetables will mature and can be harvested in rhythm with the processing plant capabilities. This minimises stockpiling and need for storage.

Cooling of vegetables in the field is common practice in some areas. Liquid nitrogen-cooled trucks may next provide transportation of fresh produce to the processing plant or directly to market. Upon arrival of vegetables at the processing centre the usual operations of cleaning, grading, peeling, cutting and the like are performed using a moderate amount of equipment but a good deal of hand labour also still remains.

Reception

This covers qualitative and quantitative control of delivered vegetables. The organoleptic control and the evaluation of the sanitary state, even if they are very important steps in vegetables' characteristics assessment, cannot establish their technological value.

On the other hand, laboratory controls do not precisely establish their technological properties because of the difficulty in putting into showing some deterioration when using rapid control methods.

One correct method of vegetable quality appraisal is their overall evaluation based on the whole complex of data that can be obtained by combining an extensive organoleptic evaluation with simple analysis that can be performed rapidly in plant laboratory. These analysis can be:

a. Refractometric extract (tomatoes, fruit, etc.);
b. Specific weight (potatoes, peas, etc.);
c. Consistency (measured with tenderometres, penetrometres, etc.);
d. Boiling tests, etc.

Temporary Storage

This step should be as short as possible and better completely eliminated. Vegetables can be stored in:

a. Simple stores, without artificial cooling;
b. In refrigerated stores; or, in some cases,
c. In silos (potatoes, etc.).

Simple stores should be covered, fairly cool, dry and well ventilated but without forced air circulation which can induce significant losses in weight through intensive water evaporation; air relative humidity should be at about 70-80%.

Refrigerated storage is always preferable and in all cases a processing centre needs a cold room for this purpose, adapted in volume I capacity to the types and quantities of vegetables (and fruits) that are further processed.

Washing

Washing is used not only to remove field soil and surface micro-organisms but also to remove fungicides, insecticides and other pesticides, since there are laws specifying maximum levels of these materials that may be retained on the vegetable; and in most cases the allowable residual level is virtually zero. Washing water contains detergents or other sanitisers that can essentially completely remove these residues.

The washing equipment, like all equipment subsequently used, will depend upon the size, shape and fragility of the particular kind of vegetable:

- Flotation cleaner for peas and other small vegetables;
- Rotary washer in which vegetables are tumbled while they are sprayed with jets of water; this type of washer should not be used to clean fragile vegetables;

Sorting

This step covers two separate operations:

a. Removal of non-standard vegetables (and fruit) and possible foreign bodies remaining after washing;

b. Quality grading based on variety, dimensional, organoleptical and maturity stage criterion.

Skin Removal/Peeling

Some vegetables require skin removal. This can be done in various ways.

a. Mechanical

This type of operation is performed with various types of equipment which depend upon the result expected and the characteristics of the fruit and vegetables, for example:

i. A machine with abrasion device (potatoes, root vegetables);

ii. Equipment with knives (apples, pears, potatoes, etc.);

iii. Equipment with rotating sieve drums (root vegetables). Sometimes this operation is simultaneous with washing (potatoes, carrots, etc.) or preceded by blanching (carrots).

b. Chemical

Skins can be softened from the underlying tissues by submerging vegetables in hot alkali solution. Lye may be used at a concentration of about 0.5-3%, at about 93° C (2000 F) for a short time period (0.5-3 min). The vegetables with loosened skins are then conveyed under high velocity jets of water which wash away the skins and residual lye.

In order to avoid enzymatic browning, this chemical peeling is followed by a short boiling in water or an immersion in diluted citric acid solutions.

It is more difficult to peel potatoes with this method because it is necessary to dissolve the cutin and this requires more concentrated lye solutions, up to 10%.

c. Thermal

Wet Heat (Steam)

Other vegetables with thick skins such as beets, potatoes, carrots and sweet potatoes may be peeled with steam under pressure (about 10 at) as they pass through cylindrical vessels. This softens the skin and the underlying tissue. When the pressure is suddenly released, steam under the skin expands and causes the skin to puff and crack. The skins are then washed away with jets of water at high pressure (up to 12 at).

Dry Heat (Flame)

Other vegetables such as onions and peppers are best skinned by exposing them to direct flame (about 1 min at 1000° C) or to hot gases in rotary tube flame peelers. Here too, heat causes steam to develop under skins and puff them so that they can be washed away with water.

Manual peeling only use when the other methods are impossible or sometimes as a completion of the other three ways. Average losses at this step are given in Table 9.2.1.

Table: Losses at Vegetable Peeling, in %

	Peeling methods		
Vegetables	**Manual**	**Mechanical**	**Chemical**
Potatoes	15-19	18-28	-
Carrots	13-15	16-18	8-10
Beets	1416	13-15	9-10

Size Reduction

This step is applied according to specific vegetable and processing technology requirements.

Blanching

The special heat treatment to inactivate enzymes is known as blanching. Blanching is not indiscriminate heating. Too little is ineffective, and too much damages the vegetables by excessive cooking, especially where the fresh character of the vegetable is subsequently to be preserved by processing.

This heat treatment is applied according to and depends upon the specificity of vegetables, the objectives that are followed and the subsequent processing/preservation methods.

Two of the more heat resistant enzymes important in vegetables are catalase and peroxidase. If these are destroyed then the other significant enzymes in vegetables also will have been inactivated. The heat treatment to destroy catalase and peroxidase in different vegetables are known, and sensitive chemical tests have been developed to detect the amounts of these enzymes that might survive a blanching treatment.

Because various types of vegetables differ in size, shape, heat conductivity, and the natural levels of their enzymes, blanching treatments have to be established on an experimental basis. As with sterilisation of foods in cans, the larger the food item the longer it takes for heat to reach the centre. Small vegetables may be adequately blanched in boiling water in a minute or two, large vegetables may require several minutes.

Blanching as a unit operation is a short time heating in water at temperatures of 100° C or below. Water blanching may be performed in double bottom kettles, in special baths with conveyor belts or in modern continuous blanching equipment.

In order to reduce losses of hydrosoluble substances (mineral salts, vitamins, sugars, etc.) occurring during water blanching, several methods have been developed:

- Temperature setting at 85-95° C instead of 100° C;
- Blanching time has to be just sufficient to inactivate enzymes catalase and peroxidase;
- Assure elimination of air from tissues.

An illustration of blanching parametres is seen in Table given below.

Table: Blanching Parametres for Some Vegetables

Vegetables	Temperature, °C	Time, min.
Peas	85-90	2-7
Green beans	90-95	2-5
Cauliflower	Boiling	2
Carrots	90	3-5
Peppers	90	3

Steam heat treatment can also be applied instead of water blanching as a preliminary step before freezing or drying, as long as the preservation method is only used for enzyme inactivation and not to modify consistency.

For drying, the vegetables are conveyed directly from steaming equipment to drying installations without cooling. Vegetable steaming is carried out in continuous installations with conveyer belts made from metallic sieves.

Cooling of vegetables after water blanching or steaming is performed in order to avoid excessive softening of the tissues and has to follow immediately after these operations; one exception is the case of vegetables for drying which can be transferred directly to drying equipment without cooling.

Natural cooling is not recommended because is too long and generates significant losses in vitamin C content. Cooling in pre-cooled air (from special installations) is sometimes used for vegetables that will be frozen

Cooling in water can be achieved by sprays or by immersion; in any case the vegetables have to reach a temperature value under 37° C as soon as possible. Too long a cooling time generates supplementary losses in valuable hydrosoluble substances; in order to avoid this, the temperature of the cooling water has to be as low as possible.

Canning

Large quantities of vegetable products are canned. A typical flow sheet for a vegetable canning operation (which also applies to fruit for the most part) covers some food process unit operations performed in sequence: harvesting; receiving;

washing; grading; heat blanching; peeling and coring; can filling; removal of air under vacuum; sealing/closing, retorting/heat treatment; cooling; labelling and packing. The vegetable may be canned whole, diced, puréed, as juice and so on.

On-line Simplified Methods for Enzyme Activity Check

Peroxidase test:

a. Solutions. In order to check the peroxidase activity two solutions have to be prepared:
   - 1% guaiacol in alcohol solution (1 g guaiacol is dissolved in about 50 cm^3 of 96% ethylic alcohol and then this preparation is brought to 100 cm° with the same solvent);
   - Peroxide solution 0.3% (1 cm^3 perhydrol is brought to 100 cm^3 with distilled water.

b. Sampling. From various parts of the material samples are taken (about 20-30 pieces, etc.); the material is then crushed in a laboratory bowl in order to obtain an average sample.

c. Check. Prom the average sample, 10-20 g of material is taken in a medium capacity test tube; on this sample are poured: 20 cm^3 distilled water; 1 cm^3 of 1% guaiacol solution; 1.6 cm^3 of peroxide solution.

The contents of the test tube is shaken well. The gradual appearance of a weak pink colour indicates an incomplete peroxidase inactivation - reaction slightly positive.

If there are no tissue colour modifications after 5 minutes, the reaction is negative and the enzymes have been inactivated.

As an orientative check it is also possible to simply pour a few drops of 1% guaiacol solution and 0.3% peroxide solution directly on blanched and crushed vegetables. A rapid and intensive brown-reddish tissue colouring indicates a high peroxidase activity (positive reaction).

Catalase Test

In order to identify the catalase enzyme activity, 2 g of dehydrated vegetables are well crushed and mixed with about 20 cm^3 of distilled water. After 15 min softening, 0.5 cm^3 of a 0.5% or 1% peroxide solution is poured on prepared vegetables. In the presence of catalase, a strong oxygen generation is observed for about 2-3 minutes.

These tests are of a paramount importance in order to determine the vegetable blanching treatments (temperature and time); incomplete enzyme inactivation has a negative effect on finished product quality.

For cabbage catalase inactivation by blanching is sufficient; blanching further to peroxidase inactivation would have negative effects on product quality and even complete browning. For all other vegetables and for potatoes, both tests MUST be negative, for catalase and for peroxidase.

FRESH VEGETABLE STORAGE

The vegetables can be stored, in some specific natural conditions, in fresh state, that is without significant modifications of their initial organoleptic properties. Fresh vegetable storage can be short term; this was briefly covered under temporary storage before processing. Also fresh vegetable storage can be long term during the cold season in some countries and in this case it is an important method for vegetable preservation in the natural state.

In order to assure preservation in long term storage, it is necessary to reduce respiration and transpiration intensity to a minimum possible; this can be achieved by:

a. Maintenance of as low a temperature as possible (down to 0° C),
b. Air relative humidity increased up to 85-95 % and
c. CO_2 percentage in air related to the vegetable species.

Vegetables for storage must conform to following conditions: they must be of one of the autumn or winter type variety; be at edible maturity without going past this stage; be harvested during dry days; be protected from rain, sun heat or wind; be in a sound state and clean from soil; be undamaged.

From the time of harvest and during all the period of their storage vegetables are subject to respiration and transpiration and this is on account of their reserve substances and water content. The more the intensity of these two natural processes are reduced, the longer sound storage time will be and the more losses will be reduced.

For this reason, vegetables have to be handled and transported as soon as possible in the storage conditions (optimal temperature and air relative humidity for the given species). Even in these optimal conditions storage will generate losses in weight which are variable and depend upon the species.

Some optimal storage conditions are shown in table given below.

Table: Optimal conditions for fresh vegetable storage

Vegetables	Storage conditions	
	Temperature, °C	Relative humidity, %
Potatoes	+1...+3	85-90
Carrots	0 ... +1	90-95
Onions	0 ... +1	75-85
Leeks	0 ... +0.5	85-90
Cabbage	-1 ... 0	90-97
Garlic	0 ... +1	85-90
Beets	0 ... +1	90-95

VEGETABLE DRYING/DEHYDRATION

Vegetable Dehydration

General technical data for vegetable dehydration in tunnels are shown in table given below.

Table: Technical Data for Vegetable Dehydration in Tunnels

Vegetables	Drying conditions			Finished products	
	Load Kg/m	Temperature °C	Time H	Moisture %	Yield %
Potatoes	8	I = 85 F = 75	4-6	8-10	12-16
Carrots	7	I = 85 F = 65	3-5	4-6	7
Cabbage	6	I = 80 F = 65	3-4	4-7	4-6
Onions	7	I = 70 F = 60	3-5	4-6	8-11
White roots	6-7	I = 65 F = 55	4-6	4-6	6-8
Green peas	5	I = 75 F = 60	3-4	4-6	9-14
Leeks	7	I = 70 F = 65	3-4	4-6	7-10
Pumpkin	7	I = 70 F = 65	5-7	6-8	6
Leafy vegetables	4-5	I = 65 F = 55	3-4	6-8	5-7
Herbs	3-4	I = 60 F = 55	3-4	5-7	5-7

I = Initial temperature, F= Final temperature

Technology for Vegetable Powder Processing

This technology has been developed in recent years with applications mainly for potatoes (flour, flakes, granulated), carrots (powder) and red tomatoes (powder). In order to obtain these finished products there are two processes:

a. Drying of vegetables down to a final water content below 4% followed by grinding, sieving and packing of products;

b. Vegetables are transformed by boiling and sieving into purées which are then dried on heated surfaces (under vacuum preferably) or by spraying in hot air.

Industrial installations that can be used for these products and technological data are summarised below:

- Dryers with plates under vacuum are equipped with plates heated with hot water. Stainless steel plates containing the purée to be dried are placed on them. Process conditions are at low residual pressure (about 10-20 mm Hg) and a product temperature of 50-70° C. This equipment is discontinuous but easy to operate.
- Drum dryers have one or two drums heated with hot water or steam as heating elements. Feeding is continuous between the two drums which are rotating in reverse direction (about 2-6 rotations per minute) and the distance of which is adjustable and determines the thickness of layer to be dried. he product is dried and removed by mechanical means during rotation.
- Drying installations by spraying in hot air; the product is introduced in equipment and sprayed by a special device in hot air. Drying is instantaneous (1/50 s) and therefore can be carried out at 130-15O° C.

Table: Technological Data for Vegetable Powders

Vegetable	Products	Preliminary treatment	Drying equipment	Temperature °C
Potatoes	Powder or granules for potato puree	Washing, peeling, cutting, steaming 15 min, crushing, sulphuring	Drums at atmospheric pressure	80
Carrots	Power	Washing, peeling, boiling 90 min, crassing, addition 0.4 g/kg ascorbic acid, price with 8% RE	Drums, under vacuum	85
Red tomatoes	Powder	Raw material: tomato paste with 28% RE + 2% dextrin + 0.04% $NaHSO_3$	Drums, under vaccum	85

Packing and Storage of Dried and Powdered Vegetables

Dried vegetables can suffer significant modifications that bring about their deterioration during storage. The factors that determine these degradations impose at same time the type of packaging materials and storage conditions for packaged products.

The main factor in maintaining the quality of dried products is to follow the maximum moisture contents that have to be as close as possible to the limits. The moisture content of dried vegetables is not constant because of their hygroscopicity and is always in equilibrium with relative humidity of air in storage rooms. Technical solutions for maintaining a low dehydrated products moisture are:

a. Storage in stores with air relative humidity below 78%;
b. Use packages that are water vapour proof. The most efficient packages are tin boxes or drums (mainly for long term storage periods); combined packages (boxes, bags, etc.) from complexes (carton with metallic sheets, plastic materials, etc.) mainly for small packages. One solution for some dried vegetables may be the use of waterproof plywood drums.

Modern solutions are oriented not only to the maintaining product moisture during storage but also reducing this parametre by the use of desiccants (substances which absorb moisture) introduced in packages, hermetically closed.

A desiccant in current use is calcium oxide. Granulated calcium oxide is introduced in small bags from a material which is permeable to water vapour but which does not permit the desiccant to escape into products. With desiccants, product moisture can be reduced to even below 4%, and this inhibits or reduces the biochemical and microbiological processes during storage.

Another factor that can deteriorate dried/dehydrated vegetables is atmospheric oxygen through the oxidative phenomena that it produces. In order to eliminate the action of this agent some packing methods under vacuum or in inert gases (carbon dioxide or nitrogen) are in use, applied mainly for packing dried carrots in order to avoid beta-carotene oxidation in beta-ionone (foreign smell, discolouration, etc.). In order to avoid the action of oxygen it is also possible to add ascorbic acid as antioxidant (for example in carrot powder).

Sun or artificial light action on dehydrated vegetables generally causes discolouration which can be avoided by using opaque packaging materials.

Dehydrated vegetable compression (especially for roots) to form blocks with a weight of 50-600 g, is practiced sometimes; it has as advantages the reduction of evaporation surface and contact with atmospheric oxygen and volume reduction. Dehydrated vegetables are compressed at about 300 at. Compressed blocks are packaged in heat sealed plastic materials.

Storage temperature has an important role because this reduces or inhibits the speed of all physico-chemical, biochemical and microbiological processes, and thus prolongs storage period. The storage temperature should be below 25° C (and preferably 15° C); lower temperatures (0-10° C) help maintain taste, colour and water rehydration ratio and also, to some extent, vitamin C.

Potato Crisp/Chip Processing

The most important steps involved in potato crisps processing are:

1. Selecting, procuring and receiving potatoes
2. Storage of potato stock under optimum conditions
3. Peeling and trimming the tubers
4. Slicing
5. Frying in oil
6. Salting or applying flavoured powders
7. Packaging

Table: Dehydrated Vegetable Potential Defects and Means to Prevent Them

Defects	Causes	Prevention
Doulding	High product moisture, above equilibrium relative	Reduce water content down to optimum vales.

	humidity corresponding to water activity $a_w = 0.70$	Pack in hermetic air tight packages.
Infestation	Presence in dried products of larva or insects.	Storage room disinfection with toxic gases. Fumigation of packed products and of packages. Disnfection by heat (60-65°C) of products before packing.
Browning	Chemical reaction (Maillard, etc.)	Reduce as much as possible water content. Store at low temperature.
	Enzyme catalysed reactions	Enzyme inactivation by blanching or steaming before drying.
Reduced rehydraton ratio	Too high temperature final stage of drying	Operate inside final temperatures as recommended.

Table: Moisture and Shipping Factors for Some Dehydrated Vegetables

Product	Form/cut	Moisture %	Weight kg/m³
Bean (green)	20 nun cut	5	1.6
Bean (lima)	5	3.3	
Beet	6 mm strips	5	1.6-1.9
Cabbage	6-12 mm shreds	4	0.7-0.9
Carrots	5-8 mm strips	5	3-5
Celery	Cut	4	
Garlic	Cloves	4	
Okra	6 mm slices	8	
Onion	Slices	4	0.4- 0.6
Pea (fresh)	Whole	5	3.4
Pepper (hot)	Ground	5	
Pepper (sweet)	5 mm strips	7	
Potato (Irish)	5-8 mm strips	6	2.9-3.2
	Diced	5	3.3-3.6
Tomato	7-10 mm slices	35	

Selection and Storage

It is important to select potatoes of high specific gravity since this characteristic indicates superior yield and lower oil absorption. It is even more important to select potatoes with low reducing sugar contents or to store them at temperatures conducive to the minimising of these substances. Sprouting and fungal damage must also be minimised by the storage conditions.

Peeling

The ideal peeling operation should only remove a very thin outer layer of the potato, leaving no eyes, blemishes, or other material for later removal by hand trimming. It should not significantly change the physical or chemical characteristics of the remaining tissue. Preferably peeling should use small amount of water and result in minimal effluent; compromises will have to be made in all of these aspects of peeling.

First, the potatoes are thoroughly washed, not only for sanitary reasons, but also to prevent dirt of grit from abrading the equipment the tubers will dater contact. Washing may take place in streams, as the potatoes are being conveyed by water streams, or in equipment provided with means for scrubbing the potato with brushes or rubber rolls.

In barrel-type washers, potatoes are cleaned by being tumbled and rubbed against each other and against the sides of the barrel while they are immersed in, or sprayed with, water. After washing, the potatoes are allowed to drain, usually on mesh conveyors, and they travel over an inspection belt where foreign material and defective tubers are removed. The more common peeling methods are abrasion, lye immersion, and steam.

Abrasion peelers which may be either batch or continuous, use disks or rollers coated with grit to grind away the potato surface. An important design feature is to ensure that all surfaces of the tuber are equally exposed to the rasping action. The peel fragments are flushed out of the unit by water sprays.

Such systems work best with uniform, round, undamaged potatoes. Some of the advantages of abrasion peelers are their simplicity, compactness, low cost, and convenience. They are particularly suitable for peeling potatoes intended for chipping, since they do not chemically alter the surface layers. About 10% of the original tuber weight is lost through abrasion peeling prior to chipping.

Slicing

The peeled potatoes are cut into slices from 1/15 to 1/25 in. by rotary slicers. Centrifugal force presses the tuber against stationary gauging shoes and knives. Thickness is varied, not only to meet consumer preferences, but also to fit the condition of the tubers and the frying temperature and time.

Slices produced at any one time must be very uniform in thickness, however, in order to obtain uniformly coloured chips. Slices with rough or torn surfaces lose excess solubles from ruptured cells and absorb larger amounts of fat.

It is necessary to remove the starch and other material released from the cut cells from the surface of slices so that the slices will separate readily and completely during frying. The slices are washed in stainless steel wire-mesh cylinders or drums rotating in a rectangular stainless steel tank. After washing and an additional rinse in similar equipment, the potatoes may or may not be dried.

Frying

The capacity of the fryer is generally the limiting factor in the process line. Most manufacturers currently use continuous fryers but some batch equipment is still employed.

Modern continuous fryers have the following essential elements: (1) a tank of hot oil in which the chips are cooked; (2) a means for heating and circulating the oil; (3) a filter for removing particles from oil; (4) a conveyor to carry chips out of the tank; (5) a reservoir in which oil is heated for adding to the circulating frying oil and (6) vapour-collecting hoods above the tank. Temperatures normally used are from 350 to 375° F at the receiving end and 320 to 345° F at the exit end.

The oil used for deep-fat frying of potato chips has two functions:

i. It serves as a medium for transferring heat from a thermal source to the tuber slices;

ii. It becomes an ingredient of the finished product.

Use of highly refined oil is of great importance in flavour and stability of the crisps. Flavour, texture, and appearance are affected both by the amount of oil absorbed and its characteristics as it exists in the crisp (i.e. not necessarily its initial chemical and physical parametres).

Oils change continuously during the frying process but the heat abuse resulting from the crisp cooking is relatively mild. Temperatures rarely rise above 385° F at any point.

Better control over crisp colour could be obtained if the final stage of moisture removal could be achieved without the browning reaction that always accompanies it in the frying process.

Crisps may be sorted for size after frying, with the larger crisps being diverted to the bulk packs and larger pouches and the smaller pieces used for vending machine packs and other individual service containers. Potato crisp sizing is also accomplished by separating the peeled potatoes into large and small sizes, which are then sliced and fried separately.

The crisps are salted immediately after they leave the fryer. It is important that the fat be liquid at this point to cause maximum adherence of the granules. Powders containing barbecue spices, cheese, or other speciality materials may be added at this point. The salt may contain added enrichment materials or antioxidants.

After salting, the crisps pass on to a conveyor belt where they are visually inspected and off-colour material is removed. I the crisps are allowed to cool before packaging, better adherence of salt and flavour powders is obtained.

Some consumers prefer the hard, curled-up crisp that is characteristic of the hand-kettle type of operation. The special flavour of the hand-kettle crisp is said to be due, at least partly, to the starch retained on the cut surfaces of the potato slices as a result of the omission of a washing process after slicing. Starch-covered slices tend to stick together in the fryer so it is necessary to use devices to prevent clumping.

The principal factors affecting potato crisp acceptability are piece size, colour, and of course, flavour. These factors are controllable primarily by selection of the raw material, adjustment of processing conditions, and packaging.

Storage Stability

If the frying oil is stabilised and has not deteriorated through use, and if the packaging is opaque and has a low moisture vapour transmittance rate (MVTR), a shelf-life of 4-6 weeks should be achieved when crisps are stored at temperatures of about 70°F.

Once potato crisps are in the bag, the three forms of quality loss which have the greatest effect on consumer acceptance are breakage, absorption of moisture with loss of crispiness, and fat oxidation leading to development of rancid odours.

The mechanical abuse causing breaking of the crisps can be partially prevented by using stiff packaging material, making the package "plump" with contained air, and avoiding crushing in the shipping case.

Absorption of moisture is prevented largely by proper choice of packaging material. Cellophane coated with various moisture barriers has proved to be a satisfactory pouch films for the relatively short shelf-life expected (generally stated to be 4-6 weeks).

Light (especially fluorescent light) accelerates oxidation, so that opaque packaging material must be used to obtain maximum shelf-life.

Potato crisps are considered commercially unacceptable when they have a moisture content above 3%, which is in equilibrium with a relative humidity of about 32%. The containers should have a high degree of resistance to moisture-vapour transfer. If pouches are used, foil-containing films are preferable, since they not only resist moisture-vapour transfer but reflect light.

VEGETABLE JUICES AND CONCENTRATED PRODUCTS

Vegetable Juices

Vegetable juices are natural products constituted from cellular juice and a part of crushed pulp, from the tissues of some vegetables. These juices contain all valuable substances from the vegetables: vitamins, sugars, acids, mineral salts and pectic substances. The most important of these products is tomato juice; in a lower proportion there are also other juices (carrots, beet, sauerkraut, etc.).

Tomato Juice

This product is characterised not only by its organoleptical properties (taste, colour, flavour) but also by its vitamin content close to those of fresh tomatoes. Modem technology is oriented to a maximum maintenance of organoleptic properties and of vitamin content.

At same time, it is important to assure juice uniformity by avoiding cellulosic particle sedimentation. Juice stability is assured by a flash pasteurization which assures the destruction of natural micro-flora, while keeping the initial properties.

The modern technological flow-sheet covers the following main operations:

Pre-Washing is carried out by immersion in water, cold or heated up to 50° C (possibly with detergents to eliminate traces of pesticides). This operation is facilitated by bubbling compressed air in the immersion vessel/equipment.

Washing is performed with water sprays, which in modern installations have a pressure of 15 at or more.

Sorting/Control on rolling sorting tables enables the removal of non-standard tomatoes - with green parts, yellow coloured, etc.

Crushing in Special Equipment

Preheating at 55-60°C facilitates the extraction, dissolves pectic substances and contributes to the maintaining of vitamins and natural pigments. In some modern installations, this step is carried out under vacuum at 630-680 mm Hg and in very short time.

Extraction of juice and part of pulp (maximum 80%) is performed in special equipment/tomato extractors with the care to avoid excessive air incorporation. In some installations, as an additional special care, a part of pulp is removed with continuous centrifugal separators.

De-Aeration under high vacuum of the juice brings about its boiling at 35-40° C.

Homogenisation is done for mincing of pulp particles and is mandatory in order to avoid future potential product "separation" in two layers.

Flash Pasteurization at 130-150° C, time = 8-12 see, is followed by cooling at 90° C, which is also the filling temperature in receptacles (cans or bottles).

Aseptic Filling

Closing of receptacles is followed by their inversion for about 5 to 7 minutes.

Cooling has to be carried out intensely.

Full cans do not need further pasteurization because the bacteria that have potentially contaminated the tomato juice during filling are easily destroyed at 90° C due to natural juice acidity.

For bottles, it may be possible to avoid further sterilisation if the following conditions can be respected: washing and sterilising of receptacles, cap sterilisation (with formic acid), filling and capping under aseptic conditions, in a space with UV lamps. In so far as this is quite difficult to achieve it may be necessary to submit bottles to a pasteurization in water baths.

The main characteristics of high quality tomato juice are:

- Natural red colour;
- Taste and flavour of fresh tomatoes;
- Uniformity (without pulp sedimentation);
- Total soluble solids: 6% minimum;
- Total soluble substances (by refractometre): 5% minimum;
- Vitamin C: 15 mg/100ml minimum.

In traditional processes it is recommended to:

- Thoroughly wash and rinse the empty receptacles (including jar caps/covers and bottle crown corks) and then "sterilize" by keeping in boiling water for 30 mini
- Add salt and lemon juice to the prepared receptacles just before filling;
- Pasteurize closed glass receptacles (bottles or jars) according to conditions recommended in technological flow-sheets and which is summarised as follows:

Receptacle size	Pre-heating	Time of pasteurization
0.33 1	60° C	40 minutes
0.501	60° C	45 minutes
0.66 1	60° C	55 minutes
0.751	60° C	60 minutes
1.0 litre	60° C	70 minutes

Carrot Juice

This product represents an important dietetic product due to its high soluble pectin content. Technological flow-sheet is oriented to the maintaining of as high as possible a pectin content and covers the following steps:

PRE-WASHING

CLEANING

WASHING

BLANCHING in steam for 20 minutes

GRATING

PRESSING

JUICE In the pressed juice will then be incorporated 25% of grated carrot (non pressed)

HOMOGENISATION in colloidal mills

ACIDIFICATION with 0.25% citric or tartric acid

DE-AERATION

FILLING in receptacles (bottles or tinplate cans)

AIRTIGHT SEALING

Pasteurization at 100° C for 30 minutes.

The main characteristics of a good quality carrot juice:

- Uniformity (no separation in layers occurs during storage);
- Good orange colour;
- Pleasant taste, close to fresh carrot taste;
- Total soluble solids: 12 %;
- Total sugar content: 8%;
- Beta-carotene: 1.3 mg/100 ml;
- Soluble pectin: 0.4 %.

Red Beet Juice

The product is obtained following this technological flow-sheet: washing, cleaning, steam treatment/steaming (30-35 min at 1050 C), pressing, strain through small hole sieve, filling in receptacles, tight sealing/closing, sterilisation (25 min at 1 15° C). In order to improve taste, the juice is acidified with 0.3% citric or tartric acid.

Sauerkraut Juice

Sauerkraut juice is produced in some countries for its dietetic value (lactic acid and vitamin C content) and its refreshing taste. The juice which is the result of the fermentation of lactic acid from cabbage, mainly from sliced sauerkraut, is used.

The juice must be the result of a normal lactic fermentation, i.e. without butyric fermentation or other deterioration.

A good quality juice must have an acidity of 1.4% lactic acid and a content of maximum 2.5% salt; this is obtained by the mixing of various sauerkraut qualities.

The collected juice (from sauerkraut production) is heated slightly in order to eliminate CO2 gas and to obtain protein coagulation. Filtration of juice is the next technological step, followed by filling in receptacles, closing of receptacles and pasteurization at 75-80° C for 4-5 minutes.

Concentrated Tomato Products

Tomato Paste

The product with highest production volumes among concentrated products is tomato paste which is manufactured in a various range of concentrations, up to 44% refractometric extract. Tomato paste is the product obtained by removal of peel and seeds from tomatoes, followed by concentration of juice by evaporation under vacuum.

In some cases, in order to prolong production period, it may be advisable or possible to preserve crushed tomatoes with sulphur dioxide as described under semi-processed fruit "pulps".

Technological flow-sheets run according to equipment/ installation lay-outs, which are especially designed for this finished product. Manufacturing steps fall into three successive categories:

a. Obtaining juice from raw materials;
b. Juice concentration and
c. Tomato paste pasteurization.

a. Obtaining juice from raw material. Preliminary operations (pre-washing, washing and sorting/control) are carried out in the same conditions as for manufacturing of "drinking" tomato juice described above. Next operation is removal of seeds from raw tomatoes: tomato crushing and seed separation with a centrifugal separator.

Tomato pulp is pre-heated at 55-60° C and then passed to the equipment group for sieving: pulper, refiner and superrefiner with sieves of 1.5 mm, 0.8 mm and 0.4-0.5 mm respectively in order to give the smoothest possible consistency to the tomato paste.

b. Juice is concentrated by vacuum evaporation, a technological step which in modern installations runs continuously, tomato paste from the last evaporation step being at the specified concentration.

In continuous installations with three evaporation steps (evaporating bodies), the juice is submitted in step/body I to pasteurization at 85-900 C for 15 min and this will determine the microbiological stability of finished product. Vacuum degree corresponding to this temperature is 330 mm Hg.

In evaporating bodies II and III, temperatures are around 42-46° C and vacuum at 680700 mm Hg. Juice concentration occurs gradually and continuously in the three evaporating bodies.

The advantages of continuous concentration are as follows:

— The taste, colour, flavour, "shine" and consistency of tomato paste are improved because:

i. The real concentration is performed in evaporating bodies II and III at low temperatures (42-46° C) and
ii. The whole concentration process time from the input of juice in body I until the output of paste from body III is of about 1 hour (for paste with 30-35% refractometric extract).

- Production capacity is raised by about 30% as compared to discontinuous installations with the same evaporation surface;
- The steam consumption is reduced by 60% because heating of bodies II and II is done with. vapours resulting from juice evaporation in body I (double effect); water and electricity consumptions are also reduced by 30-40 % .

c. Tomato paste pasteurization assures the microbiological stability of the product. For this purpose, the paste coming out from concentration equipment is passed continuously and in a "forced" mode through a tubular pasteurizer from which it emerge at a temperature of 90-92°C.

Usual commercial tomato paste types are at concentrations of 24%, 28% and 32% refractometric extract. Sometimes it is possible to obtain a tomato paste with a concentration of 44% refractometric extract; for this purpose it is necessary to eliminate a part of cellulose from tomatoes, an operation performed in a separating turbine.

Tomato paste storage and preservation is carried out after packing which is done usually in drums, metallic cans or glass jars; some modern equipment has been developed for packing in aluminium bags. As far as the concentration of tomato paste is concerned it is not possible to reduce water content down to 30% which corresponds to a water activity aw of 0.700.75 (minimum limit of mould growing), it is necessary to take special measures (e. g pasteurization, cold storage or salt addition).

Salt is not a preservative in itself but contributes to the lowering of water activity.

In drums, the preservation of tomato paste with minimum 30% refractometric extract is carried out in two ways:

- The hot paste (about 90°C) flows directly from pasteurization equipment into drums that have been previously steamed;
- The paste is cooled down to 30°C through a heat exchanger and is introduced into drums that have been previously steamed.

For preservation purposes, it is possible to add 3-8% salt.

Preservation with 3% salt must be carried out respecting the following criteria:

a. Processing of a healthy raw material;
b. Thorough washing and control;

c. Pasteurization of concentrated paste and use of well prepared drums. Paste in drums has to be stored in cold storage rooms during the hot season.

Preservation in big metal cans of 5 and 10 kg capacity of tomato paste with a minimum of 30% refractometric extract can be achieved without sterilisation if the following conditions are respected:

a. Sterilisation by steam of cans and covers;
b. Filling of paste at 92-94°C;
c. Airtight sealing/closing of cans;
d. Invert cans and then
e. Air cooling.

For small packages (tinplate cans of 1/10-1/1 or glass jars of same capacity) it is usual to use pasteurized paste, as hot as possible (92-94°C). The receptacles are first sterilised by steam. After airtight sealing, the receptacles are kept in boiling water for a short time in order to sterilize their inner surface and the paste in contact with inner receptacle surface. In some countries small receptacles are not further sterilised if the manufacturing is carried out in perfect hygienic and sanitary conditions.

Packing in small tinned aluminium tubes is carried out with concentrated paste, pasteurized and hot.

Good quality tomato paste is an homogenous mass, with a high density, without foreign bodies (seeds, peel, etc.), with a red colour, and an agreeable taste and smell, close to those of fresh tomatoes.

There are usually three types of tomato paste: 36, 30 and 24 which have refractometric extracts of respectively 34-38%, 28-32% and 24-26%. Paste of good quality must have a volatile acidity of maximum 0.15% as lactic acid. An 8% salt addition is accepted.

Concentrated Tomato Juice

Concentrated tomato juice is a product with 17-19 % refractometric extract and is a homogenous mass, finely sieved, without foreign bodies/and without any evidence of deterioration. A good quality product has a red colour, an agreeable and specific taste and smell.

Modern technology uses the same installations, equipment and flow-sheets for concentrated tomato juice as for the production of tomato paste; the final concentration is thus regulated between the above specified limits. The concentrated tomato juice is filled in receptacles (metal tinplate cans or glass bottles) and then pasteurized at 100°C during 15-25 minutes according to receptacle type.

With modern production lines it should be possible to pass the concentrated tomato juice through a tubular pasteurizer and then pack aseptically and cool, without the need to pasteurize the receptacles.

Tomato Sauces

Under the USA Code of Federal Regulation 7 CFR 52, 1991 tomato sauce is the concentrated product prepared from the liquid extract from mature, sound, whole tomatoes, the sound residue from preparing such tomatoes for canning, or the residue from partial extraction of juice, or any combination of these ingredients, to which is added salt and spices and to which may be added one or more nutritive sweetening ingredients, a vinegar or vinegars, and onion, garlic, or other vegetable flavouring ingredients. The refractive index of the tomato sauce at 20° C is not $<$ 1.3461.

These products are widespread in some countries and are used in order to spice some meals. Sauces can be obtained from fresh tomatoes or from concentrated products (tomato paste or concentrated tomato juice), those from fresh tomatoes being of superior quality. Technological processing covers the following steps: concentrated juice processing, addition of flavour/taste ingredients (salt, sugar, vinegar, spices, etc.), boiling, fine sieving, filling of receptacles, closing and pasteurization (45 min at 85° C). Tomato sauces which can be sweet, more or less spicy are prepared according to specific recipes.

Production Accidents and Product Defects; Means to Avoid Them

Tomato Juice

- "Separation" in layers is due to not enough homogenisation or low/insufficient viscosity. In the first case it is necessary to intensify homogenisation; and in second to increase the pre-heating temperature to 60° C in order to obtain protopectine hydrolisis and pectolitic enzymes inactivation.
- Moulding of the juice is brought about by significant infection of raw materials, inadequate washing and control or by use of contaminated packages. The preventive measures should be decided after cause analysis. Good pasteurization can destroy all moulds but the bad juice taste remains.
- Fermentation of juice is manifested by a significant development of gases. Prevention methods are the same as for moulding.
- Tomato juice turns sour, without the formation of gases; this defect is initiated by thermophyl and thermoresistant bacteria; the juice acquires a vinegary taste. Prevention: maintenance of flash pasteurization temperature at 130-135° C.
- Excessive vitamin C losses are due to a simultaneous action of heating and oxygen from air. Prevention:

a. Prevent air going into crusher and extractor;

b. Assure an intensive de-aeration (vacuum degree 700 mm Hg) at a temperature of at least 35-40° C; and

c. Close receptacles in vacuum.

- Weak colour of tomato juice can be avoided by the utilisation of mature tomatoes and with a pulp of as red a colour as possible.

Tomato Paste and Concentrated Juice

- Presence of sand is caused by inadequate washing or by a significant contamination of raw material; this can be prevented by a more intensive pre-washing and washing of tomatoes.

— There may be mould especially at the surface of tomato paste packed in drums. Prevention:

a. Accurate pre-washing and washing;
b. Follow pasteurization instructions;
c. Pack in clean drums or receptacles; and
d. Close receptacles immediately after filling.

— Fermentation is manifested by a weak alcohol smell or by a weak vinegar taste; when the fermentation is more advanced there is gas production in the product mass. Prevention: as for moulding prevention.

Tomato Sauces

— Surface of the product turns black at the contact zone with air; this is due to the action of iron on the tannins from spices, tomato seeds, etc. Prevention:

a. Avoid iron equipment;
b. Avoid crushing of tomato seeds and
c. Seal receptacles in vacuum.

PICKLES AND SAUERKRAUT TECHNOLOGY

Vegetable Natural Acidification Technology

Gherkins and Cucumbers

Raw materials must follow strict specifications for a high quality finished product; the following parametres must be considered as critical:

- Adapt a uniform size according to the finished product requirements; for example, gherkins will need to have a maximum length of 9 cm for raw vegetables. Generally 15 cm size/length will be a maximum for high quality cucumber products in many countries. However, according to local preferences, bigger cucumbers could be also in demand.
- Cylindrical or ovoidal shape;
- Dark green colour;

- Absence of surface defects due to cryptogamic diseases.

Cucumbers have to be picked at their ripeness for eating, when the sugar content is at about 1.5-2.2%, needed for lactic fermentation. Unripe cucumber does not have enough sugar.

The general technological flow-sheet is as follows:

RECEPTION

CONTROL

TEMPORARY STORAGE

GRADING BY SIZE

WASHING

Small holes are made in large size cucumbers skin;

Rreceptacle filling: raw material is simply put in the receptacles in bulk, with care to arrange them in such a way that a maximum of pieces could be introduced;

Salt solution preparation: 6% salt solution (NaCl);

Salt solution addition: the salt solution is poured into the receptacle;

Fermentation is carried out at 20-30° C, anaerobically. This step takes generally 4-8 weeks. Acidity reaches a value up to 1.5% lactic acid (and in some exceptional cases up to 2% lactic acid) which corresponds to a maximum pH value of 4.1.

Storage; after the last fermentation stage, drums and other receptacles have to be stored at low temperature; best conditions for 12 months shelf life should be below + 15° C. Storage temperature will determine the shelf life of the products.

Addition of 1000 ppm potassium sorbate will prevent mould development without having any influence on lactic fermentation.

Raw material grading by size is a very important technological step. In order to accelerate brine penetration, mainly for medium to large size cucumbers, the practice of making small holes in the raw material skins is generally recommended.

A major factor influencing the quality of lactic fermented cucumbers is the water durity; optimal results are obtained at 15-20° durity.

Cucumber consistency/texture is influenced by the formation of calcium pectate with the pectic substances from raw material tissues. In some countries, calcium chloride (0.3-0.5 %) is added in order to firm up the cucumber consistency. Chlorinated water which still contains active chlorine can inhibit or even stop the lactic fermentation.

Sauerkraut

In some countries cabbages are submitted to lactic fermentation as whole vegetables; however, in many countries the cabbage is shredded before fermentation. As shredded cabbage and its technology is at the basis of an important industry, giving good quality products, with a uniform fermented product and with good keeping quality and ease of distribution, this will be described first.

Cabbage as raw material for sauerkraut must be sound, ripe for eating, well-leafed and from suitable varieties. Optimum total sugar level needed for the lactic fermentation is 24%; generally good quality raw material contains up to 30-60 mg/100 g of vitamin C.

Shredded Sauerkraut

The technological flow sheet is as follows:

RECEPTION

CONTROL

Temporary storage is carried out in bulk, up to a height of about 1 m, during few days. This step produces a heat generation which facilitates later fermentation by the softening of tissues.

Removal of External Leaves

Coring is done with a specially adapted mechanical screw; this operation generates small particles of finely divided cabbage which will be mixed with the main part of vegetable during shredding/chopping. The core represents about 10% from the whole cabbage, is rich in sugar and vitamin C, but being too high in fibre content needs to be chopped separately as described.

Shredding/Cutting of cabbage is carried out with complex specific equipment which is generally installed directly on the "top" of fermentation silos and is mobile, installed on rails and moves all along the silos. The dimension of resulting shredded cabbage is about 2-3 mm thick.

The same complex equipment is designed to grind the added salt to fine particles and to distribute shredded cabbage and ground salt in an uniform manner to the fermentation silos. The usual capacity of fermentation silos is up to 30 tons, with separate compartments of 45 tons each.

Salt addition is carried out by the equipment described above; the proportion of salt is 2-2.5% with respect to cabbage.

This proportion must not be changed because the salt in this technology does not have a preservative role but only that to extract from cabbage the juice needed for fermentation.

It is be preferable to obtain a fairly light pressure on cabbage just after salt addition with some simple mechanical means. This is important in order to:

- Create an anaerobic medium for fermentation;
- Facilitate external diffusion of cellular juice;
- Assure a rational use of the fermentation space.

Fermentation: The maximum acidity level obtained is generally of about 1.5% lactic acid (and very rarely 2.5%); this is obtained in 4-6 weeks. Optimal acidity is 1.0-1.8% and pH value 4.1 or lower.

Fermentation temperature is at 20-25° C in the first phase and needs to be lowered then to 14-18° C. During fermentation, the brine from each storage/fermentation silo cell is periodically circulated with a pump in order to uniformise the fermentation process.

Storage is performed in same silos used for fermentation, or the finished products is removed from silos and packed in drums and other receptacles according to distribution schedule. These silos are usually made of reinforced concrete and coated with gritstone plates or with an acid-resisting material layer.

At small scale and in traditional processing, shredded sauerkraut can be obtained by using simple available glass or rigid plastic receptacles. At home, this process can use glass jars and/or local/traditional pottery receptacles from a minimum size of 2-3 kg up to the available/practical sizes (better limited to 10-15 kg).

In some countries shredded sauerkraut is preserved in receptacles by pasteurization, once the fermentation process has been completed.

Whole Sauerkraut

According to the consumer preference in different countries and to the specific situations it is also usual to preserve whole cabbages by lactic fermentation.

At small or medium scale operations, whole cabbage could be processed/fermented in cylindric receptacles like 30 to 200 litre rigid plastic drums, or rectangular receptacles made from food grade rigid plastic. It is possible to find this type of drum in a significant number of developing countries. These two types of rigid plastic receptacles could also be used for shredded sauerkraut production.

Prepared whole cabbages are put into fermentation receptacles and a 5-6 % salt concentration brine is poured on top. The fermentation conditions are the same as for shredded sauerkraut. In order to assure a uniform fermentation and to avoid a strict anaerobic (butyric) fermentation it is necessary to apply a periodic juice "aeration" (each 2-3 days at the beginning of the fermentation, and then each 5-7 days).

Other Acidified Vegetables

In principle all vegetables with a sugar content of at least 2 % could be preserved by lactic fermentation.

From a practical point of view it is mainly the following vegetables which are preserved by this technology: unripe tomatoes (green tomatoes), peppers, eggplant, carrots and cauliflower, alone or usually in a mix with cucumber as mixed pickles.

Fermentation of individual vegetables is carried out according to a flow-sheet as described for whole sauerkraut. The type of cut, brine concentration and frequency of operating steps have to be adapted to each case; green tomatoes are fermented as whole vegetable.

Simplified Flow-sheet for Whole Sauerkraut Processing

Process

a. Cabbage preparation
   - Remove the damaged leaves;
   - Wash the vegetable;
   - Remove 2-3 outer leaves;
   - Size grade in three categories:
     * size A: about 700 g per cabbage
     * size B: less than 1.2 kg per cabbage
     * size C: more than 1.2 kg per cabbage
   - Process each size category separately;
   - Wash cabbages;
   - Remove cores;
   - Cut size category C vegetable in halves.

b. Salt solution (brine) preparation
   - Prepare a 5% salt (NaCl) solution = 500 g salt for 10 litre water or 50 g salt for 1 litre water;
   - Stir until complete salt dissolution;
   - Filter salt solution through cheese cloth.

c. Initial processing

- Use a different receptacle for each size category;
- Arrange cabbages in fermentation receptacle;
- Pour salt solution to completely cover cabbages;
- Fix some clean wood pieces (or better some fitted covers with holes) in order to keep cabbages completely covered by salt solution. Allow about 10 cm salt solution above cabbage level;
- Store fermentation receptacles in a moderately cold and ventilated place, out of direct sunlight/ heat, protected from dust and other nuisances (insect, etc.);
- Cover each fermentation receptacle with a piece of cardboard or cloth.

d. Processing follow-up

- During the first week after initial processing. Once every 2 days, it is necessary to: remove the cover;
- Collect and carefully remove carefully (with a household spoon) the white layer ("scum") formed at the surface of salt solution;
- Wash the spoon each time and rinse;
- Put back the cover.
- During the 5 following weeks.
- Once every 4 days: repeat the operations described above.

After the first week, in order to assure a homogeneous acidification/fermentation process for big receptacles (i.e. drums or other receptacles of 20 to 2001 capacity), it will be necessary to proceed once a week to an "aeration" step. After completion of brine surface cleaning (as described above), the following operations will be carried out:

- Remove the cover and the wood spacers;
- Remove all salt solution (brine) from the receptacle;
- Filter this solution through a cheese cloth;
- Pour back the filtered solution back to the fermentation receptacle;

- Put the wood spacers back in place;
- Cover the receptacle.

These operations will be carried out for each fermentation receptacle once a week, during an estimated period of six weeks; total duration will be determined by the temperature in the storage room and by the chemical composition of specific raw material (cabbage) lots. Always keep salt solution (brine) level at 10 cm above cabbages, e. g. cabbages must be always covered by brine.

Consumption of the Finished Product

It is possible to estimate that at reasonable ambient temperatures and with a strict follow up of the above recommendations, the finished product will be ready for consumption about 6 weeks after initial processing.

The finished product could be used "as is" in vegetable salads, or prepared according to local taste: with tomato sauce, beans, minced meat, etc. as a replacement of fresh cabbages.

In the same way as with natural acidification or lactic fermentation the cabbage texture is modified and softened so that tissues are more digestible than fresh vegetable. It is possible to use the finished product in local dishes and in new recipes without having to boil it. Apart from the taste benefits of acidified cabbages, this is also produces a significant fuel savings.

The juice resulting from natural cabbage acidification is recovered and could be used separately as a refreshing vegetable juice; the preparation is described in this document.

Finished Product Storage

It is possible to store the finished product after completion of fermentation (i.e. after the estimated six weeks period); the storage time will depend on the ambient air temperature. If a cool space is available, the finished product shelf-life/storage time at a temperature of about + 15° C is estimated at six months. At an ambient temperature not exceeding +20° C, the storage time could be estimated at 2-3 months.

Artificial Vegetable Acidification Technology

This technology is based on the addition of food grade vinegar which has a bacteriostatic action in concentrations up to 4 % acetic acid and bactericidal action in higher concentrations.

Vegetables preserved in vinegar need to reach, after equilibrium between vinegar and water contained in vegetables, a final concentration of 2-3 % acetic acid in order to assure their preservation.

To achieve this final concentration, a 6-9 % acetic acid vinegar is used, as related to the specific ratios vinegar/ vegetables. In vinegar pickles, salt (2-3 %) and sometimes sugar (2-5 %) are also added.

If the vinegar concentration is lower than 2%, vinegar pickles need to be submitted to a pasteurization in order to assure their preservation.

Cucumbers in Vinegar

This represents the basic product obtained by this technology. Cucumbers have to be wholesome, with a soft texture and not have reached eating maturity. They must have a low sugar content because in this technology there is no lactic fermentation involved. Dimensions are up to 12 cm length, with a preference for small cucumbers.

The technological steps are the followings:

SIZE GRADING

WASHING

ARRANGE IN RECEPTACLES - glass jars, etc.

Pouring of vinegar is usually carried out at room temperature; however, hot vinegar addition enables a sterilisation of cucumber surface and facilitates vinegar penetration in vegetable tissues.

SALT (SUGAR) ADDITION

SPICING ADDITION

The technological cycle of artificial acidification is considered completed when acetic acid concentration reaches an equilibrium value; the time needed is about 2 weeks.

When equilibrium concentration in acetic acid is below 2 %, the cucumbers are submitted to a pasteurization for 20 min at 90-1000 C in order to assure their preservation.

Cucumbers in vinegar with previous lactic fermentation are excellent quality products because the lactic fermentation improves the taste of these cucumbers. The principle of this process is to assure preservation both by acetic acid and by lactic acid simultaneously.

Technological processing flow-sheet is as follows: small cucumbers ("cornichons" or "gherkins") are washed, brushed and small holes are made in the skin; the vegetables then are put in drums with slightly warm 6% brine which also contains spices.

The lactic fermentation runs for few days up to a lactic acid concentration of about 0.5 %. The cucumbers are removed from the brine, washed thoroughly and well drained. Preservation is usually done in glass jars by pouring a normally flavoured vinegar with about 9% acetic acid usually in order to bring the final concentration to 3% calculated as acetic acid.

In order to obtain a high quality product only wine vinegar should be used. In some pickles (e.g. in "Cornichons") the usual level of wine vinegar is set at 20 % of packaged product total weight; some alcohol vinegar could be still added and final concentration will be adjusted as described above.

Other Vinegar Pickles

One type in this category is represented by other vegetables acidified with vinegar separately or in a mix (red peppers, sweet green pepper, green tomatoes, cauliflower, etc.). The preparation steps are similar to the ones used for cucumbers in vinegar.

Significant quantities of special mixed vegetables in vinegar are manufactured in many countries, with the international name of "mixed pickles" with following composition: small cucumbers ("cornichons"/"gherkins") - maximum 70 mm in length -, sliced carrots, cauliflower, small onions (less than 25 mm diametre), mushrooms etc. and spices.

The vegetables are acidified separately in vinegar and then are put into receptacles (glass jars); a flavoured vinegar, salted and sweetened with acetic acid concentration of 3-5% is poured over them. In the case of lower acetic acid concentrations, a pasteurization at 90° C for 10-20 minutes is applied according to the receptacle size.

Vegetable acidification "accidents" and how to prevent them

Type of accident	**Causes**	**Prevention**
	Product: Shredded Sauerkraut	
Unpleasant small and tasted, reancid	Butyric fermentation	By the respect of (prevailing) lactic fermentation
Sour taste, vinegar type	Acetic fermentation by exidation of alcohol produced in first fermentation step	Avoid contact of cabbage with air in the first fermentation step
Juice with gelatinous appearance	Rapid development of certain species of lactic bacteria	Avoid high fermentation temperature
Abnormal colours; pink, brown, etc.	Abnormal microflora action (Torula, etc.)	Avoid high fermentation temperature and high juice acidity.
Softening	Too low salt concentration	Kepp salt concentration at 2 % min.
	Product: Cucumbers	
Bitter taste	Climatic and harvesting conditions spices, Need choice of	Bitter taste cannot be removed by boiling or an adequate vegetable
Hollow	Action of gas forming microorganisms in too intensive fermentation and low brine concentrations.	Create and maintain anaerobic condition for fermentation. Keep recommended salt concentrations and temperatures

Softening	Action of foreign flora because of low initial brine concentration.	Keep recommended salting and rermentation conditions.
Colour darkening	Foreign flora action; iron impact.	Keep fermentation conditions. Avoid iron in water and salt.
Wrinkled	Use of too concentrated brine.	Do not exceed 6 % brine concentration.

Vegetable Canning

Canned vegetables can be classified as follows:

1. Canned products in salt brine;
2. Canned products in tomato concentrated juice;
3. Canned products in vegetable oil.

Canned Vegetables in Salt Brine

Storage silo

Sorting

Washing

Grading

Preliminary operations

Cleaning

Cutting

Blanching or steaming

Cooling

Receptacle filling

Preheating

Hermetic sealing

Sterilisation

Cooling

Labelling

Storage

Table: Orientative Technical Data for Canned Vegetables in Salt Brine

Type of canned products	Compasition	Sterilization at 120°C, minutes			
		Cans		Jars	
		1/2	1/1	1/2	1/1
Pens (fine, extra fine,semi-fine)	Min. 60% grains; 1-3% salt solution and 1-3% sugar	10	20	20	30
Green beans (extra fine, fine, standard)	60% vegetables; 1-3% salt solution	10	15	15	20
Beans (green, yellow)	50-60% vegetables; 2% salt solution	10	15	15	20
Red tomatoes, whole, non-peeled, in brine	Min. 60% vegetables; 2% salt solution	10	15	15	20
Small carrots	65% vegetables; 2% salt solution	20	25	25	30
Peas with carrots	6065% vegetables; 2% salt solution and 2% sugar	20	25	25	30
Cauliflower	600 g in 1/1 can; 1% salt solution and 0.05% citric acid	20	-	25	-
Sauerkraut	70% cabbage + 30% sauerkraut juice	15 at 100°C	25	-	-
Peppers	12-14 Pieces in 1/1 can; 6-8 pieces in 1/2 can; 8-10 pieces in 500 ml jars	15	20	20	30

Canned Vegetables in Concentrated Tomato Juice

General technological flow-sheet covers two types of operations:

a. Preparation of vegetables is similar to the one described for canned vegetables in salt brine: sorting, washing, grading, cutting, blanching and cooling; the exception is for spices which are not blanched.

b. Preparation of canned products covering: receptacles filling with vegetables, adding concentrated tomato juice (with minimum 8% refractometric extract), hermetic closing/sealing of receptacles, sterilisation and cooling of receptacles.

Technical data for canned vegetables in tomato juice are given in Table given below.

Table: Orientative Technical Data for Canned Vegetables in Tomato Juice

Type of canned products	Compasition	Sterilization at 120°C, minutes			
		Cans		Jars	
		1/2	1/1	1/2	1/1
Mixed vegetables*	60% gegetables; 40% conc. tomato juice	20	30	25	*35
Okra in tomato juice	40% vegetable; 60% conc. tomato juice min. 8% RE	20	30	25	35
Eggplant in tomato juice	60% vegetables; 40% conc. tomato juice, min. 12% RE	20	30	25	35
Red tomatoes, whole in tomato juice	50% vegetables; 50% conc. tomato juice, min. 8% RE	10	15	15	20

One usual composition for mixed vegetables in tomato juice is:

- Eggplants (slices): 20%
- Peppers (cut): 20%
- Carrots (slices): 15%
- Green peas: 5%
- Green beans (pods): 18%
- Okra (whole): 8%
- Tomatoes (whole or halves): 14%

RE = Refractometric extract

Each vegetable is prepared separately as in general canning operation description. At receptacle filling for mixed vegetables products, each vegetable should be introduced separately in specified proportions; hot concentrated tomato juice (at least 700 C) is poured onto the vegetables.

Canned Vegetables in Vegetable Oil

General flow-sheet is described below:

Reception

Sorting

Cleaning/peeling

Washing

Cutting

Frying or Blanching

Cooling

Filling and adding of vegetable oil, sauce or tomato concentrated juice

Sealing

Sterilisation

Cooling

Labelling

Storage

General Heat Preservation Operations – Canning

The success of heat preservation operations lies in:

- Selecting suitable fruit and vegetables in good conditions;
- Preparing them hygienically and skilfully;
- Packing them in cans which are hermetically sealed and then processed under fixed conditions of time and temperature;
- Cooling these cans carefully and storing them under conditions which will not cause deterioration of either the cans or their contents.

Selection of Raw Materials

It is appreciated that some varieties of fruit and vegetables are not suitable for canning, either because they are uneconomical to prepare or because the colour, flavour or texture are poor.

Suitable varieties must be available to the canner in quantities sufficient to meet his requirements and in sound conditions for canning. The flow to the cannery should be regulated in order that perishable materials are not left for a long time before being handled, since any delay will cause deterioration.

Apart from the main ingredients, be it fruit or vegetables, minor ingredients also require careful selection. Sugar, salt, water and spices for instance may all be contaminated with spoilage organisms, so constant testing of all raw materials is essential.

Preparation

This is carried out by various methods, including grading, trimming, peeling, washing and blanching. All equipment must be scrupulously clean and preparation should be completed quickly and carefully in order to keep the bacterial load as low as possible.

Thorough washing of vegetable is necessary to remove spores of heat resistant bacteria which are present in large numbers in the soil.

Blanching in steam or hot water is of no avail against these heat resistant (thermophilic) spores because of the comparatively low temperatures involved.

Reasons for blanching are:

- The removal of gas from the tissues of the raw material;
- The shrinkage of this material;
- The inhibition of enzymic reactions, which, if not checked, will adversely affect the colour and nutritive value of the food.

Filling

Filling, be it mechanical or by hand, requires careful attention. The cans must be clean and the correct weight of foodstuffs must be added. Under-filled cans will be underweight and the headspace will be too large, resulting in too much air being left in the can. Overfilling may lead to seams being strained during processing and to ends becoming distorted and bulged.

If the product forms hydrogen on storage as is the case with coloured fruits, swelling of the can due to hydrogen pressure will occur more quickly in an overfilled can than in one which has been correctly filled. Overfilling also affects heat penetration in the can and may lead to spoilage outbreaks.

Air Removal

Before the can is seamed, air must be removed from the contents and the headspace. Normally, this is carried out by passing the cans through a steam box until the temperature at the centre of the can is at least 160° F. This operation, termed exhausting, is necessary for the following reasons:

i. To minimise strains on the seams due to expansion of air during the processing period;

ii. To remove oxygen which accelerates corrosion in the can and also causes oxidation of the food with possible serious effects on colour and flavour;

iii. To reduce the destruction of vitamin C;

iv. To enable a vacuum to be formed when the can is cooled.

This ensures that the ends remain concave, even when storage temperatures are a little higher than usual, and also acts as a reservoir for hydrogen which may be formed by reactions between the can and its contents. Thus a high vacuum makes for a long shelf life. Large cans, however, should not reach such a high exhaust temperature before seaming as smaller cans because of the danger of the can body collapsing on cooling, a condition known as "panelling".

Double Seaming

The can should be double-seamed as soon as the correct centre temperature has been attained. Any delay between exhausting and seaming will lead to loss of vacuum and may lead to bacterial spoilage. The quality of the double seam must, of curse, be frequently checked.

Heat Processing

After seaming, the cans are heated for a definite time at a definite temperature to kill or inhibit organisms which may cause spoilage. This operation is termed "heat processing".

The times and temperatures required for "heat processing" of various packs have been determined experimentally to ensure that spores of the most heat resistant food poisoning organisms known, Clostridium botulinum, are destroyed.

There are other organisms, however, whose spores are more heat resistant than those of Clostridium botulinum and which although they will not cause food poisoning may cause spoilage and for this reason the minimum heat processing time is often exceeded by recommendations made by laboratories.

At the same time there is a limit to the amount of heating which a canned food may be given without spoiling its flavour, texture and colour and this also has to be taken into consideration when process recommendations are made.

Bacterial spores have a greater resistance to heat when the growth-medium is neutral or near neutral, and neutrality is normally required for bacterial growth to commence. Because of this, canned foods have been broadly divided into two groups:

a. "acid" foods having a pH of 4.5 or lower and

b. "non-acid" foods having a pH of more than 4.5.

"Non-acid" foods (vegetables) must, therefore be "heat processed" at high temperatures using steam under pressure, whereas "acid" foods (fruit) may be processed at the (lower) temperature of boiling water, since this will kill moulds and yeasts and if any bacterial spores survive the combination of acid and heat, they will be inhibited from growth by the acid environment.

The rate of destruction by heat follows a definite pattern, the same proportion of the surviving bacteria being destroyed in successive units of time. The more bacteria there are in a pack, the more time will be need to reduce their numbers. For this reason, it is essential that the initial number of bacteria be kept low, and this may be achieved by ensuring fast and hygienic handling at all stages in the cannery.

Pressure gauges and retort temperature control equipment must be checked frequently for accuracy. Processing times and temperatures must be strictly adhered to, and complete removal of air from the retort during processing must be achieved by adequate venting. Failure to remove the air completely will result in their being cold spots in the retort and intermittent spoilage are likely.

Cooling

As soon as the heat processing time is completed, the cans are cooled in chlorinated water as rapidly as possible without damaging them. Cans processed in steam develop high internal pressure because of the expansion of the foodstuff, the expansion of air in the can and the increase in the vapour pressure of the water in the can.

During the heat process, these pressures are counter-balanced to some extent by the pressure of the steam in the retort, but on releasing this steam pressure at the commencement of the cooling period, the pressure in the can may be sufficient to strain the seams seriously and may even distort the ends.

Cans of A21/2 size or larger, when processed at temperatures of 240° F or more, are liable to undergo permanent distortion, such as peaking. This may be avoided by pressure cooling, which involves replacing steam pressure by air pressure before introducing water to the retort, and maintaining this until the pressure inside the can has fallen to a safe level.

This presents difficulties, since if the air pressure is maintained after the can has developed a vacuum, the can body is liable to collapse. Where pressure-cooling is not carried out, the retort pressure is allowed to drop slowly to atmospheric pressure and the cans are then cooled with water.

Storage

After cooling, the cans should be stored in cool, dry conditions. The maintenance of a constant temperature is desirable, since a rise in temperature may lead to condensation of moisture on the can, with possible rusting. Cool conditions are required because storage at higher temperatures not only causes chemical and physical changes in the product and the container but also introduces a risk of thermophilic spoilage.

Other known causes of container spoilage in storage are the use of labels and cardboard cases which have too high a chloride content, and the use of unseasoned wood in the manufacture of packing cases, all of which tend to cause rust formation on the cans.

General technical operations for fruit and vegetable canning lines

a. Receptacle washing will remove the impurities and, as much as possible, the microorganisms on the inner surface of metallic cans or glass jars. Washing must be performed just before receptacle filling in order to avoid a new contamination.

   Washing methods are variable and depend on receptacle type and need to be carried out with adequate mechanical equipment.

   Metal cans are washed on the can feeding lines of filling equipment; a high pressure spray of warm water (65-8° C) is directed into the receptacles while these are submitted simultaneously to a rotation and forward motion.

   Glass jars are submitted to a triple washing: wetting for 10 min in a warm detergent and disinfectant solution (40-45° C) containing 100 mg active Cl/litre;

washing with high pressure (2.5-3 at) warm water sprays (65-85° C); rinse with cold water. Special attention MUST be given to recycled glass jars; washing process must be intensified or repeated, depending upon their contamination.

b. Receptacles are filled in order to maintain a specific ratio between the solid part of the composition and the filling or covering liquid.

   For canned vegetable products, the covering liquid may be a 1-3% salt solution with or without addition of sugar (1-3%), tomato concentrated juice or various sauces based on concentrated tomato juices. Salt solution (brine) preparation may be performed with salt percolators; the resulting solution is saturated, containing 318 g/l and needs to be diluted to usual concentrations (1-3%). Brine is then heated up to filling temperatures which depend on product type (up to 85-90° C).

   Sugar solutions (syrups) for fruit products may be prepared on the same type of percolators as brine. Receptacle filling is carried out by leaving an empty space of 5-15% of the total volume, depending on filling temperature and the product type.

c. Pre-heating (exhausting) of full receptacles aims at the removal of air from the tissues and the increase of the initial temperature of the receptacle contents. On modern production lines, exhausting is eliminated and replaced by the increase of the filling liquid temperature and hermetic receptacle closing under vacuum.

When exhausting is applied, with steam or with hot water, the pre-heated receptacles must be immediately closed in order to avoid the contraction of liquid phase and thus air introduction. Exhausting is performed in special, continuous equipment; product temperature is between 80 and 95° C, during 2-10 min.

10

Quality Assurance and International Trade

QUALITY ASSURANCE

The international trade in processed fruits and vegetables is very large with an ever increasing number of different types being processed and exported. Whereas once, processing was limited to mostly temperate climate fruits and vegetables, the change has now broadened to include tropical and subtropical types.

The reasons are twofold. Firstly, consumers' dietary habits have become more diverse so that, for example people living in North America may very well like fruit and vegetables grown in Africa or Asia. Secondly, processing techniques, whether they be for canning, freezing or drying, have been improved to an extent where final product is palatable, nutritious and of long and reliable shelf life.

Many developing countries have taken advantage of the continuing worldwide demand for processed fruits and vegetables and earned valuable foreign exchange from exports of products to profitable markets.

The export quality control and inspection of processed fruits and vegetables is directed at ensuring that the final products: have been processed in a registered export establishment that is constructed, equipped and operated in an hygienic and efficient manner; conform to the requirements of the export regulations for processed fruits and vegetables, and those of the importing country, in respect of such things as quality grades, defects, ingredients, packaging materials, styles, additives, contaminants, fill of container, drained weight; and, conform to labelling requirements.

INSPECTION AND CERTIFICATION PROCEDURES

In most countries, in processing fruits and vegetables for export, it is not customary to apply continuous inspection as it is in the case of meat. Few, if any, importing countries require it, and the nature of the products themselves is such that only part time check inspection is required during processing together with statistically based inspection, including sampling and analysis, of final product.

However, in circumstances where an establishment is processing export product for the first time, it can be argued that there is an advantage in adopting continuous inspection until the operation is satisfactorily established.

In any event, inspection of raw materials should be carried out at the commencement of each processing run to ensure that only sound fruit or vegetables of sufficient maturity (degree of ripeness) are used for processing. Sampling checks of raw materials should be carried out as frequently as the inspector thinks necessary.

The inspector must ensure that adequate hygiene practices are followed during the processing of the product. For example, in the case of canned and frozen products and other processing methods, raw materials should be washed absolutely clean so that fruit and vegetables entering the processing line are free from dirt, superficial residues of agricultural chemicals, insects and extraneous plant material.

In the case of dried product, especially where the raw material is sun-dried on drying greens or racks, care must be taken to minimize contamination by bird and animal droppings, dust and extraneous plant material. It is often necessary to wash the dried product to ensure cleanliness of the final product.

In the case of canning and freezing, the inspector must obtain full details of the processing programme for at least the following day from management, so that an adequate inspection programme can be scheduled.

In much the same way as for fresh fruit and vegetables, the inspector must also be aware of the pesticides and other chemicals used in the production of the raw materials. Necessary laboratory analyses can then be arranged to ensure residue levels in the final product do not exceed tolerances adopted by importing countries.

At the commencement of and during processing, the inspector should pay attention to the state of raw materials, the preparation of raw materials for processing (peeling, slicing, dicing, blanching, etc.), preparation and density of packing medium (sugar syrup, salt brine, etc.), the state of cans or containers to be used (cleanliness and strength), the cooking or freezing process (time/temperature relationship), can filling and closure and can/container storage.

After processing, the inspector should check the final product to ensure the drained or thawed weight, the vacuum and headspace, packing medium strength and that can/container conditions are satisfactory. Statistically based sampling plans should be adopted for the examination of final product to ensure it meets the requirements of the export regulations.

The labelling applied to cans/containers should also be checked to ensure both their correctness and compliance with the export regulations and the requirements of those countries in which the product is to be marketed.

Cans should also be examined to make sure that the correct embossing relating to the product, its date of production and the registered number of the export establishment has been applied.

Each establishment registered for the export of processed fruit and vegetables or for canned or frozen foods should have its own quality laboratory sufficiently equipped and staffed to carry out physical, chemical and microbiological examinations of the goods.

Inspectors should have access to the laboratory facilities and the establishment's quality control records as and when required. Independent laboratory examination of product should be made by the agency having responsibility for export on the basis of a statistically developed sampling plan.

In those countries where fruit and vegetable production is a seasonal event, processing for export generally takes place at the time of peak production and then declines, often to a halt, as the supply of raw materials declines. As a result, most export establishments produce at their peak of production far more product than they export at that time.

Therefore, most manufacturers find it necessary to store product for considerable periods before it is exported. Thus, proper storage is essential if the product is to retain its quality and cans remain untarnished. Inspectors should regularly inspect storage facilities, noting their conditions and that of the stored product, looking for signs of deterioration such as pest infestation and rusting of cans.

Prior to export, the exporter should be required to notify the export quality and inspection agency of his intention to export in accordance with the provisions of the export processed fruits and vegetables regulations and on the prescribed "Notice of Intention to Export" form.

The notice should be submitted in sufficient time before the shipment date to enable the product to be inspected satisfactorily; the intensity of inspection depending on the original state of the product, the conditions under which it has been stored and the length of storage. When product is approved, the agency will issue the exporter an "Export Permit" authorizing Custom's clearance of the product.

Labelling

Customers and consumers expect the labelling on food to be a true description of what they are buying.

Misleading or fraudulent labelling is an unfair trade practice that cannot be tolerated. Most countries now have labelling laws stipulating how foods are to be labelled and what information labels must contain. Most, if not all of those laws have in common requirement that the label should bear:

- A statement of identity and a true, as distinct from misleading, description of the product;
- A declaration of net contents (weight or number of pieces);
- The name and address of the manufacturer, packer, distributor or consignee, and
- A list of ingredients (in descending order of volume or weight).

In addition, labels may also be required to include, amongst other things, the country of origin, date of manufacture or packing, a use-by or expiry date, nutritional qualities or values of the food, storage directions, a quality grade and directions for preparing the food.

More frequently than is often realized, consignments of food exports arriving on foreign markets are not permitted entry because the labelling does not comply with the mandatory requirements of the importing country.

This sometimes results in consignments being rejected, but more often in them being withheld from entry until the labelling is corrected or new labelling applied. In either case, trade is interrupted and the cost involved may make sales unprofitable. It is essential therefore, that exporters be familiar with the food labelling requirements of importing countries.

Export Quality Control and Inspection Systems for Foods

With the advent and development of a food consciousness amongst consumers, stimulated by the work of the Joint FAO/WHO Codex Alimentarius Commission through its elaboration of food standards, codes of hygienic practice and the Code of Ethics for International Trade in Food, an increasing number of countries have adopted sophisticated food laws and established food control agencies, some with the aid of FAO.

Consequently, those countries no longer accept products on trust that they are satisfactory, but instead, demand that food imports meet the requirements of their food laws and pass inspection by their control agencies. Moreover, many of them require exporting countries to certify that products comply with their national legislation and some also require additional special declarations.

As a result of these developments the emphasis of activity of Export Quality Control and Inspection Systems has changed. Although most of them still establish their own standards of quality control and adopt standards for foods for export, most of their effort and resources are now directed at ensuring that foods for export meet the mandatory requirements of importing countries and providing the necessary associated certification. To do otherwise is to invite either the detention or, at worst, rejection of product at point of entry.

Detentions and Rejections

Food exporting countries can no longer assume that there is a good chance that products not complying with the requirements of importing countries will escape the inspection at the point of entry.

Details of foods imports released by the United States Food and Drug Administration (FDA) indicate that significant quantities of product are at least detained, and at worst rejected, because they fail to meet U.S. food laws.

Reasons given for the detentions include:

- Non compliance with labelling requirements;
- Decomposition;
- Insect and animal filth and damage;
- Use of prohibited additives;
- Non compliance with requirements of the U.S. low acid canned food regulations;

- Heavy metal contamination;
- Excessive levels of pesticide residues;
- Excessive levels of mycotoxin;
- Mould infestation;
- Microbiological contamination;
- Swollen and otherwise faulty cans.

The message for food exporting countries is quite clear - ensure your products comply with the mandatory requirements of importing countries or run the very real risk of having them rejected at considerable financial loss to the exporter and the country and resulting in damage to the commercial reputation of both.

While the foregoing relates to the U.S.A. experience, because it is the only country that currently publishes data about detentions and rejections of food imports it can be assumed that record more or less reflects the experience of other food importing countries. It might well be asked why such significantly high levels of detentions and rejections of food imports take place.

Undoubtedly the reasons are many and varied. However, the evidence shows that the most important reasons include:

- The inability of some export food industries, especially in developing countries, to handle, process, package and transport products to meet the mandatory requirements of importing countries;
- Lack of awareness by food exporting countries of the mandatory requirements of importing countries, including certification;
- Lack of adequate export control programmes and related agencies in food exporting countries, preventing them from exercising the necessary product surveillance and giving reliable and credible certification, and
- A lack of communication, between food control authorities and agencies in exporting and importing countries.

All four can be remedied by governments if they possess sufficient political will and take the necessary steps to do so.

GOOD MANUFACTURING PRACTICES (GMP); HYGIENE REQUIREMENTS

Personnel

Disease Control

Any person who has an illness, open lesions, including boils, sores, infected wounds, or any other abnormal source of microbial contamination must not work in any operation (in a food processing centre) which could result in the food, food-contact surface, or food packaging materials becoming contaminated.

Cleanliness

The following applies to people who work in direct contact with food preparation, food ingredients or surfaces of equipment or utensils that will contact food: they must wear clean outer garments, maintain a high degree of personal cleanliness and conform to hygienic practices while on duty; they must wash their hands thoroughly and, if they are working at a job where it is necessary, they must also sanitize their hands before starting work, after each absence from the workstation and at any other time when the hands have become soiled or contaminated; they must also remove all unsecured jewelry.

People who are actually handling food, should remove any jewelry that cannot be properly sanitized from their hands; it is necessary to wear effective hair restraints, such as hairnets, caps, headbands or beard covers; operators must not store clothing or other personal belongings in food processing areas. Also, eating food, drinking beverage or using tobacco (in any form) must not be allowed in food processing area; all necessary steps have to be taken by supervisors to prevent operators from contaminating foods with microorganisms or foreign substances such as perspiration, hair, cosmetics, tobacco, chemicals and medicants.

Education and Training

Persons who are monitoring the sanitation programmes must have the education and/or experience to demonstrate that they are qualified. Food handlers and supervisors should receive training that will make them aware of the danger of poor personal hygiene and unsanitary work habits.

Supervision

Someone must be assigned the responsibility that all personnel will comply with all the requirements of these GMP's.

Plants and Grounds

Grounds around a food processing centre which are under the control of this centre must be free from conditions such as: improperly stored equipment; litter, waste or refuse; uncut weeds or grass close to buildings; excessively dusty roads, yards or parking lots; inadequately drained areas - potential foot-borne filth or breeding places for insects or microorganisms; inadequately operated systems for waste treatment and disposal.

Plant construction and design shall: provide enough space for sanitary arrangement of equipment and storage of materials; floors, walls and ceilings must be constructed so that they are cleanable and must be kept clean and in good repair; separate by partition, location, time and other means, any operations that may cause cross-contamination of food products with undesirable microorganisms, chemicals, filth or other extraneous material; provide effective screening or other protection to keep out birds, animals and vermin such as insects and rodents.

Provide adequate ventilation to prevent contamination of foods with odours, noxious fumes or vapours (including steam); light bulbs, skylights or any other glass must be of the safety type or protected so that glass contamination cannot occur in case of breakage.

Sanitary operations

General Maintenance

The plant and all fixtures must be kept in good repair and be maintained in a sanitary condition. Cleaning operations must be conducted in a manner that will minimize the possibility of contaminating foods or equipment surfaces that contact food.

Pest Control

- No animals or birds are allowed anywhere in the plant
- Programmes must be in effect to prevent contamination by animals, birds and pests, such as rodents and insects;
- Insecticides and rodenticides may be used as long as they are used properly (according to label instructions);
- These pesticides must not contaminate food or packaging materials with illegal residues;

Sanitation of Equipment and Utensils

- Utensils and equipment surfaces that are in contact with food must be cleaned as often as necessary to prevent food contamination;
- Equipment surfaces that are not in contact with food should be cleaned as frequently as necessary to minimize accumulation of dust, dirt, food particles, etc.
- Single-service articles such as disposable utensils, paper cups, paper towels, etc., should be:
- Stored in appropriate containers;
- Handled, dispensed, used and disposed of in a manner that prevents contamination of food or equipment;
- Where there is the possibility of introducing undesirable microorganisms into food, all utensils and equipment surfaces that contact food must be cleaned and sanitized before use and following any interruption during which they may have become contaminated;

- When utensils or equipment are used in a continuous production operation, they must be cleaned and sanitized on a predetermined schedule;
- Any facility, procedure, machine or device may be used for cleaning and sanitizing, as long as it has been established that the procedure will do the job effectively.

Storage and Handling of Clean Portable Equipment and Utensils

a. This refers to portable equipment or utensils which have surfaces that will contact foods;
b. When such equipment or utensils have been cleaned and sanitized, they should be stored in a manner that will protect the food contact surfaces from splash, dust and other contamination.

Sanitary Facilities and Controls

Water Supply

Any water that comes into contact food or processing equipment must be safe and of adequate sanitary quality.

Sewage Disposal

Must flow into an adequate sewage system or disposed of through other adequate means.

Plumbing

Must be of adequate size and design to:

a. Supply enough water to areas in the plant where it is needed;
b. Properly convey sewage or disposable liquid waste from the plant;
c. Not create a source of contamination or unsanitary condition;
d. Provide adequate floor drainage where hosing-type cleaning is done or where operations discharge water or liquid waste onto the floor;

e. Insure that there is no backflow from cross-connection between piping systems that discharge waste water or sewage, and those that carry water for food or food manufacturing.

Toilet Facilities

a. Toilets and hand-washing facilities must be provided inside the fruit and vegetable processing centres;
b. Toilet tissue must be provided;
c. Toilets must be kept sanitary and in good repair;
d. Toilet rooms must have self-closing doors;
e. Toilet rooms must not open directly into areas where food is exposed unless steps have been taken to prevent airborne contamination (example: double doors, positive airflow, etc.);
f. Signs must be posted that direct employees to wash their hands with soap or detergent after using the toilet.

Hand-washing Facilities

a. Adequate and convenient hand-washing and, if necessary, hand-sanitizing facilities must be provided anywhere in the plant where the nature of employees jobs requires that they wash, sanitize and dry their hands;
b. These hand-washing facilities must provide:
    - Running water at a suitable temperature;
    - Effective hand-cleaning and hand-sanitizing preparations;
    - Clean towel service or suitable drying devices;
    - Easily cleanable waste receptacle;
    - Water control valves designed and constructed to protect against recontamination of clean, sanitized hands;
    - Signs directing employees handling unprotected food to wash and, if appropriate, sanitize theirs

hands before starting work, after each absence from the workstation, and any other time when the hands have become soiled or contaminated.

Rubbish and offal disposal must be handled in such a manner that they do not serve to attract or harbour pests or create contaminating conditions.

Equipment and Utensils

a. Equipment and utensils must be designed and constructed so that they are adequately cleanable and will not adulterate food with lubricants, fuel, metal fragments, contaminated water, etc.
b. Equipment should be installed so that it, and the area around it, can be cleaned;
c. Food contact surfaces shall be made of nontoxic materials and must be corrosion-resistant;
d. Seams on food contact surfaces shall be smoothly bonded, or maintained in order to minimize the accumulation of food particles, dirt and organic matter;
e. Equipment in processing areas that does not come into contact with food shall be constructed so that it can be kept clean;
f. Holding, conveying and manufacturing systems, including gravimetric, pneumatic, closed and automated systems, shall be maintained in a sanitary condition;
g. Each freezer and cold storage compartment shall have an indicating thermometre, temperature measuring or recording device, and should have an automatic control for regulating temperature, or an automatic alarm system to indicate a significant temperature change;
h. Instruments and controls used for measuring, regulating or recording temperatures, pH, acidity, water activity, etc. shall be adequate in number, accurate and maintained.

Processes and Controls

There must be an individual who is responsible for supervising the overall sanitation of the plant.

Raw materials and ingredients:

a. Must be inspected and sorted to insure that they are clean, wholesome and fit for processing into human food;

b. Must be stored under conditions that will protect against contamination and minimize deterioration;

c. Must be washed or cleaned to remove soil and other contamination:

   - Water used for washing, rising or conveying food products must be of sanitary quality;
   - Water must not be reused for washing, rinsing or conveying if contamination of food may result;
   - Containers and carriers (such as trucks or railcars) should be inspected to assure that their condition has not contaminated raw ingredients;

d. Raw materials shall not contain levels of microorganisms that may produce food poisoning or other disease, or they shall be pasteurized or otherwise treated during manufacturing operations so that the product will not be adulterated;

e. Materials susceptible to contamination with natural toxins, e.g., aflatoxin, shall comply with national and international official levels before they are incorporated into the finished food;

f. Materials susceptible to contamination with pests, undesirable microorganisms, or extraneous material, shall comply with national and international regulations, guidelines and defect action levels;

g. Materials shall be stored in containers, and under conditions which protect against contamination;

h. Frozen materials shall be kept frozen. If thawing is required prior to use, it shall be done in a manner that prevents contamination.

Manufacturing operations:

a. Food processing equipment must be keep in a sanitary condition through frequent cleaning and, when necessary, sanitizing. If necessary, such equipment must be taken apart for thorough cleaning.

b. It is necessary to process, package and store food under conditions that will minimize the potential for undesirable microbiological growth, toxin formation, deterioration or contamination. To accomplish this may require careful monitoring of such factors as time, temperature, humidity, pressure, flow rate, etc. The object is to assure that mechanical breakdowns, time delays, temperature fluctuations or other factors do not allow the foods to decompose or become contaminated.

c. Food shall be held under conditions that prevent the growth of undesirable microorganisms as follows:
   - Refrigerated foods shall be maintained at 45° F or below;
   - Frozen foods shall be maintained in a frozen state;
   - Acid or acidified foods to be held in hermetically sealed containers at ambient temperatures shall be heat-treated to destroy mesophyllic microorganisms;

d. Measures such as sterilizing, irradiating, pasteurizing, etc., shall be adequate to destroy or prevent the growth of undesirable microorganisms;

e. Work-in-process shall be protected against contamination;

f. Finished food shall be protected from contamination;

g. Equipment, containers and utensils shall be constructed, handled and maintained to protect against contamination;

h. Measures, e.g., sieves, traps, metal detectors, shall be used to protect against the inclusion of metal or other extraneous material in food;

i. Food or materials that are adulterated shall be disposed of in a manner that prevents other food from being contaminated;

j. Mechanical manufacturing steps such as washing, peeling, etc., shall be performed to protect against contamination by providing adequate protection from contaminants that may drip, drain or be drawn into the food, by adequately cleaning and sanitizing all food-contact surfaces and by using time and temperature controls at and between each manufacturing step;

k. Heat-blanching should be done by heating the food to the required temperature, holding it at this temperature for the required time, and then either rapidly cooling the food or passing it to the next manufacturing step without delay;

l. Filling, assembling, packaging, and other operations shall be performed in such a way that the food is protected against contamination by:
   - Use of a quality control operation in which the Critical Control Points are identified and controlled during manufacturing;
   - Adequate cleaning and sanitizing of all food-contact surfaces and food containers;
   - Using materials for food containers and food-packaging materials that are safe and suitable;
   - Providing physical protection from contamination, particularly airborne contamination;
   - Using sanitary handling procedures.

m. Food such as, but not limited to, dry mixes, nuts, intermediate moisture food, and dehydrated food, that relies on the control of aw for preventing the growth of undesirable microorganisms shall be processed to and maintained at a safe moisture level by:
   - Monitoring the aw of food;
   - Controlling the soluble solids/water ratio in finished food;

- Protecting finished food from moisture pickup, by use of a moisture barrier, or by other means, so that the Aw of the food does not increase to an unsafe level;

n. Food such as, but not limited to, acid and acidified food, that relies principally on the control of pH for preventing the growth of undesirable microorganisms shall be monitored and maintained at a pH of 4.6 or below by: - Monitoring the pH of raw materials, food in process, and finished food; - Controlling the amount of acid or acidified food added to low-acid food;

o. If ice is used and comes in contact with food products, it must be made from potable water and be in a sanitary condition;

p. Areas and equipment that are used to process human food should not be used to process non-human food-grade animal feed, or inedible products unless there is no possibility of contaminating the human food;

q. A coding system should be utilized that will allow positive lot identification in the event it is necessary to identify and segregate lots of food that may be contaminated.
   - Records should be kept for a period of time that exceeds the self life of the product, except that
   - Records need not be kept beyond two years.

HAZARD ANALYSIS AND CRITICAL CONTROL POINTS (HACCP)

Preprocessing Steps - Converting Raw Foods to Ingredients

Fruit and vegetables as raw materials start as living cells and as such can vary in composition, colour, flavour structure and nutrient content. Thus a key part of describing a process is the preparation of detailed specifications for ingredients and packaging materials to ensure that final product performance and composition specifications can be met with the specified process and equipment. This is only possible if ingredients are preprocessed to the desired specifications.

Thus the processing of foods must be separated into two broad areas: preparation of raw fruit and vegetables for further processing to consumer products or ingredients; assembly of preprocessed ingredients to finished consumer products.

The assembly of preprocessed ingredients to finished consumer products will be discussed to illustrate principles used to describe a process for quality control. These principles apply to the conversion of raw foods to processed products. The chief differences are the variations in raw product specifications and certain washing, peeling, size reduction and blanching or heat treatment steps needed to convert highly variable raw materials to standardized ingredients.

Typical operations using in converting raw fruits and vegetables to processed- ingredients for packaging and preservation or prior to a further heat treatment processing are as follows:

Harvesting or Gathering → Transport → Storage → Washing → Size Grading → Peeling (Removal of outer surface) → Size Reduction → Separation of waste → Sorting Inspection→ Storage.

Process Description for Quality Control

One of the most important specifications of a product is its safety in terms of microbial contamination, freedom from hazardous chemicals and absence of foreign materials such as metal pieces, non-edible parts such as pits or woody stem material and dirt, insect parts or other extraneous material.

The microbial safety of processed fruits and vegetables is of prime importance from a quality viewpoint. The following analysis is to provide a description of a process to help ensure that microbial safety can be achieved with a minimum opportunity for failure of the finished product to meet specifications.

Process Operations

Food processing steps require a detailed description when microbial safety is a concern. The reason for this is that ingredients, packages, equipment, and the surroundings all potentially can contaminate the final product with pathogenic or spoilage microorganisms.

Further, if the conditions of pH (acidity), temperature, moisture and nutrient level are suitable, rapid microbial growth is possible on processing equipment and in the food itself. Thus while microbiological specifications can be written for incoming ingredients, actual microbial counts can increase during each process step if the process is not designed properly.

One of the first requirements for the description of a process is to determine if an individual process step will increase (+), decrease (-) or result in nonchange (=) in the microbial content of food undergoing the processing step. This can be determined from the chemical and physical conditions of the food and surroundings in each processing step.

The physical and chemical conditions of a food passing through a processing step can be recorded for each process step needed to prepare a finished product. A hot fill can be used since the product has pH below 4.5 and thus is considered an acid product. The product contains four ingredients: fruit concentrate, flavour mix, sugar and water. Two package components are shown: the can and the can cover.

Individual processing steps are identified in the preparation of the canned juice drink from warehouse inventory to just prior to can labelling. Processing steps needed to prepare the package for filling and sealing are listed on the right side of the chart.

For purpose of analyses the juice drink must have a pH of 3.8, a fill temperature of no lower than 190° F and must leave the cooling tunnel at a temperature below 90° F. These requirements are highlighted in their appropriate column to ensure that the proper process control and quality control procedures are in place.

This column is included to allow each step to be challenged from a microbiological viewpoint. "What ifs" will show whether the specified Critical Control Points will protect the product from microbial failure.

Two sources of failure are evident. The can fill temperature must be 190° F or above and regular can and lid inspections are needed to ensure that double-seals are always within specifications. The pH of the system may be less critical since the fruit concentrate will bring the pH below 4.5 even without the dry mix.

The process steps shown above can be contrasted with the process used in the preparation of a vacuum packed, refrigerated, cooked meat soup. This product depends on low temperatures for preservation as well as low vegetative microbial counts. Equipment sanitation, prevention of air borne contamination during filling, seal integrity and rapid cooling are essential parts of the process.

Even with these requirements in control, the heat treatment given the products (heating to 200° F), with a variable 0-60 min hold) is not sufficient to inactivate Clostridium botulinum. Thus the product must be cooled to 35° F within 40 minutes to prevent any possible germination and outgrowth of Clostridium botulinum spores.

Further, the manufacturer of this product must provide a means to ensure that the product is used within a specified time and is always kept at or below 35° F if it is to be released to the public.

Operation	Equipment	(+,-,=)	Reason	Temp. °F
1. Storage	Warehouse			
2. Transport	Fork lift			
3. Storage	Storage tank			
4. Weigh dry ingred	Scale	+	Poor sanitation	
5. Weigh wet ingred	Weigh Kettle			
6. Blend	Kettle			
7. Heat	Kettle	=	Low temp.	195
8. Transport	Pump	=	Sanitation	190
9. Delay	Surge tank	=	Low temp.	190
10. Filler bowel level control	Valve	=	Sanitation	190

11. Separation	Pipe filter	=	Sanitation	190
12. Can fill	Filler	=	Low temp.	190
13. Lid coding	Coder			
14. Seam	Double seamer	+	(Poor seams)	190
15. Lid sterilisation	Can inverter	=		190
16. Hold delay	Conveyor	=		190
17. Can cooling	Cooling tunnel	=		90
18. Drying	Can dryer	+	Insufficient heat, leaks	

Food Processes in General

The above figures show typical product preparation sequences for a thermally preserved and a refrigerated products. It is important to know the following information to determine the microbial safety of a product and to determine what quality control actions will be needed to achieve a safe product when used under the conditions for which it was designed.

First, all raw material, ingredients and packaging materials in contact with the food must be specified and if needed tested to meet specifications.

Second, it is important that an element of food be observed as it enters, passes through and leaves the process. This "ride" on a particle of the food should provide the following data at each process step from entry to discharge:

- Food temperature;
- Time at each temperature;
- pH;
- Oxygen concentration;
- Water activity.

Further if preservatives are required to prevent microbial growth, their addition point and concentration throughout the entire food mass should be shown. Finally for products which depend on a sealed package one should check the seal integrity of each container produced.

As one rides along the food as it travels through each step it is necessary also to observe the number and types of microorganisms entering or leaving the food and if these numbers are increasing (+), decreasing (-) or remaining the same (=).

These data when reviewed for quality control procedures will help ensure a safe, reliable and cost effective process.

Table: Vacuum packed refrigerated meat soup. Inventory of process steps for ingredients, packages and process conditions to provide a basis for Hazard Analysis

Operation	Equipment	(+,-,=)++	Reason	Temp. °C
Storage	Warehouse			
Transport	Fork lift			
Weigh water	Weigh Kettle			
Rlend ****	Kettle	+	Poor sanitation	
Heat ****	Lettle	+	Slow heating	200
Transport	Pump	+	Por sanitation	195
Filter	Screen	+	Sanitation	195
Control	Float in bowl	+	Sanitation	190
Fill	Filter	+	Sanitation, air contamination	190
Lid	Sealer	+	Contaminated, Poor packaging, seal	190
Tab	Cooling	+	Slow, poor cooling ***** Insufficient heat, leaks	35

Source: D.F. Farkas (1991)

** "Potential for microbial growth if out of control"

*** pH of the product is 6.3

**** 30 min. total time (60 min. as kettle is used as filler supply tank for 30 min.)

***** Product must be held at 35°F untill used.

Hazard analysis and critical control points (HACCP) in food industry - steps to be considered:

a. Acquire a good knowledge of the product flow-sheet, from raw and pack material suppliers to consumers.

b. Assess each step and establish associated potential risk for:

- Consumer safety (e.g. foreign bodies, microbiology, aflatoxins, pesticides, heavy metals, monomers, etc.);
- Edible quality of the product (e.g. taste, texture, colour, smell, appearance, etc.).

c. Plot a complete product flow-sheet and establish the Critical Control Points (CCP).

d. Associate with each CCP an action in order to eliminate risks and prepare an action plan.

e. Implement the agreed actions and keep records of results.

f. Evaluate the results of actions vs. risks and prepare an on-going working plan.

g. Decide on a permanent monitoring of CCP.

Table: Simple process description for hazard analysis

Onion Processing Unit - Technological Line for Dehydration Dehydration in belt dryers

Equipment	Operation
(1) Device for emptying of raw material transport boxes	Unloading
(2) Vertical elevator	Transport
(3) Peeling machine	Peeling/"cleaning" of raw material by dry method
(4) Sorting and control belt	Control
(5) Size grader	Control
(6) Distribution table	
(7) Bagging machine	
(8) Vertical transporter	Transport
(9) Machine for cutting of ends	Cutting
(10) Transporter with weighing device	Transport and weight measure

(11) Cleaning machine	Cleaning
(12) Vertical transpoeter	Transport
(13) Cutting machine	Cutting
(14) Transport belt with water sprays	Transport and washing
(15) Vertical transporter	Transport
(16) and (17) Device for adjusting drying belt speed	Belt speed regulation
(18) Belt type dryer	Drying

11

Fruit and Vegetable Processing Units

PRELIMINARY STUDY

Each new fruit and vegetable processing centre needs a good, specific preliminary study including, among other considerations, the following aspects:

a. Raw material availability;

b. Raw material quality in adequate varieties for the types of finished products that will be manufactured;

c. Harvesting and transport practices and organisation from the field to the processing centre;

d. Processing capacity related to raw material availability: quantities, seasonability, etc.

e. Processing equipment size/capacity suitable for above points;

f. Availability of trained operators and resources to improve their knowledge;

g. Availability of workforce in the area and resources for training them in order to be able to assure adequate trained operators;

h. Availability of utilities: electricity, etc.

i. Position of the future processing centre as related to raw material fields and to closest transportation means; road access, railway access.

j. Last but not least, market availability for finished products and for optional semi-processed products.

The decision to invest in fruit and vegetable equipment MUST be taken case by case and only after an adequate, specific preliminary study has been carried out by specialists or a specialist organisation.

HOW TO PREPARE, START AND OPERATE A FRUIT AND VEGETABLE PROCESSING CENTRE

Additional recommendations and "hints" to prepare, start and operate a fruit and vegetable processing centre are as follows:

a. Assure a raw material temporary storage capacity/ surface for 2-5 processing days. Invest in an adequate size cold room for sensible raw materials;

b. Plan the equipment to operate at the start-up for at least one working shift (about 7-9 hours) per day, for 5 working days per week; when needed, a second shift could be organized;

c. Plan to operate the processing centre for a maximum number of working days per year). In order to achieve this, invest in the buildings and equipment which will be able to:.

    - Process as many species of fruits and vegetables as possible/as available;
    - Use as many preservation methods as possible, e.g. drying, dehydration, concentration, sugar preservation, etc.

d. Whenever possible, "rush" the utilisation of available raw materials during crop season by additional manufacturing of semi-processed products and transform these in consumer finished products during the off-season.

e. Excessive automatization of processing equipment DOES NOT directly imply a good quality of finished product;

f. Raw material quality is a major element with positive impact on finished product quality;

g. Initial and continuous personnel training and motivation is also an important factor in the success or failure of a processing centre and in assuring a constant finished product quality;

h. Keep finished product stocks at a minimum adequate level;

i. Remember that the three main "outputs" of the processing centre have to be prioritized in the following order:

   Priority 1: Finished product quality conforms to specifications and standards: national and/or international, consumer special requests, etc.

   Priority 2: Continuous and reliable supply of finished products to the domestic and export markets throughout the year (or at least throughout the "marketing season" of specific products);

   Priority 3: Manufacturing and transport costs as low as possible, inside the stringent need to cover the first two priorities;

j. When deciding on the equipment output, take into consideration all elements specified and mainly raw material availability and market demand for a specific finished product;

k. Invest in simple, modular processing lines which can, with some simple on-site configuration modifications, process various types of finished products; this is mainly important for the first technological steps (preparation of raw materials, etc);

l. Plan to use as much as possible of the raw materials supplied/received to the processing centre.

   This should be facilitated by the initial design and by a good day-to-day organisation and management; all these should enable, if necessary, to make a different use of each "quality" or grade of raw materials, e. g. using them for different finished products: one quality for drying/dehydration, an other quality for juices, etc.

m. Take into account the fact that the marketability of finished products will be differ in terms of types and quality for domestic and export markets.

   Be sure that an export specialized staff/organisation will help with specific export advice. To export successfully is a different job to processing fruit and vegetables.

n. Avoid investing in one "big" processing line, very sophisticated in terms of automation, etc. with a high output capacity but having potential following drawbacks: being able to "generate"/produce only one finished product type from only one raw material; having too high a degree of equipment fixation work for installation and therefore very high difficulties in using the processing equipment in a modular " interchangeable " way.

o. As an initial investment prefer small size processing lines, with modular equipment arrangement (i.e. able to be integrated in various technological configurations for processing of as many raw materials as possible and generating different finished products).

p. As compared with important processing units in developed countries, it is possible to formulate as a very general rule for developing countries, that for the usual size of equipment, for a comparable environment frame, the scale/size should be approximatively 1:10 from those actually in use in developed countries.

Fruit and Vegetable Processing Centre - Module "Level 5" Family Level

a. Buildings

   i. Covered area for temporary storage of raw materials and washing; surface = 10 sq. m.

   ii. Room for wet processing (cutting, dipping, boiling, water blanching, pasteurization, etc.) = 25 sq. m.

   iii. Room for dry processing = 25 sq. m. iv. Room for storage of processed products = 10 sq. m.

Area (i) is simply covered; area (ii) could be similar to a simple house kitchen; areas (iii) and (iv) could be similar to house rooms.

b. Outside drying yard

This area is needed in order to install: simple sun drying trays; tent sun dryer; cabinet sun dryer.

At best, this area have to be cemented to avoid excessive dust generation.

A minimum surface of 50 sq. m. is necessary.

c. Equipment and material

Working tables (2)

Improved stoves (3)

Stainless steel pots 51(2)

Stainless steel pots 101(2)

Stainless steel pots 151(1)

Stainless steel knives, 12-15 cm blade (10)

Stainless steel spoons, various shapes and sizes (5).

Stainless steel household sieves (3)

Wooden spoons (5)

Glass jars, various sizes and screw-on caps (200)

Aluminium pots: 251(1); 401(2);

Hand-operated pulp extractor

Bottle brushes (10)

Plastic lemon-squeezer

Stainless steel skimmer

Aluminium ladle

Sun dryer (tent type)

Sun dryer (cabinet type)

Standard wood sun drying trays (20)

Bottles (0.33 1)

Crown tops

Jars (0.300 1)

Screw-tops for jars

Wood (or other available fuel) heating plates

Hand-operated capping device (capper)

Work bench (3)

Stainless steel vegetable cutter (5)

d. Simple technological recommendations

i. Ingredients

- Sugar and potassium metabisulphite (K2S2O5) are used as preservatives;
- Lemon or lime juice is added to the products to rectify the acidity (this improves storage stability and taste).

ii. Hygiene measures

- The workers should carefully wash their hands before any product processing operations;
- The utensils and equipment will have to be properly cleaned before and after use, in order to remove dust and any possible organic particle;
- The packaging materials, i. e. bottles and jars, have to be washed with a hand-operated appliance, hot clean water and sand. After washing, rinsing with clean water will be carried out;
- Damaged parts of the fresh raw materials, as well as waste, will have to be discharged and disposed outside of the working area;
- Before storage, the finished products will be washed and dried (this apply for jars and bottles) and properly labelled;

- The preparation and drying areas must NOT be located in the vicinity of a stock-farm.

Fruit and Vegetable Processing Unit - Module "Level 4" Farm and/or Community Level

a. Buildings

   i. Covered platform for temporary storage of raw materials and washing; surface = 25 sq. m.

   ii. Room for wet processing (cutting, dipping, boiling, water blanching, pasteurization, etc.) = 40 sq. m.

   iii. Room for dry processing = 40 sq. m.

   iv. Storage room for processed products = 20 sq. m.

   All areas need to be on a cemented platform.

   Area (i) is simply covered and surrounded by plastic sheeting to avoid dust contamination.

b. Outside drying yard

   This area is needed in order to install various dryers: simple sun drying trays; tent sun dryer; cabinet sun dryer; cabinet solar dryer with heat collector, etc.

   Ideally, this area should be cemented to avoid excessive dust generation.

   A minimum surface of 70 sq. m. is necessary.

   Access to the drying yard must be closed to non-production personnel.

   It is useful to construct some surface for shade drying from the beginning; this surface could be also be used in order to protect, if needed, drying trays in case of rain.

c. Equipment and material

   Working tables (3)

   Scales: 0-50 kg, precision 1 kg

   Hand refractometre 0-90 ° Brix (2)

   Thermometres 10-100° C (5)

   Improved stoves (3)

   Stainless steel pots 51(2)

Stainless steel pots 101(2)
Stainless steel pots 151(3)
Stainless steel knives, 12-15 cm blade (10)
Stainless steel spoons, various shapes and sizes (5)
Stainless steel household sieves (3)
Wooden spoons (5)
Rigid plastic funnels, large bottom (10)
Glass jars, various sizes and screw-on caps (500)
Aluminium pots: 251(1); 401(2); 501(3)
Hand-operated pulp extractor
Electrical pulp extractor
Bottle brushes (10)
Plastic lemon-squeezer
Plastic colanders
Stainless steel skimmer
Aluminium ladle
Sun dryers (tent type)
Sun dryers (cabinet type)
Solar dryers (cabinet type) with heat collector
Standard wood sun/solar drying trays (30)
Bottles (0.5 1)
Bottles (0.33 1)
Crown tops
Jars (0.580 1)
Jars (0.300 1)
Screw-tops for jars
Electrical heating plates
Gas-fired heating plates and/or available fuel heating plates (wood, etc.)
Hand-operated capping device (capper)
Rigid plastic drums 501(5)

Work benches (3)

Stainless steel vegetable cutter (5)

d. Simple technological recommendations

   i. Ingredients

   - Sugar and potassium metabisulphite (K2S2O5) are used as preservatives;
   - Lemon or lime juice are added to the products to rectify the acidity (this improves storage stability and taste).

   ii. Hygiene measures

   - The workers should carefully wash their hands before any product processing operations;
   - The utensils and equipment will have to be properly cleaned before and after use, in order to remove dust and any possible organic particle;
   - The packaging materials, i. e. bottles and jars, have to be washed with a hand-operated appliance, hot clean water and sand. After washing, a rinse with clean water will be carried out;
   - Damaged parts of the fresh raw materials, as well as the waste, will have to be discharged and disposed of outside of the working area;
   - Before storage, the finished products will be washed and dried (this apply to jars and bottles) and properly labelled;
   - The preparation and drying areas must NOT be located in the vicinity of a stock-farm.

Fruit and Vegetable Processing Unit - Module "Level 3" Community and/or Entrepreneurial Level

a. Buildings

   i. Covered platform for temporary storage of raw materials and washing; surface = 50 sq. m.

ii. Workshop for wet processing (cutting, dipping, boiling, water blanching, pasteurization, etc.) = 70 sq. m.

iii. Workshop for dry processing = 70 sq. m.

iv. Storage room for finished products = 30 sq. m.

v. Room for simple Quality Control checks = 15 sq. m.

All areas need to be on a cemented platform.

Area (i) is simply covèred and surrounded by plastic sheets in order to avoid dust contamination.

b. Outside drying yard

This area is needed in order to install various dryers: simple sun drying trays; tent sun dryer; cabinet sun dryer; cabinet solar dryer with heat collector, etc.

Ideally, this area should be cemented to avoid excessive dust generation.

An approximate surface of 100 sq. m. is necessary.

Access to the drying yard must be closed to non-production personnel.

It is useful to build some surface for shade drying from the beginning; this surface could be used also in order to protect drying trays with products in case of rain. Drums/receptacles with vegetables could be stored here during first step of lactic fermentation (preservation by natural acidification).

c. Equipment and material

Working tables (5)

Scales: 0-50 kg, precision 0.1 kg

Scales: 0-3 kg, precision 1 g

Hand refractometre 0-900 Brix (2)

Thermometres 10-100° C (10)

Screen pulper-finisher; capacity 50 kg/in sieves: 0.015 in; 0.030 in; 0.045 in.

Improved stoves (5)

Stainless steel pots 5 1(3)
Stainless steel pots 10 1(3)
Stainless steel pots 15 1(3)
Medium size SO2 generator
Electrical heated ventilated oven, cap. 30 1
Small cool/cold room: volume = 20 m^2;
temperature = +4° C to + 15° C
Stainless steel knives, 12-15 cm blade (15)
Stainless steel spoons, various shapes and sizes (10)
Stainless steel household sieves (5)
Wooded spoons (5)
Rigid plastic funnels, large bottom (10)
Glass jars, various sizes and screw-on caps (500)
Aluminium pots: 251(3); 401(3); 501(5)
Hand-operated pulp extractor
Electrical pulp extractor
Bottle brushes (25)
Plastic lemon-squeezer
Plastic colanders
Stainless steel skimmer
Aluminium ladle
Sun dryers (tent type)
Sun dryers (cabinet type)
Solar dryers (cabinet type) with heat collector
Stainless steel drying trays (15) - for fruit leather
Standard wood sun/solar drying trays (45)
Bottles (0.5 1) Bottles (0.33 1)
Crown tops
Jars (0.580 1) Jars (0.300 1)

Screw-tops for jars

Electrical heating plates

Gas fired heating places

Hand-operated capping device (capper)

Rigid plastic drums 501(5)

Work benches (5)

Stainless steel vegetable cutter (5)

d. Simple technological recommendations

i. Ingredients

- Sugar and potassium metabisulphite (K2S2O5) are used as preservatives;
- Lemon or lime juice are added to the products to rectify the acidity (this improves storage stability and taste).

ii. Hygiene measures

- The workers should carefully wash their hands before any product processing operations;
- The utensils and equipment will have to be properly cleaned before and after use, in order to remove dust and any possible organic particle;
- The packaging materials, i. e. bottles and jars, have to be washed with a hand-operated appliance, hot clean water and sand. After washing, a rinse with clean water will be carried out;
- Damaged parts of the fresh raw materials, as well as waste, will have to be discharged and disposed of outside of the working area;
- Before storage, the finished products will be washed and dried (this applies to jars and bottles) and properly labelled;
- The preparation and drying areas must NOT be located in the vicinity of a stock-farm.

Fruit and Vegetable Processing Unit - Module "Level 2" Business Level

a. Buildings

   i. Covered platform for temporary storage of raw materials and washing; surface = 100 sq. m.

   ii. Workshop for wet processing (cutting, dipping, boiling, water blanching, pasteurization, etc.) = 100 sq. m.

   iii. Workshop for dry processing = 100 sq. m.

   iv. Storage room for finished products = 70 sq. m.

   v. Quality Control Laboratory = 25 sq. m.

   All areas need to be on a cemented platform; recommendations about processing workshops and all points related to buildings, equipment, etc. as presented in section 10.2 of this document (Good Manufacturing Practices - GMP - and Hygiene Requirements) must be integrated in the design and respected during construction, installation and operation.

   Area (i) is covered and surrounded by plastic sheets to avoid dust contamination. Areas (ii), (iii), (iv) and (v) should conform to the quality standards described in section 10.2.

b. Outside drying yard

   This area is needed in order to install:

   i. Various dryers: simple sun drying trays; tent sun dryer; cabinet sun dryer; cabinet solar dryer with heat collector;

   ii. SO_2 generator; sulphuring cells.

   This area should be cemented to avoid excessive dust generation. A approximate surface of 150 to 200 sq. m. is necessary.

   Access to the drying yard must be closed to non-production personnel.

   It is useful to build some surface for shade drying from the beginning; this surface could be used also in order to protect drying trays with products in case of rain. Drums/receptacles with vegetables could be stored here during first step of lactic fermentation (preservation by natural acidification).

c. Equipment and material

i. Equipment for small size operations, trials, etc. similar to module "level 3".

ii Equipment for raw material preparation before processing

Washing machine - dip washer A 106 with exit elevator out of tank.

Peeler with abrasive action A 302 B

Peeler for special products (with holes and knives) A 302 KS

Cutting machines - two models

iii. Equipment for preparation of pulp/juice extraction

Continuous simple crusher A 502 V

Horizontal pulper A 602

Turbo refiner A 605

Continuous extractor A 810

iv. Equipment for blanching/cooking/concentration/ evaporation

Cooking kettle - adapted to available heating source in the centre: gas direct or indirect heating (B 201); steam jacketed pans (B 202); electrical heating (oil jacketed) (B 2010). At least 3 cooking kettles (70-901; 100-1201 and 150-2001 capacity) are needed.

Continuous water blencher rotating drum model for vegetables B 204

Vacuum cooker B 2030

Large stainless steel tank for cooling after blanching

Steam generator

Double bottom tanks for scalding/blanching

v. Equipment for pasteurization, including preparation (deaeration, etc)

De-aerator for pulps, juices, etc.

Multitubular cooker - pasteurizer for pulps, juices, concentrates, etc.

Horizontal steriliser

Steam heated processing retort 120 l, model D 200 (or gas heated processing retort 120 l, model D100)

vi. Equipment for drying/dehydration

Cabinet dryers (5) - electrical/steam/fuel heated according to source of energy available in the processing centre

Medium size SO_2 generator

Sulphuring cells (3)

Small size tunnel dryer vii. Filling machines

Pouch filler model E 104 for all liquid and paste products, dosing capacity: between 0.5 and 25 kg

Semi-automatic pneumatic closer model E 101 for all kinds of liquids, semi-liquids, pasty products and mixed products (with pieces)

viii. Seaming and capping machines

Seamer model V 10 C 502

Semi-automatic capping machine model C 604 for twist off, screw type, crown type

Relief marker for lids model C 701

ix. Miscellaneous equipments: mobile product wagons; storage tanks; mixing tanks; rotating mixer for mixed vegetables.

x. Medium size cool/cold room; volume = 30-40 m^3; temperature = + 2 to + 15° C.

xi. Laboratory equipment:

laboratory refractometre model ABBE F 1602;

thermobalance model F 1604;

laboratory retort model F 2500 (autoclave);

processing control oven (60° C) model F 1200;

pocket model pH metre F 1701;
laboratory model pH metre F 1703.
penetrometre;
microscope;
incubation oven;
analytical balance;
miscellaneous equipment & supplies: inoculation tubes, Petri dishes, Colony Counter, beakers, pipettes, etc.

xii. Control equipment:
can seaming checking display (on base and hand models);
reflexiometre model F 1603 for dense products;
jars vacuum detector with measure of cap deflexion;
various thermometres; various manometres: can vacuum indicator;
vacuum and pressure; standard);
hand model refractometres model F 1601 for juices, concentrates, jams, etc.

Fruit and Vegetable Processing Centre - Module "Level 1" Business and/or National Level

The "level 1" module has two main characteristics: utilisation of complete processing lines; specific equipment for particular fruit or vegetable, for example: specific mango destoning machines, etc.

a. Buildings
   i. Covered platform for temporary storage of raw materials and washing; surface = 100 sq. m.
   ii. Workshop for wet processing (cutting, dipping, boiling, water blanching, pasteurization, etc.) = 150 sq. m.
   iii. Workshop for dry processing = 200 sq. m.
   iv. Storage room for processed products = 120 sq. m.

v. Quality Control Laboratory = 35 sq. m.

All areas need to be on a cemented platform; recommendations about processing workshops and all points related to buildings, equipments, etc. as presented in section 10.2 (Good Manufacturing Practices - GMP - and Hygiene Requirements) must be integrated in the design and respected during construction, installation and operation.

Area (i) is covered and surrounded by plastic sheets to avoid dust contamination.

Areas (ii), (iii), (iv) and (v) should conform to the quality standards described in section 10.2.

b. Outside yard

This area is needed in order to install:

i. various dryers: simple sun drying trays; tent sun dryer; cabinet sun dryer; cabinet solar dryer with heat collector;

ii. SO_2 generator; sulphuring cells;

iii. storage of drums for natural acidified vegetables (preservation by lactic fermentation);

The area should be cemented to avoid excessive dust generation. An approximate surface of 250 sq. m. is necessary.

Access to the outside yard must be closed for non-production personnel.

It is useful to build some surface for shade drying from the beginning; this surface could be used also in order to protect drying trays with products in case of rain. Drums/receptacles with vegetables could be stored here during first step of lactic fermentation (preservation by natural acidification).

c. Equipment and material

As a basic minimum, a "level 1" processing unit module needs the same equipment as a "level 2" module.

The following pages list recommendations for various specialised processing lines for tomato products and for tropical fruit products.

Manufacturing Processing Lines for Tomato Products and Tropical Fruit Products

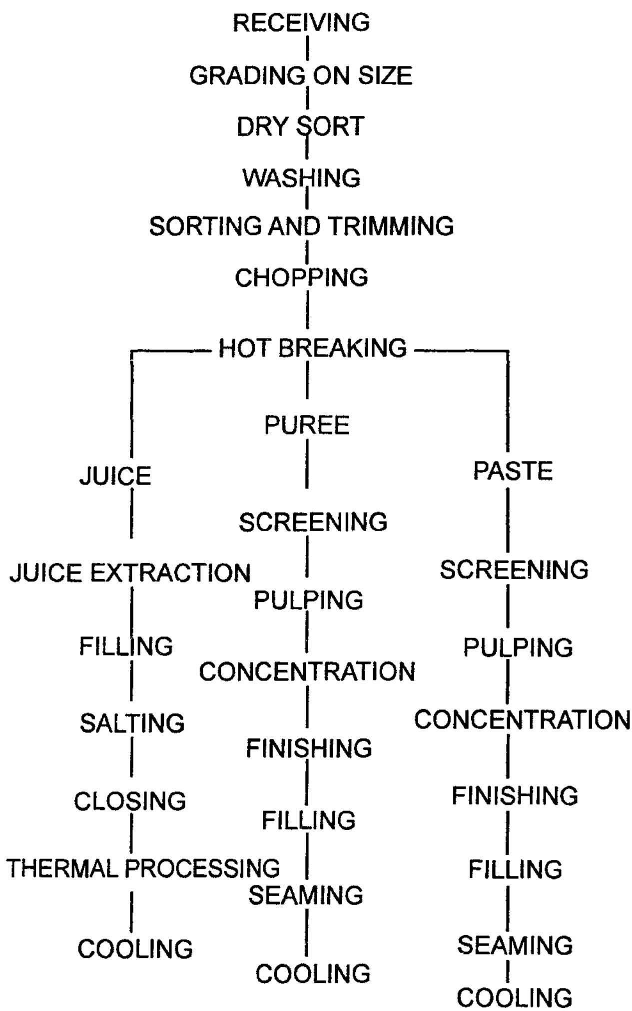

Fig: Flow-sheet of processing operations for tomato products

Factors affecting product quality:

a. Causes of flat-sour spoilage of tomato juice:
   - Use of unsound, poor quality raw stock;
   - Rough handling of raw stock during transport and before and/or during washing operations;
   - Poor washing operations;
   - High pH of raw juice;
   - High level of contamination;
   - Insufficient heat treatment;
   - Contaminated equipment;
   - Poor sanitation.

b. Causes of spoilage of canned tomatoes:
   - Hydrogen swell - physico-chemical reaction between the metal of the can and the acids in the fruits;
   - Bacteria swell is usually caused by one or more members of the Lactobacillus group.

c. Causes of spoilage of tomato paste:
   - Leakage of container;
   - Inadequate cooling for product temperature;
   - Inadequate residual chlorine in the cooling water.

Most of these factors can affect also the quality of canned guava nectar, canned passion fruit nectar and of other tropical fruit products.

Table: Recommended process times for canned tomatoes by can size, minutes

	Still retort, 212°F		Agitating cooker, 212°F	
Can Size	**Water-cool**	**Air-cool**	**Water-cool**	**Air-cool**
303 x 406	45	35	14	9
307 x 409	45	35	14	9
401 x 411	55	45	18	13
603 x 700	100	80	25	20

The relationship of direct refractometric readings for natural tomato solids are listed in Table given below.

Table: Refractometric readings for natural tomato solids

Tomato pulp- puree Concentration	Tomato paste % solids	% solids
Light	8.0 - 10.1	24.0 - 28.0
Medium	10.1 - 11.3	28.0 - 32.0
Heavy	11.3 - 15.0	32.0 - 38.5
Extra heavy	15.0 - 24.0	over 38.5
Concentrated tomato juice	20.0 - 24.0	

Manufacturing Equipment for Canned Tomato Products and Tropical Fruit Products Factory

The products obtained in this factory would be mainly:

- Passion fruit nectar;
- Whole tomatoes;
- Tomato juice;
- Tomato paste; tomato purée.

The list of equipment by product is presented below; the first six items are common for all products:

1. Bin dumper;
2. Sizer;
3. Roller inspection table;
4. Soak tank washer;
5. Rotary washer;
6. Sorting, trimming table.

a. Production line for whole tomato products

7. Caustic peeler;
8. Inspection table;
9. Hand pack;
10. Salt dispenser;
11. Conveyor;
12. Juice filler; (juice is provided from pump 26)**;
13. Conveyor;
14. Steam flow steamer;
15. Conveyor;

16. Rotary pressure cooker;
17. Rotary cooler.

b. Production line for tomato juice

18. Distribution belt (common for all other lines);
19. Chopper;
20. Pump;
21. Hot break tank;
22. Pump;
23. Juice extractor;
24. Pump;
25. Heating tank;
26. Pump; (juice is fed into juice filler at (12) in whole tomato line from this point);
27. Strainer;
28. Filler;
29. Conveyor;
30. Seamer;
31. Conveyor;
32. Rotary pressure cooker;
33. Rotary cooler.

c. Production line for tomato purée, paste line

Tomatoes are fed into this production line from the hot break tank 21.

34. Pump;
35. Vibrating screen;
36. Pulper;
37. Pump;
38. Heating tank;
39. Pump;
40. Kettle;
41. Kettle;
42. Kettle;
43. Vacuum pan for paste;
44. Pump;

45. Finisher;
46. Pump;
47. Holding tank;
48. Pump;
49. Filler;
50. Conveyor;
51. Seamer;
52. Conveyor;
53. Cooler;

d. Production line for passion fruit and guava nectar

54. Elevator;
55. Passion fruit slicer;
56. Centrifugal peel separator;
57. Pump;
58. Distribution belt;
59. Disintegrator; (for guava nectar)
60. Pump;
61. Pulper; (for both passion fruit and guava)
62. Pump;
63. Finisher;
64. Pump;
65. De-aerator;
66. Formulation tank; (preparation of syrup for both passion fruit and guava nectars)
67. Pump;
68. Flash pasteurizer;
69. Pump;
70. Filler;
71. Conveyor;
72. Seamer;
73. Conveyor;
74. Spin-cooker-cooler;
75. Cooling belt;
76. Conveyor.

All products use a labeller/caser (77) and a conveyor for finished products. A passion fruit finished product can be processed as a good quality beverage base with sugar: juice ratio of 58:42, on dilution with 4 times its volume with water.

Passion fruit jelly is prepared containing 25% juice. Tomato juice concentrated with a Bertuzzi vacuum evaporator and centritherm equipment can be obtained. For tomato juice, two products have commercial application: canned natural tomato juice and spiced juice.

With small alterations of preparation equipment, mango products can also be obtained using the manufacturing plant described above for tomato and tropical fruits.

Temperate and tropical fruit jellies, marmalades, syrups, jams and various types of sugar preserves can also be manufactured in this plant as far as preparation and juice extraction equipment are available and that kettle can be used for cooking the preserves. The preparation equipment should be arranged in a "modular" way in order to enable multiple fruit processing steps.

Equipment specifications:

a. Equipment should be designed to hold the product with minimum spills and overflow.
b. Surfaces in contact with food should be inert and non-toxic, smooth and non-porous.
c. No coatings or paints should be used that could possibly chip, flake or erode into the product stream.
d. Equipment should be designed and arranged to avoid having pipes, mechanisms, drives, etc., above the open product streams.
e. Bearings and seals must be located outside the product zone or sealed and self lubricating.
f. Proper design avoids sharp or inaccessible corners, pockets, ledges so that all parts can be reached and cleaned easily. Build so that units are easy to take apart if necessary.

g. Loose items like locking pins, clips, handles, gates, keys, tools, fasteners, etc. that could fall into the product stream should be eliminated.

h. Equipment should be laid out for easy access for cleaning and servicing. Three feet from walls and between lines is recommended.

i. Any and all containers, bins, cans, lug boxes, etc., used in the packaging or handling of food products should not be used for any purpose other than their primary use. Special containers should be provided which are readily identifiable and cannot get into the product stream.

j. All equipment parts that come in contact with foods must be constructed with rust-resistant metal such as stainless steel.

Mango Processing Unit - Mango Juice in Bags "Hot Fill" Procedure

a. Main production equipment
   i. Scalder/washing machine model 1 106
   ii. Destoner model 1602
   iii. Thermobreak model CC05
   iv. Refiner
   v. Reception tank
   vi. Transfer pump
   vii. Mixing tank with shaking
   viii. Transfer pump
   ix. Tubular pasteurizer
   x. Bag filling machine model E 104
   xi. Cooling tunnel
b. Packaging materials
   i. Special bags, capacity from 5 kg to 25 kg, with adequate valve systesm for filling and closing; adapted to bag filling machine model E 104.

Table: Overall raw material consumption data/yield for fruit and vegetable processed products - approximate data

Finished products	Raw materials			kg/kg
	1. Vegetable pickles			
Red or green pepper	Cut pepper			1.250
in vinegar	Whole pepper			0.650
Cucumber in vinegar	Cucumbers			0.850
Cucumber in brine	Cucumbers			1.150
	2. Vegetable concentrated products			
2.1 Tomato paste type:	24%RE	30%RE	38%RE	
Tomato: 4% RE	6.000	8.300	10.450	
5% RE	5.300	6.000	8.360	
6% RE	4.400	5.500	6.970	
2.2 Tomato conc. juice	Tomatoes 4% RE			4.950
18% refractometric	5% RE			3.960
extract	6% RE			3.300
2.3 Tomato juice	Tomatoes			1.250
2.4 Tomato sauce 28 % RE	Tomato 5% RE			5.600
	3. Dehydrated vegetables			
Potatoes	Potatoes			7.600
Carrots	Carrots			9.000
Beets	Beets			8.000
Cabbage	Autumn cabbage			16.000
	Summer cabbage			20.000
Onions	Onions			9.000
Peas	Green peas, pods			11.500
Beans	Green beans			10.000
Pepper	Pepper			11.000
Garlic	Garlic			4.000
Okra	Okra			10.000
Eggplant	Eggplant			10.000

RE-Refractometric extract

	4. Dehydrated fruits	
Dehydrated plums	Plums	4.000
Dehydrated apricots, halves	Apricots	6.500

Dehydrated apples, cored, Peeled	Apples	10.000
Dehydrated apples, cored, non peeled	Apples	7.000
5. "Fruits in syrup"		
Whole apricots in syrup	Apricots	0.640
Half apricots in syrup	Apricots	0.750
Whole plums in syrup	Plums	0.630
Whole peaches in syrup	Peaches	0.630
Half peaches in syrup	Peaches	0.700
Apples in syrup	Apples	0.850
Pears in syrup	Pears	1.100
Quines in syrup	Quinces	0.900
Cherries in syrup	Cherries	0.740
Raspberry in syrup	Raspberries	0.750
Wild berries in syrup	Fruits	1.000
Strawberries in syrup	Strawberries	0.900
6. Special fruit jams		
Peaches	Peaches	0.880
Apricots	Apricots	0.800
Plums	Plums	0.750
Mixed fruit	Mixed fruit	0.830
Cherries	Cherries	0.815
Strawberries	Strawberries	0.920
Quinces	Quinces	0.840
Raspberry	Raspberry	0.800
Oranges	Oranges	0.860
RE= Refractometric extract		
7. Marmalades and non-gelified marmalades		
Special non gelified plum Marmalade	Plum	3.800
Marmalades	Semi-processed plump products:	
	9% RE	1.280
	10% RE	1.155
	11% RE	1.050
	12% RE	0.962
	13% RE	0.888

	8. Fruit syrups		
Fruit syrups	Juice	6% RE	0.540
		7% RE	0.460
		8% RE	0.400
		9% RE	0.350
		10% RE	0.320
		11% RE	0.300
	9. Fruit jams		
Strawberry	Strawberries		0.750
Cherry jam	Cherries		0.700
Apricot jam	Apricots		0.600
	Peeled apricots		0.800
	10. Fruit jellies		
Fruit jellies	Fruit juices		
		8% RE	0.400
		9% RE	0.350
RE=Refractometric extract			
	11. Fruit juices		
Clarified apple juice	Apples		1.900
Non clarified apple juice	Apples		1.800
Cherry juice	Cherries		1.550
Raspberry juice	Raspberry		1.500
Grape juice	Grapes		1.300
Concentrated apple juice	Apples		12.000
RE=Refractometric extract			

Recommended sampling plan on production/processing line:

- Frequency: every two hours
- Quantity of finished product to be sampled from production line: two cardboard cases (shipping packages)
- Analyze the two cases for defects according to specific control sheet (A)
- Analyze all receptacles or overwrapped units for specific defects (B)
- Open at least five receptacles or overwrapped units per shipping case and evaluate defects (C)
- Analyze at least two consumer packs for defects (D)

Index

V

W

Y