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Foreword

This bulletin offers practical information to persons interested in the processing of fruits and vegetables. It replaces AGS Bulletin No. 13 "Fruit Juice Processing", which was published in 1972. The new bulletin provides a much wider information base.

The publication starts with describing the general properties of fruits and vegetables, their chemical composition and nutritional values. Following a presentation of the factors that affect the deterioration of fruits and vegetables, various methods, traditional as well as modern for preservation of foods are presented. Auxiliary materials used in the preparation of fruit and vegetable products as well as adequate packaging materials are discussed.

Two major chapters are dedicated to the specific preservation technologies used for fruits and vegetables. These chapters contain the description of the processes to be used, machinery, processing time, temperatures, etc. They will provide technical personnel with useful and helpful information.

FAO will be delighted to receive your comments and provide you with any additional information that you may require. Address your enquiry to:

The Chief
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00100 Rome, Italy
Chapter I Introduction

1.1 General introduction

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.
1.2 Importance of fruit and vegetables in world agriculture

Fruit and vegetables represent an important part of world agriculture production; some figures are seen in Table 1.1.

**TABLE 1.1 Fruit and Vegetable World Production, 1991**

<table>
<thead>
<tr>
<th>Crop (Fruit)</th>
<th>Production, 1000 T</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total World</td>
</tr>
<tr>
<td>Apples</td>
<td>39404</td>
</tr>
<tr>
<td>Apricots</td>
<td>2224</td>
</tr>
<tr>
<td>Avocados</td>
<td>2036</td>
</tr>
<tr>
<td>Bananas</td>
<td>47660</td>
</tr>
<tr>
<td>Citrus fruits NES</td>
<td>1622</td>
</tr>
<tr>
<td>Cantaloupes and other melons</td>
<td>12182</td>
</tr>
<tr>
<td>Dates</td>
<td>3192</td>
</tr>
<tr>
<td>Grapes</td>
<td>57188</td>
</tr>
<tr>
<td>Grapefruit and pomelo</td>
<td>4655</td>
</tr>
<tr>
<td>Lemons and limes</td>
<td>6786</td>
</tr>
<tr>
<td>Mangoes</td>
<td>16127</td>
</tr>
<tr>
<td>Oranges</td>
<td>55308</td>
</tr>
<tr>
<td>Peaches and nectarines</td>
<td>8682</td>
</tr>
<tr>
<td>Pears</td>
<td>9359</td>
</tr>
<tr>
<td>Papayas</td>
<td>4265</td>
</tr>
<tr>
<td>Plantains</td>
<td>26847</td>
</tr>
<tr>
<td>Plums</td>
<td>5651</td>
</tr>
<tr>
<td>Pineapples</td>
<td>10076</td>
</tr>
<tr>
<td>Raisins</td>
<td>1041</td>
</tr>
<tr>
<td>Tangerines, mandarines, clementines</td>
<td>8951</td>
</tr>
<tr>
<td>Watermelons</td>
<td>28943</td>
</tr>
<tr>
<td>------------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Currants</td>
<td>536009</td>
</tr>
<tr>
<td>Raspberries</td>
<td>369087</td>
</tr>
<tr>
<td>Strawberries</td>
<td>2469117</td>
</tr>
<tr>
<td>Beans, green</td>
<td>3213</td>
</tr>
<tr>
<td>Cabbages</td>
<td>36649</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>5258</td>
</tr>
<tr>
<td>Carrots</td>
<td>13511</td>
</tr>
<tr>
<td>Chilies + peppers, green</td>
<td>9145</td>
</tr>
<tr>
<td>Cucumbers and gherkins</td>
<td>13619</td>
</tr>
<tr>
<td>Eggplants</td>
<td>5797</td>
</tr>
<tr>
<td>Garlic</td>
<td>3102</td>
</tr>
<tr>
<td>Onions, dry</td>
<td>27977</td>
</tr>
<tr>
<td>Peas, green</td>
<td>4856</td>
</tr>
<tr>
<td>Pumpkins, squash, gourds</td>
<td>7933</td>
</tr>
</tbody>
</table>

1.3 What 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.

1.4 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.
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.

1.5 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.

1.6 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.

1.7 Choice of processing technologies for developing countries

FAO maintains (in FAO, 1992c), 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.

1.8 Fruit and vegetables - global marketing view

Fruit and vegetables - global marketing view

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Chapter 2 General properties of fruit and vegetables; chemical composition and nutritional aspects; structural features

2.1 General properties

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 2.1.

<table>
<thead>
<tr>
<th>Category</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth vegetables</td>
<td>sweet potatoes, carrots</td>
</tr>
<tr>
<td>modified stems</td>
<td>potatoes</td>
</tr>
<tr>
<td>modified buds</td>
<td>onions, garlic</td>
</tr>
<tr>
<td>Herbage vegetables</td>
<td>cabbage, spinach, lettuce</td>
</tr>
<tr>
<td>leaves</td>
<td>celery, rhubarb</td>
</tr>
<tr>
<td>flower buds</td>
<td>cauliflower, artichokes</td>
</tr>
<tr>
<td>sprouts, shoots</td>
<td>asparagus, bamboo shoots</td>
</tr>
<tr>
<td>Fruit vegetables</td>
<td></td>
</tr>
<tr>
<td>legumes</td>
<td>peas, green beans</td>
</tr>
<tr>
<td>cereals</td>
<td>sweet corn</td>
</tr>
<tr>
<td>vine fruits</td>
<td>squash, cucumber</td>
</tr>
<tr>
<td>berry fruits</td>
<td>tomato, egg plant</td>
</tr>
<tr>
<td>tree fruits</td>
<td>avocado, breadfruit</td>
</tr>
</tbody>
</table>

Source: Feinberg (1973)

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
Fruit and vegetable processing - Ch02 General properties of fruit and vegetables; chemical composition and nutritional aspects; structural features

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 2.2.

**TABLE 2.2 Typical percentage composition of foods from plant origin**

<table>
<thead>
<tr>
<th>Food</th>
<th>Carbohydrate</th>
<th>Protein</th>
<th>Fat</th>
<th>Ash</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>wheat flour, white</td>
<td>73.9</td>
<td>10.5</td>
<td>1.9</td>
<td>1.7</td>
<td>12</td>
</tr>
<tr>
<td>rice, milled, white</td>
<td>78.9</td>
<td>6.7</td>
<td>0.7</td>
<td>0.7</td>
<td>13</td>
</tr>
<tr>
<td>maize, whole grain</td>
<td>72.9</td>
<td>9.5</td>
<td>4.3</td>
<td>1.3</td>
<td>12</td>
</tr>
<tr>
<td>Earth vegetables</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>potatoes, white</td>
<td>18.9</td>
<td>2.0</td>
<td>0.1</td>
<td>1.0</td>
<td>78</td>
</tr>
<tr>
<td>sweet potatoes</td>
<td>27.3</td>
<td>1.3</td>
<td>0.4</td>
<td>1.0</td>
<td>70</td>
</tr>
<tr>
<td>Vegetables</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>carrots</td>
<td>9.1</td>
<td>1.1</td>
<td>0.2</td>
<td>1.0</td>
<td>88.6</td>
</tr>
<tr>
<td>radishes</td>
<td>4.2</td>
<td>1.1</td>
<td>0.1</td>
<td>0.9</td>
<td>93.7</td>
</tr>
<tr>
<td>asparagus</td>
<td>4.1</td>
<td>2.1</td>
<td>0.2</td>
<td>0.7</td>
<td>92.9</td>
</tr>
<tr>
<td>beans, snap, green</td>
<td>7.6</td>
<td>2.4</td>
<td>0.2</td>
<td>0.7</td>
<td>89.1</td>
</tr>
<tr>
<td>peas, fresh</td>
<td>17.0</td>
<td>6.7</td>
<td>0.4</td>
<td>0.9</td>
<td>75.0</td>
</tr>
<tr>
<td>lettuce</td>
<td>2.8</td>
<td>1.3</td>
<td>0.2</td>
<td>0.9</td>
<td>94.8</td>
</tr>
<tr>
<td>Fruit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>banana</td>
<td>24.0</td>
<td>1.3</td>
<td>0.4</td>
<td>0.8</td>
<td>73.5</td>
</tr>
<tr>
<td>orange</td>
<td>11.3</td>
<td>0.9</td>
<td>0.2</td>
<td>0.5</td>
<td>87.1</td>
</tr>
<tr>
<td>apple</td>
<td>15.0</td>
<td>0.3</td>
<td>0.4</td>
<td>0.3</td>
<td>84.0</td>
</tr>
<tr>
<td>strawberries</td>
<td>8.3</td>
<td>0.8</td>
<td>0.5</td>
<td>0.5</td>
<td>89.9</td>
</tr>
</tbody>
</table>

Source: Anon. (1960)

Compositions of vegetables and fruit not only vary for a given kind in accordance 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.
2.2 Chemical composition

2.2.1 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%.

2.2.2 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.

2.2.3 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.

2.2.4 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%).

2.2.5 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.

2.2.6 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.

2.2.7 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.

2.2.8 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).
2.2.9 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.

2.2.10 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.
2.3 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 an 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 a 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 decrease 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.

2.4 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. The key is in the specific sensitivities of the various nutrients, the principles of which are illustrated in Table 2.4.1.

**TABLE 2.4.1 Specific sensitivity and stability of nutrients**

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Neutral pH 7</th>
<th>Acid &lt; pH 7</th>
<th>Alkaline &gt; pH 7</th>
<th>Air or Oxygen</th>
<th>Light</th>
<th>Heat</th>
<th>Cooking Losses, Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamins</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## General properties of fruit and vegetables; chemical composition and nutritional aspects; structural features (cont.)

| Vitamin       | Stability | Strength | Unstable | Stability | Strength | Unstable | Stability | Strength | Unstable | Stability | Strength | Unstable | Stability | Strength | Unstable | Stability | Strength |
|---------------|-----------|----------|-----------|-----------|----------|-----------|-----------|----------|-----------|-----------|----------|-----------|-----------|----------|-----------|-----------|----------|-----------|-----------|
| 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        | S         | U         | 0-60     |          |           |           |          |           |           |          |           |           |          |           |           |
| Carotenes (pro A) | S        | U        | S         | U         | U        | U         | 0-30     |          |           |           |          |           |           |          |           |           |          |           |           |
| 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        | U         | 0-10     |          |           |           |          |           |           |          |           |           |          |           |           |
| Essential fatty acids | S        | S        | U         | U         | U        | S         | 0-10     |          |           |           |          |           |           |          |           |           |          |           |           |
| 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     |          |           |           |          |           |           |          |           |           |          |           |           |
| Pantothenic acid | S       | U        | U         | S         | U        | S         | 0-50     |          |           |           |          |           |           |          |           |           |          |           |           |
| p-Amino acid  | S         | S        | S         | U         | S        | S         | 0-5      |          |           |           |          |           |           |          |           |           |          |           |           |
| Benzoic acid  |           |           |           |           |           |           |          |           |           |           |           |           |           |           |           |           |           |           |
| Vitamin B6    | S         | S        | S         | S         | U        | U         | 0-40     |          |           |           |          |           |           |          |           |           |          |           |           |
| Riboflavin (B2) | S        | S        | U         | U         | U        | U         | 0-75     |          |           |           |          |           |           |          |           |           |          |           |           |
| Thiamin (B1)  | U         | S        | U         | U         | S        | U         | 0-80     |          |           |           |          |           |           |          |           |           |          |           |           |
| Tocopherols   | S         | S        | S         | U         | U        | U         | 0-55     |          |           |           |          |           |           |          |           |           |          |           |           |

*Source: Harris and Karmas, 1975  
(U = Unstable; S = Stable)

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 program 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
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.

### 2.5 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 2.5.1.

#### TABLE 2.5.1 Structural and chemical components of the cells

<table>
<thead>
<tr>
<th>Vacuole</th>
<th>H₂O, inorganic salts, organic acids, oil droplets, sugars, water-soluble pigments, amino acids, vitamins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protoplast</td>
<td></td>
</tr>
<tr>
<td>- Membrane tonoplast (inner)</td>
<td>protein, lipoprotein, phospholipids, physic acid</td>
</tr>
<tr>
<td>plasmalemma (outer)</td>
<td></td>
</tr>
<tr>
<td>Component</td>
<td>Contents</td>
</tr>
<tr>
<td>------------------</td>
<td>----------------------------------------------</td>
</tr>
<tr>
<td>Nucleus</td>
<td></td>
</tr>
<tr>
<td>Cytoplasm</td>
<td></td>
</tr>
<tr>
<td>*active</td>
<td></td>
</tr>
<tr>
<td>Chloroplasts</td>
<td>Chlorophyll</td>
</tr>
<tr>
<td>Mesoplasm</td>
<td>enzymes, intermediary metabolites, nucleic acid</td>
</tr>
<tr>
<td>Mitochondria</td>
<td>enzymes (protein), Fe, Cu, Mo vitamin coenzyme</td>
</tr>
<tr>
<td>Microsomes</td>
<td>nucleoproteins, enzymes (proteins), nucleic acid</td>
</tr>
<tr>
<td>*inactive</td>
<td></td>
</tr>
<tr>
<td>Starch grains</td>
<td>reserve carbohydrate (starch), phosphorus</td>
</tr>
<tr>
<td>Aleurone</td>
<td>reserve protein</td>
</tr>
<tr>
<td>Chromoplast</td>
<td>pigments (carotenoids)</td>
</tr>
<tr>
<td>Oil droplets</td>
<td>triglycerides of fatty acids</td>
</tr>
<tr>
<td>Crystals</td>
<td>calcium oxalate, etc.</td>
</tr>
<tr>
<td>Cell Wall</td>
<td></td>
</tr>
<tr>
<td>Primary wall</td>
<td>cellulose, hemicellulose, pectic substances and non-cellulose</td>
</tr>
<tr>
<td>Middle lamella</td>
<td>pectic substances and non-cellulose polysaccharides, Mg, Ca</td>
</tr>
<tr>
<td>Plasmodesmata</td>
<td>cytoplasmic strands interconnecting cytoplasm of cells through pores in the cell wall</td>
</tr>
<tr>
<td>Surface materials</td>
<td>esters of long chain fatty acids (cutin or cuticle) and long chain alcohols</td>
</tr>
</tbody>
</table>

Source: Feinberg (1973)
A summary of overall deterioration reactions in fruits and vegetables is presented below.

3.1 Enzymic changes

Enzymes which are endogenous to plant tissues can have undesirable or desirable consequences. Examples involving endogenous enzymes include a) the post-harvest senescence and spoilage of fruit and vegetables; b) oxidation of phenolic substances in plant tissues by phenolase (leading to browning); c) sugar-starch conversion in plant tissues by amylases; d) post-harvest demethylation of pectic substances in plant tissues (leading to softening of plant tissues during ripening, and firming of plant tissues during processing).

The major factors useful in controlling enzyme activity are: temperature, water activity, pH, chemicals which can inhibit enzyme action, alteration of substrates, alteration of products and pre-processing control.

3.2 Chemical changes

3.2.1 Sensory quality

The two major chemical changes which occur during the processing and storage of foods and lead to a deterioration in sensory quality are lipid oxidation and non-enzymatic browning. Chemical reactions are also responsible for changes in the colour and flavour of foods during processing and storage.

3.2.1.1 Lipid oxidation rate and course of reaction is influenced by light, local oxygen concentration, high temperature, the presence of catalysts (generally transition metals such as iron and copper) and water activity. Control of these factors can significantly reduce the extent of lipid oxidation in foods.

3.2.1.2 Non-enzymic browning is one of the major causes of deterioration which occurs during storage of dried and concentrated foods. The non-enzymic browning, or Maillard reaction, can be divided into three stages: a) early Maillard reactions which are chemically well-defined steps without browning; b) advanced Maillard reactions which lead to the formation of volatile or soluble substances; and c) final Maillard reactions leading to insoluble brown polymers.

3.2.1.3 Colour changes

Chlorophylls. Almost any type of food processing or storage causes some deterioration of the chlorophyll
pigments. Phenophytinisation (with consequent formation of a dull olivbrown phenophytin) is the major change; this reaction is accelerated by heat and is acid catalysed.

Other reactions are also possible. For example, dehydrated products such as green peas and beans packed in clear glass containers undergo photo-oxidation and loss of desirable colour.

Anthocyanins. These are a group of more than 150 reddish water-soluble pigments that are very widespread in the plant kingdom. The rate of anthocyanin destruction is pH dependent, being greater at higher pH values. Of interest from a packaging point of view is the ability of some anthocyanins to form complexes with metals such as Al, Fe, Cu and Sn.

These complexes generally result in a change in the colour of the pigment (for example, red sour cherries react with tin to form a purple complex) and are therefore undesirable. Since metal packaging materials such as cans could be sources of these metals, they are usually coated with special organic linings to avoid these undesirable reactions.

Carotenoids. The carotenoids are a group of mainly lipid soluble compounds responsible for many of the yellow and red colours of plant and animal products. The main cause of carotenoid degradation in foods is oxidation. The mechanism of oxidation in processed foods is complex and depends on many factors. The pigments may auto-oxidise by reaction with atmospheric oxygen at rates dependent on light, heat and the presence of pro- and antioxidants.

3.2.1.4 Flavour changes

In fruit and vegetables, enzymically generated compounds derived from long-chain fatty acids play an extremely important role in the formation of characteristic flavours. In addition, these types of reactions can lead to significant off-flavours. Enzyme-induced oxidative breakdown of unsaturated fatty acids occurs extensively in plant tissues and this yield characteristic aromas associated with some ripening fruits and disrupted tissues.

The permeability of packaging materials is of importance in retaining desirable volatile components within packages, or in permitting undesirable components to permeate through the package from the ambient atmosphere.

3.2.2 Nutritional quality

The four major factors which affect nutrient degradation and can be controlled to varying extents by packaging are light, oxygen concentration, temperature and water activity. However, because of the diverse nature of the various nutrients as well as the chemical heterogeneity within each class of compounds and the complex interactions of the above variables, generalizations about nutrient
degradation in foods will inevitably be broad ones.

Vitamins. Ascorbic acid is the most sensitive vitamin in foods, its stability varying markedly as a function of environmental conditions such as pH and the concentration of trace metal ions and oxygen. The nature of the packaging material can significantly affect the stability of ascorbic acid in foods. The effectiveness of the material as a barrier to moisture and oxygen as well as the chemical nature of the surface exposed to the food are important factors.

For example, problems of ascorbic acid instability in aseptically packaged fruit juices have been encountered because of oxygen permeability of the package and the oxygen dependence of the ascorbic acid degradation reaction.

Also, because of the preferential oxidation of metallic tin, citrus juices packaged in cans with a tin contact surface exhibit greater stability of ascorbic acid than those in enamelled cans or glass containers. The aerobic and anaerobic degradation reactions of ascorbic acid in reduced-moisture foods have been shown to be highly sensitive to water activity, the reaction rate increasing in an exponential fashion over the water activity range of 0.1-0.8.

3.3 Physical changes

One major undesirable physical change in food powders is the absorption of moisture as a consequence of an inadequate barrier provided by the package; this results in caking. It can occur either as a result of a poor selection of packaging material in the first place, or failure of the package integrity during storage. In general, moisture absorption is associated with increased cohesiveness.

Anti-caking agents are very fine powders of an inert chemical substance that are added to powders with much larger particle size in order to inhibit caking and improve flowability. Studies in onion powders showed that at ambient temperature, caking does not occur at water activities of less than about 0.4.

At higher activities, however, (aw > 0.45) the observed time to caking is inversely proportional to water activity, and at these levels anti-caking agents are completely ineffective. It appears that while they reduce inter-particle attraction and interfere with the continuity of liquid bridges, they are unable to cover moisture sorption sites.

3.4 Biological changes

3.4.1 Microbiological

Micro-organisms can make both desirable and undesirable changes to the quality of foods depending on whether or not they are introduced as an essential part of the food preservation process or arise unintentionally and subsequently grow to produce food spoilage.
The two major groups of micro-organisms found in foods are bacteria and fungi, the latter consisting of yeasts and moulds. Bacteria are generally the fastest growing, so that in conditions favourable to both, bacteria will usually outgrow fungi.

Foods are frequently classified on the basis of their stability as non-perishable, semi-perishable and perishable. For example, hermetically sealed and heat processed (e.g. canned) foods are generally regarded as non-perishable. However, they may become perishable under certain circumstances when an opportunity for recontamination is afforded following processing.

Such an opportunity may arise if the can seams are faulty, or if there is excessive corrosion resulting in internal gas formation and eventual bursting of the can. Spoilage may also take place when the canned food is stored at unusually high temperatures: thermophilic spore-forming bacteria may multiply, causing undesirable changes such as flat sour spoilage.

Low moisture content foods such as dried fruit and vegetables are classified as semi-perishable. Frozen foods, though basically perishable, may be classified as semi-perishable provided that they are properly stored at freezer temperatures.

The majority of foods (e.g. meat and fish, milk, eggs and most fresh fruits and vegetables) are classified as perishable unless they have been processed in some way. Often, the only form of processing which such foods receive is to be packaged and kept under controlled temperature conditions.

The species of micro-organisms which cause the spoilage of particular foods are influenced by two factors: a) the nature of the foods and b) their surroundings. These factors are referred to as intrinsic and extrinsic parameters.

The intrinsic parameters are an inherent part of the food: pH, $a_w$, nutrient content, antimicrobial constituents and biological structures. The extrinsic parameters of foods are those properties of the storage environment that affect both the foods and their microorganisms. The growth rate of the micro-organisms responsible for spoilage primarily depends on these extrinsic parameters: temperature, relative humidity and gas compositions of the surrounding atmosphere.

The protection of packaged food from contamination or attack by micro-organisms depends on the mechanical integrity of the package (e.g. the absence of breaks and seal imperfections), and on the resistance of the package to penetration by micro-organisms.

Metal cans which are retorted after filling can leak during cooling, admitting any microorganisms which may be present in the cooling water, even when the double seam is of a high quality. This fact is widely known in the canning industry and is the reason for the mandatory chlorination of cannery cooling water.

Extensive studies on a variety of plastic films and metal foils have shown that microorganisms (including
mounds, yeasts and bacteria) cannot penetrate these materials in the absence of pinholes.

In practice, however, thin sheets of packaging materials such as aluminium and plastic do contain pinholes. There are several safeguards against the passage of micro-organisms through pinholes in films:

- because of surface tension effects, micro-organisms cannot pass through very small pinholes unless the micro-organisms are suspended in solutions containing wetting agents and the pressure outside the package is greater than that within;
- materials of packaging are generally used in thicknesses such that pinholes are very infrequent and small;
- for applications in which package integrity is essential (such as sterilisation of food in pouches), adequate test methods are available to assure freedom from bacterial recontamination.

3.4.2 Macrobiological

3.4.2.1 Insect Pests

Warm humid environments promote insect growth, although most insects will not breed if the temperature exceeds about 35°C or falls below 10°C. Also many insects cannot reproduce satisfactorily unless the moisture content of their food is greater than about 11%.

The main categories of foods subject to pest attack are cereal grains and products derived from cereal grains, other seeds used as food (especially legumes), dairy products such as cheese and milk powders, dried fruits, dried and smoked meats and nuts.

As well as their possible health significance, the presence of insects and insect excrete in packaged foods may render products unsaleable, causing considerable economic loss, as well as reduction in nutritional quality, production of off-flavours and acceleration of decay processes due to creation of higher temperatures and moisture levels.

Early stages of infestation are often difficult to detect; however, infestation can generally be spotted not only by the presence of the insects themselves but also by the products of their activities such as webbing, clumped-together food particles and holes in packaging materials.

Unless plastic films are laminated with foil or paper, insects are able to penetrate most of them quite easily, the rate of penetration usually being directly related to film thickness. In general, thicker films are more resistant than thinner films, and oriented films tend to be more effective than cast films. The looseness of the film has also been reported to be an important factor, loose films being more easily penetrated than tightly fitted films.
Generally, the penetration varies depending on the basic resin from which the film is made, on the combination of materials, on the package structure, and of the species and stage of insects involved. The relative resistance to insect penetration of some flexible packaging materials is as follows:

- excellent resistance: polycarbonate; poly-ethylene-terephthalate;
- good resistance: cellulose acetate; polyamide; polyethylene (0.254 mm); polypropylene (biaxially oriented); poly-vinyl-chloride (unplasticised);
- fair resistance: acrylonitrile; poly-tetra-fluoro-ethylene; polyethylene (0.123 mm);
- poor resistance: regenerated cellulose; corrugated paper board; kraft paper; polyethylene (0.0254 - 0.100 mm); paper/foil/polyethylene laminate pouch; poly-vinylchloride (plasticised).

Some simple methods for obtaining insect resistance of packaging materials are as following:

- select a film and a film thickness that are inherently resistant to insect penetration;
- use shrink film over-wraps to provide an additional barrier;
- seal carton flaps completely.

3.4.2.2 Rodents

Rats and mice carry disease-producing organisms on their feet and/or in their intestinal tracts and are known to harbour salmonella of serotypes frequently associated with food-borne infections in humans. In addition to the public health consequences of rodent populations in close proximity to humans, these animals also compete intensively with humans for food.

Rats and mice gnaw to reach sources of food and drink and to keep their teeth short. Their incisor teeth are so strong that rats have been known to gnaw through lead pipes and unhardened concrete, as well as sacks, wood and flexible packaging materials.

Proper sanitation in food processing and storage areas is the most effective weapon in the fight against rodents, since all packaging materials apart from metal and glass containers can be attacked by rats and mice.

Summary

Major causes of food deterioration include the following:

a. growth and activities of micro-organisms, principally bacteria, yeasts and moulds;
b. activities of natural food enzymes;
c. insects, parasites and rodents;
d. temperature, both heat and cold;
Extrinsic factors controlling the rate of food DETERIORATION reactions are mainly:

a. Effect of temperature;
b. Effect of water activity (a_\text{w});
c. Effect of gas atmosphere;
d. Effect of light.
Chapter 4 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.

4.1 Technical methods of reducing food deterioration

These technical means can be summarised as follows:

<table>
<thead>
<tr>
<th>Physical</th>
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<tbody>
<tr>
<td>Heating</td>
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<tr>
<td>Cooling</td>
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<tr>
<td>Lowering of water content</td>
<td>Drying/dehydration. Concentration</td>
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<tr>
<td>Sterilising filtration</td>
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<tr>
<td>Irradiation</td>
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<tr>
<td>Other physical means (high pressure, vacuum, inert gases)</td>
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<table>
<thead>
<tr>
<th>Chemical</th>
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<tr>
<td>Salting</td>
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<td>Smoking</td>
<td></td>
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<tr>
<td>Sugar addition</td>
<td></td>
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<tr>
<td>Artificial acidification</td>
<td></td>
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<tr>
<td>Ethyl alcohol addition</td>
<td></td>
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<tr>
<td>Antiseptic substance action</td>
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<table>
<thead>
<tr>
<th>Biochemical</th>
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<tbody>
<tr>
<td>Lactic fermentation (natural acidification)</td>
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<tr>
<td>Alcoholic fermentation</td>
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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.

4.2 Procedures for fruit and vegetable preservation

<table>
<thead>
<tr>
<th>Procedures</th>
<th>Practical applications</th>
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<tbody>
<tr>
<td>Fresh storage</td>
<td>Fruits, vegetables</td>
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<tr>
<td>Cold storage</td>
<td>Fruits, vegetables</td>
</tr>
<tr>
<td>Freezing</td>
<td>Fruits, vegetables</td>
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</table>
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).

### 4.3 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. [unclear]

### 4.3.1 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.

4.3.2 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.

4.3.3 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.

4.3.4 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. \( a_w = 0.70...0.75 \)).

4.3.5 Chemical preservation is combined with:

● acidification of food medium (lowering pH);

● using combined chemical preservatives.

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

4.3.7 Preservation with sugar is combined with pasteurization for some preserves having a sugar content below 65%.
Chapter 5 General procedures for fruit and vegetable preservation

5.1 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 (Source: Thompson, 1989).

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.

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5.2 Preservation by reduction of water content: drying/dehydration and concentration

5.2.1 Water and water activity (aw) 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:

\[ a_w = \frac{RH}{100} \]

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 are affected by at the micro-environmental level in food materials.

Two foods with the same water content can have very different aw 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 (below 5% moisture in Fig. 5.2.1) 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 (above 20% moisture in Fig. 5.2.1) is thought to exist largely as multi-molecular layers of water less tightly held to food constituent surfaces.

5.2.2 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 micro-organisms 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.

5.2.2.1 Heat and mass transfer

Dehydration involves the application of heat to vaporise 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.

5.2.2.2 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 5.2.1 indicates the applicability of the more common dryer types to liquid and solid type foods.

**TABLE 5.2.1 Common dryer types used for liquid and solid foods**

<table>
<thead>
<tr>
<th>Dryer type</th>
<th>Usual food type</th>
</tr>
</thead>
</table>

### 5.2.3 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 discoloration 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.

As a rule fruit is not blanched.

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 5.2.2 Dilutions of sodium metabisulphite with water to obtain "PM" of sulphur dioxide (SO2)**

<table>
<thead>
<tr>
<th>PPM SO2</th>
<th>SODIUM METABISULPHITE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grams per litre of water</td>
</tr>
<tr>
<td>1000</td>
<td>1.5</td>
</tr>
<tr>
<td>2000</td>
<td>3.0</td>
</tr>
<tr>
<td>3000</td>
<td>4.5</td>
</tr>
<tr>
<td>4000</td>
<td>6.0</td>
</tr>
<tr>
<td>5000</td>
<td>7.5</td>
</tr>
<tr>
<td>6000</td>
<td>9.0</td>
</tr>
<tr>
<td>7000</td>
<td>10.5</td>
</tr>
</tbody>
</table>

One level teaspoon of sodium metabisulphite = c. 5 g.
5.3 Chemical preservation

Many chemicals will kill micro-organisms or stop their growth but most of these are not permitted in foods; chemicals that are permitted as food preservatives are listed in Table 5.3.1. 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 parameters (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.

5.3.1 Traditional chemical food preservatives and their use in fruit and vegetable processing technologies could be summarised as follows:

5.3.1.1. common salt: brined vegetables;
5.3.1.2. sugars (sucrose, glucose, fructose and syrups):
  5.3.1.2.1 foods preserved by high sugar concentrations: jellies, preserves, syrups, juice concentrates;
  5.3.1.2.2 interaction of sugar with other ingredients or processes such as drying and heating;
  5.3.1.2.3 indirect food preservation by sugar in products where fermentation is important (naturally acidified pickles and sauerkraut).

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

5.3.2.1 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.

5.3.2.2 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.

5.3.2.3 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.

5.3.3 Commonly used lipophilic acid food preservatives

5.3.3.1 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.

5.3.3.2 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.

5.3.4 Gaseous chemical food preservatives

5.3.4.1 Sulphur dioxide and sulphites. Sulphur dioxide (SO2) 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 SO2 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.

5.3.4.2 Carbon dioxide (CO2) 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 cm²) 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 CO2 inhibits growth of psychrotrophic microorganisms 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 O2 and CO2 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 CO2 (5-10%) is determined by factors such as nature of product, variety, climate and extent of storage.

4.3.4.3 Chlorine. The various forms of chlorine constitute the most widely used chemical sanitiser in the food industry. These chlorine forms include chlorine (Cl2), sodium hypochlorite (NaOCl), calcium hypochlorite (Ca(OCl)2) and chlorine dioxide gas (ClO2).

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.

5.3.5 General rules for chemical preservation

5.3.5.1 Chemical food preservatives have to be used only at a dosage level which is needed for a normal preservation and not more.

5.3.5.2 "Reconditioning" of chemical preserved food, e.g. a new addition of preservative in order to stop a microbiological deterioration already occurred is not recommended.

5.3.5.3 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.
5.3.6 Factors which determine/ influence the action of chemical food preservatives

5.3.6.1 Factors related to the chemical preservatives:

a. chemical composition;
   b. concentration.

5.3.6.2 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.

5.3.6.3 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.)

5.3.6.4 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 5.3.1.

TABLE 5.3.1 Chemical Food Preservatives
<table>
<thead>
<tr>
<th>Agent</th>
<th>Acceptable Daily intake (mg/Kg body weight)</th>
<th>Commonly used levels (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lactic acid</td>
<td>No limit</td>
<td>No limit</td>
</tr>
<tr>
<td>Citric acid</td>
<td>No limit</td>
<td>No limit</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>No limit</td>
<td>No limit</td>
</tr>
<tr>
<td>Sodium Diacetate</td>
<td>15</td>
<td>0.3-0.5</td>
</tr>
<tr>
<td>Sodium benzoate</td>
<td>5</td>
<td>0.03-0.2</td>
</tr>
<tr>
<td>Sodium propionate</td>
<td>10</td>
<td>0.1-0.3</td>
</tr>
<tr>
<td>Potassium sorbate</td>
<td>25</td>
<td>0.05-0.2</td>
</tr>
<tr>
<td>Methyl paraben</td>
<td>10</td>
<td>0.05-0.1</td>
</tr>
<tr>
<td>Sodium nitrite</td>
<td>0.2</td>
<td>0.01-0.02</td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>0.7</td>
<td>0.005-0.2</td>
</tr>
</tbody>
</table>

Source: FDA, 1991

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.

5.4 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.

5.4.1 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 in Table 5.4.1.

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. Fig. 5.4.1 shows the factors which can influence the texture, where the enzymes are particularly important.

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.

Figure 5.4.6 Factors influencing the texture of fermented vegetables (Source: P. Meurer, 1992).

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.

5.4.2 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 acidoanabiosis and, to a lesser extent, acidoabiosis.

5.4.3 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 (7 CFR 52, 1991) 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 5.4.1 Some industrial fermentation processes in food industries

<table>
<thead>
<tr>
<th>I. Lactic acid bacteria</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- cucumbers</td>
<td>dill pickles, sour pickles</td>
</tr>
<tr>
<td>- cabbage</td>
<td>sauerkraut</td>
</tr>
<tr>
<td>- turnips</td>
<td>sauerruben</td>
</tr>
<tr>
<td>- lettuce</td>
<td>lettuce kraut</td>
</tr>
<tr>
<td>- mixed vegetables, turnips, radish, cabbage</td>
<td></td>
</tr>
<tr>
<td>- mixed Chinese vegetables,</td>
<td></td>
</tr>
<tr>
<td>cabbage</td>
<td>Kimchi</td>
</tr>
<tr>
<td>- vegetables and milk</td>
<td>Tarhana</td>
</tr>
<tr>
<td>- vegetables and rice</td>
<td>Sajur asin</td>
</tr>
</tbody>
</table>
### II. Lactic acid bacteria with other microorganisms

- 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

Source: Pederson (1)
5.5 Preservation with sugar

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: \[ i + S + s + n + w = 100; \]

\[ i = \text{insoluble substance}; \]
\[ s = \text{sugar from fruits}; \]
\[ S = \text{added sucrose}; \]
\[ n = \text{soluble "non sugar"}; \]
\[ w = \text{water}. \]

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

\[ X = \frac{100 (S + s)}{100 - (n + i)} \% \]

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:

\[ X = \frac{100 (55 + 8)}{100 - (5 + 3)} = 68.5\% \]

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 antisepatisation 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.

5.6 Heat preservation/heat processing

5.6.1 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.

5.6.2 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 5.6.1 lists various types of fruit and vegetables and their pH value, together with the heat processing requirements.

**TABLE 5.6.1 Heat processing requirements - dependence on product acidity**

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

Source: Desrosier and Desrosier (1977)
5.6.3 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:

<table>
<thead>
<tr>
<th>Food preparation:</th>
<th>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.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can/receptacle</td>
<td>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.</td>
</tr>
<tr>
<td>Vacuum production</td>
<td>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.</td>
</tr>
<tr>
<td>Thermal processing</td>
<td>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.</td>
</tr>
<tr>
<td>Cooling</td>
<td>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.</td>
</tr>
<tr>
<td>Labelling and packing</td>
<td>Labels are applied to the can body, and the cans are then packed into cases.</td>
</tr>
</tbody>
</table>

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).

5.6.4 Technological principles of pasteurization

5.6.4.1 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.

5.6.4.2 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 gives 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.

5.6.4.3 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.

5.6.4.4 Heating may precede or follow packaging. These principles of different temperature time combinations very largely determine the design parameters 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.
5.7 Food irradiation

5.7.1 Introduction

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 5.6.2 Possible causes of spoilage (real or apparent) in canned goods

<table>
<thead>
<tr>
<th>Type of food: Acid and high acid foods (canned fruits)</th>
<th>Action to be taken to identify cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insufficient vacuum or headspace</td>
<td>Check vacuum and headspace in relation to storage temperature and altitude</td>
</tr>
<tr>
<td>&quot;Springer&quot; or &quot;flipper&quot;</td>
<td>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</td>
</tr>
<tr>
<td>Hydrogen swell</td>
<td>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.</td>
</tr>
<tr>
<td>&quot;Hard&quot; or &quot;soft swell&quot;</td>
<td>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.</td>
</tr>
</tbody>
</table>

Source: FAO/WFP, 1970

5.7.2 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.
5.7.3 Global developments

Consensus on wholesomeness.

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 (kilorays) 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 5.7.1 shows commercial applications of food irradiation to fruits and vegetables by country.

TABLE 5.7.1 International commercial applications of radiation for fruit and vegetables

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

Thailand
Bangkok (1971)
Onions

Chapter 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.

6.1 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.

6.1.1 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 pest 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.

### 6.1.2 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.

### 6.1.3 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.

6.2 Sweeteners

6.2.1 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 refractometer reading or with areometers graduated in various ways: Brix, Baumé, etc. The correspondence between these measuring units and quantity of water by volume unit is indicated in Table 6.2.1.

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.

6.2.2 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.

6.3 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 6.2.1 Physical characteristics of sugar solutions**

<table>
<thead>
<tr>
<th>Specific weight</th>
<th>deg. Bé</th>
<th>Sugar in solution</th>
<th>Boiling temperature °C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>deg. Bx (K/100 g)</td>
<td>g/l</td>
</tr>
<tr>
<td>1.144</td>
<td>18.5</td>
<td>33</td>
<td>377</td>
</tr>
<tr>
<td>1.149</td>
<td>19.0</td>
<td>34</td>
<td>391</td>
</tr>
<tr>
<td>1.154</td>
<td>19.6</td>
<td>35</td>
<td>404</td>
</tr>
<tr>
<td>1.159</td>
<td>20.1</td>
<td>36</td>
<td>417</td>
</tr>
<tr>
<td>1.164</td>
<td>20.7</td>
<td>37</td>
<td>430</td>
</tr>
<tr>
<td>1.169</td>
<td>21.2</td>
<td>38</td>
<td>444</td>
</tr>
<tr>
<td>1.174</td>
<td>21.8</td>
<td>39</td>
<td>457</td>
</tr>
<tr>
<td>1.179</td>
<td>22.3</td>
<td>40</td>
<td>470</td>
</tr>
<tr>
<td>1.185</td>
<td>22.9</td>
<td>41</td>
<td>486</td>
</tr>
<tr>
<td>1.190</td>
<td>23.4</td>
<td>42</td>
<td>500</td>
</tr>
<tr>
<td>1.195</td>
<td>23.9</td>
<td>43</td>
<td>513</td>
</tr>
<tr>
<td>1.200</td>
<td>24.5</td>
<td>44</td>
<td>527</td>
</tr>
<tr>
<td>1.206</td>
<td>25.0</td>
<td>45</td>
<td>543</td>
</tr>
<tr>
<td>1.211</td>
<td>25.6</td>
<td>46</td>
<td>557</td>
</tr>
<tr>
<td>1.216</td>
<td>26.1</td>
<td>47</td>
<td>571</td>
</tr>
<tr>
<td>1.222</td>
<td>26.6</td>
<td>48</td>
<td>586</td>
</tr>
<tr>
<td>1.227</td>
<td>27.2</td>
<td>49</td>
<td>600</td>
</tr>
<tr>
<td>1.233</td>
<td>27.7</td>
<td>50</td>
<td>616</td>
</tr>
<tr>
<td>1.238</td>
<td>28.2</td>
<td>51</td>
<td>630</td>
</tr>
<tr>
<td>1.244</td>
<td>28.8</td>
<td>52</td>
<td>646</td>
</tr>
<tr>
<td>1.249</td>
<td>29.3</td>
<td>53</td>
<td>660</td>
</tr>
<tr>
<td>1.255</td>
<td>29.8</td>
<td>54</td>
<td>677</td>
</tr>
<tr>
<td>1.261</td>
<td>30.4</td>
<td>55</td>
<td>693</td>
</tr>
<tr>
<td>1.267</td>
<td>30.9</td>
<td>56</td>
<td>709</td>
</tr>
</tbody>
</table>
From a microbiological point of view, salt 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/l 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 6.2.2.

### TABLE 6.2.2 Physical characteristics of salt solutions

<table>
<thead>
<tr>
<th>Specific Weight</th>
<th>Salt Content</th>
<th>Temperature</th>
<th>Physical Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.272</td>
<td>31.4</td>
<td>57</td>
<td>723</td>
</tr>
<tr>
<td>1.278</td>
<td>31.9</td>
<td>58</td>
<td>740</td>
</tr>
<tr>
<td>1.284</td>
<td>32.5</td>
<td>59</td>
<td>757</td>
</tr>
<tr>
<td>1.290</td>
<td>33.0</td>
<td>60</td>
<td>774</td>
</tr>
<tr>
<td>1.296</td>
<td>33.5</td>
<td>61</td>
<td>790</td>
</tr>
<tr>
<td>1.302</td>
<td>34.0</td>
<td>62</td>
<td>807</td>
</tr>
<tr>
<td>1.308</td>
<td>34.5</td>
<td>63</td>
<td>824</td>
</tr>
<tr>
<td>1.314</td>
<td>35.1</td>
<td>64</td>
<td>840</td>
</tr>
<tr>
<td>1.320</td>
<td>35.6</td>
<td>65</td>
<td>857</td>
</tr>
<tr>
<td>1.326</td>
<td>36.1</td>
<td>66</td>
<td>874</td>
</tr>
<tr>
<td>1.332</td>
<td>36.6</td>
<td>67</td>
<td>891</td>
</tr>
<tr>
<td>1.338</td>
<td>37.1</td>
<td>68</td>
<td>909</td>
</tr>
<tr>
<td>1.345</td>
<td>37.6</td>
<td>69</td>
<td>928</td>
</tr>
<tr>
<td>1.351</td>
<td>38.1</td>
<td>70</td>
<td>945</td>
</tr>
<tr>
<td>1.357</td>
<td>38.6</td>
<td>71</td>
<td>962</td>
</tr>
<tr>
<td>1.364</td>
<td>39.1</td>
<td>72</td>
<td>981</td>
</tr>
<tr>
<td>1.370</td>
<td>39.6</td>
<td>73</td>
<td>999</td>
</tr>
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<td>Specific weight</td>
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<td>24.8</td>
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<td>24</td>
<td>1.200</td>
<td>26.0</td>
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<tr>
<td>24.5</td>
<td>1.204</td>
<td>26.4</td>
<td>318</td>
</tr>
</tbody>
</table>
6.4 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

6.5 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.

6.6 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 100-150 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.
Chapter 7 Packaging materials

7.1 Introduction

7.1.1 Requirements and functions of food containers

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

- they must be non-toxic and compatible with the specific foods;
- sanitary protection;
- moisture and fat protection;
- gas and odour protection;
- light protection;
- resistance to impact;
- transparency;
- tamperproofness;
- ease of opening;
- pouring features;
- reseal features;
- ease of disposal;
- size, shape, weight limitations;
- appearance, printability;
- low cost;
- special features.

7.1.2 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.

7.1.3 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.

### 7.2 Protection of food by packaging materials

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

#### Figure 7.1 Factors for selection a packaging material for food storage

### 7.3 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 7.1. 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 7.1 Properties of packaging films

<table>
<thead>
<tr>
<th>Material</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper</td>
<td>Strength; rigidity; opacity; printability.</td>
</tr>
<tr>
<td>Aluminium foil</td>
<td>Negligible permeability to water-vapour, gases and odours; grease proof, opacity and brilliant appearance; dimensional stability; dead folding characteristics.</td>
</tr>
<tr>
<td>Cellulose film (coated)</td>
<td>Strength; attractive appearance; low permeability to water vapour (depending on the type of coating used), gases, odours and greases; printability.</td>
</tr>
<tr>
<td>Polythene</td>
<td>Durability; heat-sealability; low permeability to water-vapour; good chemical resistance; good low-temperature performance.</td>
</tr>
<tr>
<td>Rubber hydrochloride</td>
<td>Heat-sealability; low permeability to water vapour, gases, odours and greases; chemical resistance.</td>
</tr>
<tr>
<td>Cellulose acetate</td>
<td>Strength; rigidity; glossy appearance; printability; dimensional stability.</td>
</tr>
<tr>
<td>Material</td>
<td>Properties</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Vinylidene chloride</td>
<td>Low permeability to water vapour, gases, copolymer odours and greases; chemical resistance; heat-sealability.</td>
</tr>
<tr>
<td>Polyvinyl chloride</td>
<td>Resistance to chemicals, oils and greases; heat-sealability.</td>
</tr>
<tr>
<td>Polyethylene terephtalate</td>
<td>Strength; durability; dimensional stability; low permeability to gases, odours and greases.</td>
</tr>
</tbody>
</table>

Source: FAD/WFP, (1970)

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.

### 7.3.1 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.

### 7.3.2 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.

### 7.3.3 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.

7.4 Glass containers

7.4.1 Introduction

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.

7.4.2 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.)

7.4.2.1 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;

7.4.2.2 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.

7.4.2.3 Glass bottles

These receptacles are widely used both for

a) finished products which need pasteurization (e.g. tomato juice, Knit juices, etc.) and for

b) those which are preserved as such (e.g. 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.

7.4.2.4 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 (e.g. 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.

7.5 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.

7.5.1 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.

7.5.2 Receptacles from paper or cardboard

(paper = 8 to 150 g/m²; cardboard = 150 to 450 g/m²).
7.6 "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 classes of foods requiring different steels are seen in Table 7.2.

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.

Common organic coatings of FDA approved materials and their uses are indicated in Table 7.3.

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 7.3 General types of can coatings**

<table>
<thead>
<tr>
<th>Coating</th>
<th>Typical uses</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruit enamel</td>
<td>Dark coloured berries, cherries and other fruits requiring protection from metallic salts</td>
<td>Oleoresinous</td>
</tr>
<tr>
<td>C-enamel</td>
<td>Corn, peas and other sulphur-bearing products</td>
<td>Oleoresinous w. suspended zinc oxide</td>
</tr>
<tr>
<td>Citrus enamel</td>
<td>Citrus products and concentrates</td>
<td>Modified oleoresinous</td>
</tr>
<tr>
<td>Beverage can enamel</td>
<td>Vegetable juices; red fruit juices; highly corrosive fruits; non-carbonated beverages</td>
<td>Two-coated w. resinous base coat and vinyl top coat</td>
</tr>
</tbody>
</table>
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 8.1.1 shows which of the above mentioned properties have a major impact on the finished products obtained by fruit processing.

**TABLE 8.1.1 Optimal use of fruits as a function of their properties**

<table>
<thead>
<tr>
<th>Processed Finished Products</th>
<th>Organoleptic (Sensory) Properties</th>
<th>Chemical Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shape</td>
<td>Texture</td>
</tr>
<tr>
<td>Dried Fruits</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Fruit Juices</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Marmalade</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Jams</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Jellies</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Fruit Paste</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**8.1.1 When to pick**

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,
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.

8.1.2 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 refractometer or a hydrometer. The refractometer measures the ability of a solution to bend or refract a light beam which is proportional to the solution's concentration. A hydrometer 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.

8.2 Harvesting and preprocessing

8.2.1 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:

- growth and activity of micro-organisms;
- activities of the natural food enzymes;
- insects, parasites and rodents;
- temperature, both heat and cold;
- moisture and dryness;
- air and in particular oxygen;
- light and
- time.

The rapidity with which foods spoil if proper measures are not taken is indicated in Table 8.2.1.

**TABLE 8.2.1 Useful storage life of some food products**

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

Source: Desrosier and Desrosier (1977)

**8.2.2 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
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 refractometer, consistency/texture measured with simple penetrometers, etc. Some useful checks/control to be performed at reception are summarised in Table 8.2.2.

### 8.2.3 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 8.2.2 Raw Material Control - Fresh Fruits and Vegetables at Reception

<table>
<thead>
<tr>
<th>Checks at each delivery/raw material lot</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Colour</td>
</tr>
<tr>
<td>1.2 Texture</td>
</tr>
<tr>
<td>1.3 Taste</td>
</tr>
<tr>
<td>1.4 Flavour</td>
</tr>
<tr>
<td>1.5 Appearance</td>
</tr>
<tr>
<td>1.6 Refractometric extract</td>
</tr>
<tr>
<td>1.7 Number per kg</td>
</tr>
</tbody>
</table>
1.8 Variety
1.9 Sanitary evaluation

2. Checks at each ten lots (for the same raw material)

2.1 Density
2.2 Water content: oven method
2.3 Total sugars, reducing sugars
2.4 Total acidity

3. Audits - every six months - on five different lots

3.1 Ascorbic acid
3.2 Mineral substances
3.3 Tannic substances
3.4 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%.

8.2.4 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 be 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/shower 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,
8.2.5 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).

8.2.6 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.

8.2.7 Cutting

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

8.2.8 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.
8.2.9 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.

8.2.10 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 SO2 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. SO2 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 SO2 or its SO2 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 SO2. Then the slices are allowed to stand for about one to two hours so that the SO2 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 SO2 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.

8.2.11 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 SO2 treatment.

### 8.3 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.
8.4 Fruit drying and dehydration technology

The sequence of operations employed in the production of dried / dehydrated fruit is presented in section 8.4.1.

General technical data for fruit dehydration in tunnels are presented in Table 8.4.1.

**TABLE 8.4.1 Technical data for fruit dehydration in tunnels**

<table>
<thead>
<tr>
<th>FRUITS</th>
<th>Drying Conditions</th>
<th>Finished Product</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Load kg/m²</td>
<td>Temperature °C</td>
<td>Time</td>
<td>Moisture %</td>
</tr>
<tr>
<td>Plums</td>
<td>15</td>
<td>I. 40-50</td>
<td>6 H</td>
<td>18-20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>II. 75-80</td>
<td>14 H</td>
<td></td>
</tr>
<tr>
<td>Apples (Rings)</td>
<td>10</td>
<td>75-55</td>
<td>5-6 H</td>
<td>20</td>
</tr>
<tr>
<td>Apricots (Halves)</td>
<td>10</td>
<td>70-60</td>
<td>15-15</td>
<td>15-20</td>
</tr>
<tr>
<td>Cherries (w. stones)</td>
<td>10</td>
<td>55-70</td>
<td>6-8</td>
<td>12-15</td>
</tr>
<tr>
<td>Pears (Halves and quarters)</td>
<td>15</td>
<td>70-65</td>
<td>15-22</td>
<td>18-20</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>70-60</td>
<td>10-15</td>
<td>15-20</td>
</tr>
</tbody>
</table>

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 8.4.2.

Technical data on some osmotically dehydrated products are presented in Table 8.4.3. Moisture and shipping factors for some dried / dehydrated fruit are seen in Table 8.4.4.

**TABLE 8.4.3 Technical data on some osmotically dehydrated products**

<table>
<thead>
<tr>
<th>Fruit or vegetable</th>
<th>Type of cut</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banana</td>
<td>5 mm slices</td>
<td>2 hours, 80% sugar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2000 ppm SO2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>at 70°C</td>
</tr>
<tr>
<td>Carrots</td>
<td>10 x 10 x 2 mm dices or 5 mm slices</td>
<td>4 hours, 60% sugar + 10% salt</td>
</tr>
<tr>
<td>Mango, green</td>
<td>8 mm slices</td>
<td>2 hours, 25% salt</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8000 ppm SO2</td>
</tr>
<tr>
<td>Mango, ripe</td>
<td>8 mm slices</td>
<td>2 hours, 60% sugar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8000 ppm SO2</td>
</tr>
<tr>
<td>Onions</td>
<td>2 mm slices</td>
<td>2 hours, 60% sugar + 10% salt</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4000 ppm SO2</td>
</tr>
<tr>
<td>Papaya</td>
<td>8 x 8 mm slices</td>
<td>4 hours, 80% sugar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2000 ppm SO2 at 70°C</td>
</tr>
<tr>
<td>Strawberries</td>
<td>Whole</td>
<td>4 hours, 80% sugar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4000 ppm SO2</td>
</tr>
</tbody>
</table>
Sweet peppers, red
6 mm dices
2 hours, 60 % sugar + 10 % salt
4000 ppm SO2

Source: FAO, 969a

TABLE 8.4.4 Moisture and shipping factors for some dried/dehydrated fruits

<table>
<thead>
<tr>
<th>Products</th>
<th>Form</th>
<th>moisture, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apples</td>
<td>6 mm rings</td>
<td>20</td>
</tr>
<tr>
<td>Apricots</td>
<td>Caps</td>
<td>17-20</td>
</tr>
<tr>
<td>Banana</td>
<td>Cut pieces</td>
<td>15</td>
</tr>
<tr>
<td>Cherries</td>
<td>Whole</td>
<td>12-15</td>
</tr>
<tr>
<td>Figs</td>
<td>Whole</td>
<td>23</td>
</tr>
<tr>
<td>Guava</td>
<td>Quarters</td>
<td>6</td>
</tr>
<tr>
<td>Mango</td>
<td>15 mm pulp sheets</td>
<td>15</td>
</tr>
<tr>
<td>Peaches</td>
<td>Caps</td>
<td>15-20</td>
</tr>
<tr>
<td>Pears</td>
<td>Halves</td>
<td>23</td>
</tr>
<tr>
<td>Prunes</td>
<td>Whole</td>
<td>18-20</td>
</tr>
<tr>
<td>Raisins</td>
<td>Whole</td>
<td>17</td>
</tr>
</tbody>
</table>

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.

8.4.2 Processing of fruit bars (Source: FAO 1992c, FAO 1990a)

The fruit bar processing method developed for FAO only involves a single major operation, which is 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:

<table>
<thead>
<tr>
<th>Type of fruit</th>
<th>Fruit required in kg</th>
<th>Pulp obtained in kg</th>
<th>Sugar required in kg</th>
<th>Yield (% of fresh fruit) approx.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mango</td>
<td>720</td>
<td>360</td>
<td>33</td>
<td>14</td>
</tr>
<tr>
<td>Banana</td>
<td>600</td>
<td>360</td>
<td>30</td>
<td>17</td>
</tr>
<tr>
<td>Guava</td>
<td>406</td>
<td>325</td>
<td>60</td>
<td>25</td>
</tr>
<tr>
<td>Mango + banana</td>
<td>540 + 150</td>
<td>360</td>
<td>35</td>
<td>15</td>
</tr>
<tr>
<td>Papaya + banana</td>
<td>500 + 140</td>
<td>336</td>
<td>54</td>
<td>23</td>
</tr>
</tbody>
</table>

Source: Amoriggi (1992), FAO (1990)

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/m²). 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.

Ciiku leather is prepared by mixing ciiku 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.

8.4.3 Osmotic dehydration in fruit and vegetable processing

8.4.3.1 introduction

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.

8.4.3.2 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;
- phenomena 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.

A pilot plant equipment used for detailed study of process parameters in osmotic concentration of fruits is seen in Figure 8.4.2 (Source: Garrote, R.L. et al., 1992).

8.4.3.3 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 discoloration.

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.

Various applications of the technique as a unit operation in the food area are summarised in Fig. 8.4.1 together with the process parameters regarded as optimal in the light of the published literature.
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 SO2 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 8.4.4 Osmoappertisation in the processing of apricots*
8.5 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.

8.5.1 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.

8.5.1.1 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 SO2 are: SO2 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 SO2 for about 12 months is 0.18-0.20% SO2 (with respect to the product to be preserved).

This level could be reduced to 0.09% SO2 for 3 months and to 0.12% SO2 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% SO2 water solutions or by direct introduction of sulphur dioxide gas in the product (for "purées-marks"). The preparation of 6% SO2 solutions is done by bubbling the gas from cylinders in cold water; from a 50 kg SO2 compressed gas cylinder results 830 l of 6% SO2 solution.

These SO2 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 - (see Table 8.5.3).

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.

8.5.1.2 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.

8.5.1.3 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.

8.5.1.4 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% SO2 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% SO2 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% SO2 solution and calcium bisulphite solution (containing also 6% SO2).

Preparation of calcium bisulphite solution is done by the introduction of 30 kg of CaO in 1 m³ SO2 solution and mixing up to clarification. The resulting solution is mixed with the initial 6% SO2 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 8.5.1.

**TABLE 8.5.1 General technical processing data for semi-processed fruit "pulps"

<table>
<thead>
<tr>
<th>Fruit species</th>
<th>Preliminary operations</th>
<th>Preservation means</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apples, pears, quinces</td>
<td>Sorting, washing, coring, cutting</td>
<td>Sulphur dioxide</td>
</tr>
<tr>
<td>Prunes, peaches, wax cherries, apricots</td>
<td>Sorting, washing, stone removal (pitting)</td>
<td>Sulphur dioxide or sodium benzoate</td>
</tr>
<tr>
<td>Cherries</td>
<td>Sorting, washing</td>
<td>Sulphur dioxide or sodium benzoate, sometimes with calcium bisulphite addition</td>
</tr>
<tr>
<td>Strawberries</td>
<td>Sorting, washing</td>
<td>Sulphur dioxide in mix with calcium bisulphite</td>
</tr>
<tr>
<td>Wild berries</td>
<td>Sorting, washing</td>
<td>Sulphur dioxide or sodium benzoate; in some cases with calcium bisulphite addition</td>
</tr>
</tbody>
</table>

8.5.1.5 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.).

PRESERVATION is 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 8.5.2.
TABLE 8.5.2 General technical processing data for semi-processed "purées - marks"

<table>
<thead>
<tr>
<th>Fruit species</th>
<th>Preliminary operations</th>
<th>Preservation means</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apples, pears, quinces</td>
<td>Sorting, washing, boiling, refining</td>
<td>Sulphur dioxide; in less frequent cases formic acid or sodium benzoate</td>
</tr>
<tr>
<td>Prunes, peaches, wax cherries, apricots,</td>
<td>Sorting, washing, boiling, refining</td>
<td>Sulphur dioxide, formic acid or sodium benzoate; cherries freezing with or without sugar; self-pasteurization</td>
</tr>
<tr>
<td>Strawberry, wild berries</td>
<td>Sorting, washing, refining</td>
<td>Chemical preservation, freezing or self pasteurization</td>
</tr>
</tbody>
</table>

Fig. 8.5.1 shows a technological line for the preparation of semi-processed purée-marks”.

Figure 8.5.1 Technological line for semi-processed fruit products

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 SO2)

TABLE 8.5.3 Correlation between density and concentration for SO2 solutions

<table>
<thead>
<tr>
<th>Density at 15°C</th>
<th>Concentration of solutions % SO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0168</td>
<td>3.00</td>
</tr>
<tr>
<td>1.0181</td>
<td>3.25</td>
</tr>
<tr>
<td>1.0194</td>
<td>3.50</td>
</tr>
<tr>
<td>1.0206</td>
<td>3.75</td>
</tr>
<tr>
<td>1.0221</td>
<td>4.00</td>
</tr>
<tr>
<td>1.0234</td>
<td>4.25</td>
</tr>
<tr>
<td>1.0248</td>
<td>4.50</td>
</tr>
<tr>
<td>1.0261</td>
<td>4.75</td>
</tr>
<tr>
<td>1.0275</td>
<td>5.00</td>
</tr>
<tr>
<td>1.0289</td>
<td>5.25</td>
</tr>
<tr>
<td>--------</td>
<td>------</td>
</tr>
<tr>
<td>1.0302</td>
<td>5.50</td>
</tr>
<tr>
<td>1.0315</td>
<td>5.75</td>
</tr>
<tr>
<td>1.0340</td>
<td>6.25</td>
</tr>
<tr>
<td>1.0353</td>
<td>6.50</td>
</tr>
<tr>
<td>1.0365</td>
<td>6.75</td>
</tr>
<tr>
<td>1.0377</td>
<td>7.00</td>
</tr>
</tbody>
</table>
8.6 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.

8.6.1 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 8.6.1. 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>
<thead>
<tr>
<th>TABLE 8.6.1 Composition of some fruit jams</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of Jam</strong></td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>Jam made from berry fruits: strawberry, raspberry, etc.</td>
</tr>
<tr>
<td>Jam made from stone fruits: apricot, peach, etc.</td>
</tr>
</tbody>
</table>
8.6.2 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%".

8.6.3 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.

8.6.4 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
   
   * to the batch while stirring very vigorously
   * Pectin which has previously been mixed with 5 times its weight in sugar taken from the recipe

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

* Note: the pectin in solution can also be added at the end of the step (e) and has to be prepared as follows: use a strong blender. For one litre of water add slowly into the blender 25 g of pectin mixed with 100 g of sugar taken from the recipe.

8.6.5 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:
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

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>10 kg of fruit at 10% TSS</td>
<td>1.000 kg</td>
</tr>
<tr>
<td>10 kg of sugar</td>
<td>10.000 kg</td>
</tr>
<tr>
<td>60 g of pectin (grade 200)</td>
<td>0.060 kg</td>
</tr>
<tr>
<td>55 g of citric acid</td>
<td>0.055 kg</td>
</tr>
<tr>
<td></td>
<td>11.115 kg</td>
</tr>
</tbody>
</table>

\[
\text{Yield} = \frac{11.115 \times 100}{68} = 16.4 \text{ Kg}
\]

Recipe 2. Fruit: sugar = 45:55; desired Brix in the finished product is 68.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>10 kg of fruit at 10% TSS</td>
<td>1.000 kg</td>
</tr>
<tr>
<td>12.2 kg of sugar</td>
<td>12.200 kg</td>
</tr>
<tr>
<td>60 g of pectin grade 200</td>
<td>0.060 kg</td>
</tr>
<tr>
<td>55 g of citric acid</td>
<td>0.060 kg</td>
</tr>
<tr>
<td></td>
<td>13.325 kg</td>
</tr>
</tbody>
</table>

\[
\text{Yield} = \frac{13.325 \times 100}{68} = 19.6 \text{ Kg}
\]

Recipe 3. Fruit: sugar = 40:60; desired Brix in the finished product is 68.
<table>
<thead>
<tr>
<th>d10 kg of fruit at 10% TSS</th>
<th>1.000 kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.3 litre of water</td>
<td>-</td>
</tr>
<tr>
<td>15 kg of sugar</td>
<td>15.000 kg</td>
</tr>
<tr>
<td>85 g of pectin grade 200</td>
<td>0.085 kg</td>
</tr>
<tr>
<td>80 g of citric acid</td>
<td>0.080 kg</td>
</tr>
<tr>
<td></td>
<td>16.165 kg</td>
</tr>
</tbody>
</table>

\[
\text{Yield} = \frac{16.165 \times 100}{68} = 23.8 \text{ Kg}
\]

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.

<table>
<thead>
<tr>
<th>If container capacity is between:</th>
<th>Increase pectin by:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 kg and 2.5 kg</td>
<td>5%</td>
</tr>
<tr>
<td>2.5 kg and 5.0 kg</td>
<td>10%</td>
</tr>
<tr>
<td>5.0 kg and 10.0 kg</td>
<td>20%</td>
</tr>
<tr>
<td>10.0 kg and 20.0 kg</td>
<td>30%</td>
</tr>
</tbody>
</table>

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
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%.

### 8.6.6 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:

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pineapple pulp</td>
<td>25.0</td>
</tr>
<tr>
<td>Papaya pulp</td>
<td>25.0 pounds</td>
</tr>
<tr>
<td>Cane sugar</td>
<td>50.0</td>
</tr>
<tr>
<td>Apple pectin (150 grade)</td>
<td>6.0 ounces</td>
</tr>
<tr>
<td>Citric acid</td>
<td>6.4</td>
</tr>
<tr>
<td>Fresh ground ginger</td>
<td>7.5</td>
</tr>
</tbody>
</table>

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 refractometer 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 meter) and Total Soluble Solids (with a refractometer 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.

8.6.7 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.
6. Take off steam, remove foam.
7. Add 300 cc citric acid solution 50%.
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:

<table>
<thead>
<tr>
<th></th>
<th>Ratio 50:50</th>
<th>Ratio 45:55</th>
<th>Ratio 40:60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruit</td>
<td>55 lb</td>
<td>49.5 lb</td>
<td>44 lb</td>
</tr>
<tr>
<td>Water</td>
<td>-</td>
<td>11 lb</td>
<td>13.2 lb</td>
</tr>
<tr>
<td>Sugar</td>
<td>55 lb</td>
<td>60.5 lb</td>
<td>66 lb</td>
</tr>
<tr>
<td>Pectin (150 grade)</td>
<td>225 g</td>
<td>237.5 g</td>
<td>250 g</td>
</tr>
<tr>
<td>Citric acid (50% sol.)</td>
<td>300 cc</td>
<td>320 cc</td>
<td>335 cc</td>
</tr>
</tbody>
</table>
8.7 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".

8.7.1 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/DISINTEGRATION 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-TARTARISATION is 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 CO2 pressure may be done at a concentration of 1.5% CO2 under a pressure of 7 kg/cm². At the distribution step, proceed at CO2 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 steps for processing of specific fruit juices without pulp are seen in Table 8.7.1.

**TABLE 8.7.1 Technological steps for processing of specific fruit juices without pulp**
Fig. 8.7.1 describes a general technological line for the production of fruit juices without pulp.

**Figure 8.7.1 General technological flow-sheet Fruit Juices w/o pulp**

### 8.7.2 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.

A general technological flow-sheet for fruit juice processing is presented below.

8.8 Banana and plantain processing technologies

8.8.1 Traditional processing

8.8.1.1 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.
8.8.1.2 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.

8.8.1.3 Product stability and storage problems

There is little experimental data on the storage life of the traditionally made banana and plantain products.

8.8.1.4 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 discoloration 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.

8.8.2 Industrial processing

8.8.2.1 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.

8.8.2.2 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.

8.8.2.2.1 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.

8.8.2.2 Banana purée

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 discoloration 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.

8.8.2.3 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%.

8.8.2.4 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.

8.8.2.5 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.

8.8.2.2 6 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.

8.8.2.2.7 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-blached 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.

8.8.2.2.8 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.

8.8.2.3. Product stability and spoilage problems

All dried banana products are very hydroscopic and susceptible to flavour deterioration and discoloration, 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.

8.8.2.4. 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

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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.

8.8.3 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.

8.8.3.1 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.
8.8.3.2 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.

8.8.3.3 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.

8.8.3.4 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.
8.9 Mango and guava processing technologies

8.9.1 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.

8.9.1.1 Green mango processing

8.9.1.1.1 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:

<table>
<thead>
<tr>
<th>Mango pieces</th>
<th>Tumeric powder</th>
<th>Salt</th>
<th>Fenugreek seeds</th>
<th>Mustard powder</th>
<th>Bengal gram seeds</th>
<th>Chili powder</th>
<th>Gingelly oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>250 g</td>
<td>2 to 4 g</td>
<td>60 g</td>
<td>2 to 4 g</td>
<td>30 g</td>
<td>2 to 4 g</td>
<td>20 g</td>
<td>20 to 30 g</td>
</tr>
</tbody>
</table>

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.

8.9.1.1.2 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.

8.9.1.1.3 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.

8.9.1.2 Ripe mango processing

8.9.1.2.1 Purée.

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 another 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.

8.9.1.2.2 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.

8.9.1.2.3 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.

<table>
<thead>
<tr>
<th>Brix of purée</th>
<th>15°</th>
<th>17°</th>
<th>20°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nectar components</td>
<td>150</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>Purée</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Sugar</td>
<td>45</td>
<td>43</td>
<td>40</td>
</tr>
<tr>
<td>Water</td>
<td>255</td>
<td>257</td>
<td>260</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>900</th>
<th>1100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mango pulp</td>
<td>900</td>
<td>900</td>
</tr>
<tr>
<td>Sugar</td>
<td>900</td>
<td>1100</td>
</tr>
<tr>
<td>Citric acid</td>
<td>18</td>
<td>15</td>
</tr>
<tr>
<td>Water</td>
<td>900</td>
<td>900</td>
</tr>
</tbody>
</table>

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 \(\frac{1}{2}\)a pulp + \(\frac{1}{2}\) water + \(\frac{1}{2}\) 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.

8.9.1.2.4 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 SO2, 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.

8.9.1.2.5 Canning.

This preservation technology is described in various technological flow-sheets in this bulletin.

8.9.1.2.6 Mango bar or "fruit leather" is presented in various flow-sheets.

8.9.2 Guava processing technologies

8.9.2.1 Guava purée

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.

8.9.2.2 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.

8.10 Recent trends in fruit and vegetable processing

8.10.1 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.

The major trends in the development of fruit and vegetable heat processed products in recent years are shown in table 8.10.1; the number of new fruit and vegetable products is seen in table 8.10.2.

TABLE 8.10.1 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.

Source: C. Dennis (1993)

### TABLE 8.10.2 Numbers of new fruit and vegetable products

<table>
<thead>
<tr>
<th></th>
<th>1990</th>
<th>1991</th>
<th>1992 Jan-June</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frozen vegetable products</strong></td>
<td>66</td>
<td>95</td>
<td>21</td>
</tr>
<tr>
<td><strong>Chilled vegetable products</strong></td>
<td>76</td>
<td>81</td>
<td>78</td>
</tr>
<tr>
<td><strong>Heat processed vegetables</strong></td>
<td>51</td>
<td>60</td>
<td>38</td>
</tr>
<tr>
<td><strong>Heat processed fruits</strong></td>
<td>13</td>
<td>14</td>
<td>5</td>
</tr>
<tr>
<td><strong>Fruit juices and drinks</strong></td>
<td>73</td>
<td>83</td>
<td>46</td>
</tr>
<tr>
<td><strong>Potato crisps</strong></td>
<td>32</td>
<td>33</td>
<td>16</td>
</tr>
</tbody>
</table>
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.

8.10.2 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.

8.10.3 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 than 0.15%.
c. Supplement antioxidant potential: 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.

8.10.4 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 amygdaalin, 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 8.10.3.

TABLE 8.10.3 Specification of purity for cherry and apricot kernel oils as determined by UK ACNFP

<table>
<thead>
<tr>
<th>Contaminants limits</th>
<th>Cherry</th>
<th>Apricot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy metals (total)</td>
<td>0.5 mg/kg</td>
<td>0.5 mg/kg</td>
</tr>
<tr>
<td>Aflatoxins (total)</td>
<td>4.0 g/kg</td>
<td>4.0 g/kg</td>
</tr>
<tr>
<td>Cyanide</td>
<td>0.15 mg/kg</td>
<td>0.15 mg/kg</td>
</tr>
<tr>
<td>Pesticide residues</td>
<td>0.01 mg/kg</td>
<td>0.01 mg/kg</td>
</tr>
<tr>
<td>Tocopherols:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>alpha/delta/gamma (mg/kg)</td>
<td>356-886</td>
<td>569-899</td>
</tr>
</tbody>
</table>

Source: Anon. (1993)
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.

8.10.5 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.
Chapter 9 Vegetable specific processing technologies

9.1 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.

9.2 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 CO2 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.

9.2.1 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 tenderometers, penetrometers, etc.);
d. boiling tests, etc.

9.2.2 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.

9.2.3 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.

9.2.4 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.

9.2.5 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 9.2.1 Losses at vegetable peeling, in %**

<table>
<thead>
<tr>
<th>Vegetables</th>
<th>Peeling methods</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Manual</td>
</tr>
<tr>
<td>Potatoes</td>
<td>15-19</td>
</tr>
<tr>
<td>Carrots</td>
<td>13-15</td>
</tr>
<tr>
<td>Beets</td>
<td>1416</td>
</tr>
</tbody>
</table>

9.2.6 Size reduction.

This step is applied according to specific vegetable and processing technology requirements.

9.2.7 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. Catalase and peroxidase inactivation tests are presented in section 9.2.9.

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 parameters is seen in Table 9.2.2.

**TABLE 9.2.2 Blanching parameters for some vegetables**

<table>
<thead>
<tr>
<th>Vegetables</th>
<th>Temperature, °C</th>
<th>Time, min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peas</td>
<td>85-90</td>
<td>2-7</td>
</tr>
<tr>
<td>Green beans</td>
<td>90-95</td>
<td>2-5</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>Boiling</td>
<td>2</td>
</tr>
<tr>
<td>Carrots</td>
<td>90</td>
<td>3-5</td>
</tr>
<tr>
<td>Peppers</td>
<td>90</td>
<td>3</td>
</tr>
</tbody>
</table>

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 it 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.

9.2.8 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.

9.2.9 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 cm³ of 96% ethylic alcohol and then this preparation is brought to 100 cm³ with the same solvent);
- peroxide solution 0.3% (1 cm³ perhydrol is brought to 100 cm³ 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. From the average sample, 10-20 g of material is taken in a medium capacity test tube; on this sample are poured: 20 cm³ distilled water; 1 cm³ of 1% guaiacol solution; 1.6 cm³ 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 cm³ of distilled water. After 15 min softening, 0.5 cm³ 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.

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9.3 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. CO2 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 9.3.1

<table>
<thead>
<tr>
<th>Vegetables</th>
<th>Storage conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Temperature, °C</td>
</tr>
<tr>
<td>Potatoes</td>
<td>+1…+3</td>
</tr>
<tr>
<td>Carrots</td>
<td>0 … +1</td>
</tr>
<tr>
<td>Onions</td>
<td>0 … +1</td>
</tr>
<tr>
<td>Leeks</td>
<td>0 … +0.5</td>
</tr>
<tr>
<td>Cabbage</td>
<td>-1 … 0</td>
</tr>
<tr>
<td>Garlic</td>
<td>0 … +1</td>
</tr>
<tr>
<td>Beets</td>
<td>0 … +1</td>
</tr>
</tbody>
</table>

9.4 Vegetable drying/dehydration

9.4.1 Vegetable dehydration
General technical data for vegetable dehydration in tunnels are shown in table 9.4.1.

**TABLE 9.4.1 Technical data for vegetable dehydration in tunnels**

A schematic flow-sheet for vegetable dehydration in belt driers is seen in Fig. 9.4.1.

**Figure 9.4.1 General technological flow-sheet for vegetable dehydration in belt dryers**

Belt dryer/dehydration equipment is illustrated in Fig. 9.4.2.

**Figure 9.4.2 Belt dryer**

### 9.4.2 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. The 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 130-150°C.

**TABLE 9.4.2 Technological data for vegetable powders**

### 9.4.3 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 indicated in Table 9.4.4. 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 parameter 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, discoloration, 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 discoloration 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.

9.4.4 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 9.4.3 Dehydrated vegetable potential defects and means to prevent them

TABLE 9.4.4 Moisture and shipping factors for some dehydrated vegetables
<table>
<thead>
<tr>
<th>Product</th>
<th>Form/cut</th>
<th>Moisture %</th>
<th>Weight kg/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bean (green)</td>
<td>20 nun cut</td>
<td>5</td>
<td>1.6</td>
</tr>
<tr>
<td>Bean (lima)</td>
<td>5</td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td>Beet</td>
<td>6 mm strips</td>
<td>5</td>
<td>1.6-1.9</td>
</tr>
<tr>
<td>Cabbage</td>
<td>6-12 mm shreds</td>
<td>4</td>
<td>0.7-0.9</td>
</tr>
<tr>
<td>Carrots</td>
<td>5-8 mm strips</td>
<td>5</td>
<td>3.5</td>
</tr>
<tr>
<td>Celery</td>
<td>Cut</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Garlic</td>
<td>Cloves</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Okra</td>
<td>6 mm slices</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Onion</td>
<td>Slices</td>
<td>4</td>
<td>0.4- 0.6</td>
</tr>
<tr>
<td>Pea (fresh)</td>
<td>Whole</td>
<td>5</td>
<td>3.4</td>
</tr>
<tr>
<td>Pepper (hot)</td>
<td>Ground</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Pepper (sweet)</td>
<td>5 mm strips</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Potato (Irish)</td>
<td>5-8 mm strips</td>
<td>6</td>
<td>2.9-3.2</td>
</tr>
<tr>
<td></td>
<td>Diced</td>
<td>5</td>
<td>3.3-3.6</td>
</tr>
<tr>
<td>Tomato</td>
<td>7-10 mm slices</td>
<td>35</td>
<td></td>
</tr>
</tbody>
</table>

**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 abrating 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 parameters).

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. If 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.
Fruit and vegetable processing - Ch09 Vegetable specific processing technologies (cont.)

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.

9.5 Vegetable juices and concentrated products

9.5.1 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.).

9.5.1.1 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. Modern 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 refractometer): 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 min
- 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:

<table>
<thead>
<tr>
<th>Receptacle size</th>
<th>Pre-heating</th>
<th>Time of pasteurization</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.33 l</td>
<td>60° C</td>
<td>40 minutes</td>
</tr>
<tr>
<td>0.50 l</td>
<td>60° C</td>
<td>45 minutes</td>
</tr>
<tr>
<td>0.66 l</td>
<td>60° C</td>
<td>55 minutes</td>
</tr>
<tr>
<td>0.75 l</td>
<td>60° C</td>
<td>60 minutes</td>
</tr>
<tr>
<td>1.0 litre</td>
<td>60° C</td>
<td>70 minutes</td>
</tr>
</tbody>
</table>

9.5.1.2 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)

AI RTIGHT 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 %.

9.5.1.3 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.

9.5.1.4 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.

9.5.2 Concentrated tomato products

9.5.2.1 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 0.70-0.75 (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.

9.5.2.2 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.

9.5.2.3 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.

9.5.3 Production accidents and product defects; means to avoid them

9.5.3.1 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.

9.5.3.2 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.

9.5.3.3 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.
9.6 Pickles and sauerkraut technology

9.6.1 Vegetable natural acidification technology

9.6.1.1 Gherkins and cucumbers

Raw materials must follow strict specifications for a high quality finished product; the following parameters 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;

RECEPTACLE 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.

9.6.1.2 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.

9.6.1.2.1 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 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.

Fig. 9.6.1 shows a medium scale industrial installation for the processing of shredded sauerkraut.

Figure 9.6.1 Technological equipment and buildings for medium scale processing and storage/packing of shredded sauerkraut

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.

9.6.1.2.2 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).

A simple flow-sheet for preparation of whole sauerkraut at family / farm / community levels is presented in section 9.6.1.4.

9.6.1.3 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 (section 9.6.1.4). 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.

9.6.1.4 Simplified flow-sheet for whole sauerkraut processing

9.6.1.4.1 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 (see § c);
- 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 (see § c);
- 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.

9.6.4.1.2 Consumption of the finished product

It is possible to estimate that at reasonable ambient temperatures and with a strict followup 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.

9.6.1.4.3 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.

9.6.2 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.

9.6.2.1 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.

9.6.2.2 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.

9.6.2.3. 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 diameter), 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**

**9.7 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.

**9.7.1 Canned vegetables in salt brine**

The technological flow-sheet covers steps that are applied partly or completely according to Fig. 9.7.1.; orientative technical data for processing are seen in Table 9.7.1.

**Figure 9.7.1 Technological flow-sheet for vegetable canning in salt solution (brine)**

Storage silo (1)
Sorting (2)
Washing (3)
Grading (4) Preliminary operations

Cleaning (5)

Cutting (6)

Blanching (7) or steaming (8)

Cooling (9)

Receptacle filling (10)

Preheating (11)

Hermetic sealing (12)

Sterilisation (13)

Cooling (14)

Labelling (15)

Storage (16)

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TABLE 9.7.1 Orientative technical data for canned vegetables in salt brine

NOTES:

1. For preparation of these products the general canning operations description will be taken into account.
2. The sterilization temperature is 120°C, with exceptions noted for individual products.
3. Time for increasing and decreasing the retort temperature are the same:
   a. for 112 cans = 15 mini for 1/1 cans = 20 min.
   b. for 1/2 and 1/1 glass jars = 25 min.
4. Sterilization; conditions are indicated for discontinuous operations.
5. For sterilization of glass jars an air counterpressure of 1.8-2.5 is used.

9.7.2 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 9.7.2.

TABLE 9.7.2 Orientative technical data for canned vegetables in tomato juice

* 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.

Sterilisation is carried out according to the instructions given in Table 9.7.2 and then receptacles have to be thoroughly cooled.

9.7.3 Canned vegetables in vegetable oil
General flow-sheet is described in figure 9.7.2

**Figure 9.7.2 Flow-sheet for vegetable canning in vegetable oil**

Reception (1)
Sorting (2)
Cleaning/peeling (3)
Washing (4)
Cutting (5)

Frying (6) or Blanching (7)
Cooling (8)

Filling and adding of vegetable oil, sauce or tomato concentrated juice (9)

Sealing (10)
Sterilisation (11)
Cooling (12)
Labelling (13)
Storage (14)

### 9.7.4 General heat preservation operations - canning

Introduction
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 course, 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 is 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.

Figure 9.7.4.1 Vertical retort ("autoclave")

Figure 9.7.4.2 Horizontal retort ("rotoclave")
Chapter 10 Quality control/quality assurance and international trade; good manufacturing practices (gmp); hygiene requirements; hazard analysis and critical control points (haccp)

10.1 Quality control/quality assurance and international trade

10.1.1 General

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.
10.1.2 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.

### 10.1.3 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.

10.1.4 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.

10.1.5 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,
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.

10.2 Good manufacturing practices (gmp); hygiene requirements

10.2.1 Personnel

10.2.1.1. 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.

10.2.1.2. 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.

10.2.1.3. Education and training

Persons who are monitoring the sanitation programs 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.

10.2.1.4. Supervision

Someone must be assigned the responsibility that all personnel will comply with all the requirements of these GMP's.

10.2.2 Plants and grounds

10.2.2.1. 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. 10.2.2.2. 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.

10.2.3 Sanitary operations

10.2.3.1. 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.

10.2.3.2. Pest control

- No animals or birds are allowed anywhere in the plant
- Programs 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;
10.2.3.3. 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.

10.2.3.4. 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.

10.2.4 Sanitary facilities and controls

10.2.4.1. Water supply.

Any water that comes into contact food or processing equipment must be safe and of adequate sanitary quality.

10.2.4.2. Sewage disposal

Must flow into an adequate sewage system or disposed of through other adequate means.

10.2.4.3. 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.

10.2.4.4. 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.

10.2.4.5. 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.

10.2.4.6. 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.

10.2.5 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 thermometer, 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.

10.2.6 Processes and controls

There must be an individual who is responsible for supervising the overall sanitation of the plant.

10.2.6.1. 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.

10.2.6.2. Manufacturing operations

a. Food processing equipment must be kept 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;

1. 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.
10.3 Hazard analysis and critical control points (HACCP)

10.3.1 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

10.3.2 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.

10.3.3 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. Table 10.3.1 is a simple process description from a Hazard Analysis point of view.

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.

Fig. 10.3.1 is an example of a process for preparing a canned juice drink using a hot fill to prevent subsequent spoilage. 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.

Fig. 10.3.1 has a column titled: "Potential for microbial growth if out of control". 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 (shown in Figure 10.3.2). 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.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Equipment</th>
<th>(+,-,=)**</th>
<th>Reason</th>
<th>Temp. °F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Storage</td>
<td>Warehouse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Transport</td>
<td>Fork lift</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Storage</td>
<td>Storage tank</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Weigh dry ingred.</td>
<td>Scale</td>
<td>+</td>
<td>Poor sanitation</td>
<td></td>
</tr>
<tr>
<td>5. Weigh wet ingred.</td>
<td>Weigh Kettle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Blend***</td>
<td>Kettle</td>
<td>=</td>
<td>Low temp.</td>
<td>195</td>
</tr>
<tr>
<td>7. Heat</td>
<td>Kettle</td>
<td>=</td>
<td>Sanitation</td>
<td>190</td>
</tr>
<tr>
<td>8. Transport</td>
<td>Pump</td>
<td>=</td>
<td>Low temp.</td>
<td>190</td>
</tr>
<tr>
<td>9. Delay</td>
<td>Surge tank</td>
<td>=</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step</td>
<td>Action</td>
<td>Condition</td>
<td>Result</td>
<td></td>
</tr>
<tr>
<td>---------------</td>
<td>---------------------------------</td>
<td>------------</td>
<td>-----------------</td>
<td></td>
</tr>
<tr>
<td>10. Filler bowel level</td>
<td>Valve</td>
<td>=</td>
<td>Sanitation</td>
<td>190</td>
</tr>
<tr>
<td>11. Separation</td>
<td>Pipe filter</td>
<td>=</td>
<td>Sanitation</td>
<td>190</td>
</tr>
<tr>
<td>12. Can fill</td>
<td>Filler</td>
<td>=</td>
<td>Low temp.</td>
<td>190</td>
</tr>
<tr>
<td>13. Lid coding</td>
<td>Coder</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Seam</td>
<td>Double seamer</td>
<td>+</td>
<td>(Poor seams)</td>
<td>190</td>
</tr>
<tr>
<td>15. Lid sterilisation</td>
<td>Can inverter</td>
<td>=</td>
<td></td>
<td>190</td>
</tr>
<tr>
<td>16. Hold delay</td>
<td>Conveyor</td>
<td>=</td>
<td></td>
<td>190</td>
</tr>
<tr>
<td>17. Can cooling</td>
<td>Cooling tunnel</td>
<td>=</td>
<td></td>
<td>90</td>
</tr>
<tr>
<td>18. Drying</td>
<td>Can dryer</td>
<td>+</td>
<td>Insufficient heat, leaks</td>
<td>190</td>
</tr>
</tbody>
</table>

Source: D.F. Farkas (1991)
** "Potential for microbial growth if out of control"
*** pH of the product is 3.8

Figure 10.3.1 Canned juice drink- Inventory of process steps for ingredients, packages and process conditions to provide a basis for Hazard Analysis (HACC)

### 10.3.4 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.

Figure 10.3.2 Vacuum packed refrigerated meat soup. Inventory of process steps for ingredients, packages and process conditions to provide a basis for Hazard Analysis
10.3.5 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 10.3.1 Simple process description for hazard analysis
Chapter 11 Fruit and vegetable processing units - general approach; preliminary study; how to invest, install and operate a processing centre; modular units: from farm/family to community/business level

11.1 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.

11.2 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
m) Take into account the fact that the marketability of finished products will be different 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 approximately 1:10 from those actually in use in developed countries.

11.3 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 l)
Crown tops

Jars (0.300 l)
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
Fruit and vegetable processing - Ch011 Fruit and vegetable processing units...cessing centre; modular units: from farm/family to community/business level

properly labelled;

- The preparation and drying areas must NOT be located in the vicinity of a stock-farm.

11.4 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 refractometer 0-90 ° Brix (2)

Thermometers 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.

11.5 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 covered 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 refractometer 0-900 Brix (2)

Thermometers 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 l(3)

Stainless steel pots 10 l(3)

Stainless steel pots 15 l(3)

Medium size SO2 generator

Electrical heated ventilated oven, cap. 30 l
Small cool / cold room: volume = 20 m²; 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 l) Bottles (0.33 l)

Crown tops

Jars (0.580 l) Jars (0.300 l)

Screw-tops for jars

Electrical heating plates

Gas fired heating places

Hand-operated capping device (capper)

Rigid plastic drums 50l(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.

11.6 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. SO2 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 (70-90l; 100-120l and 150-200l 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 SO2 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 m³; temperature = +2 to +15°C.

xi. Laboratory equipment:

laboratory refractometer 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 meter F 1701;
laboratory model pH meter F 1703.
penetrometer;
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);
reflexiometer model F 1603 for dense products;
jars vacuum detector with measure of cap deflexion;
various thermometers; various manometers: can vacuum indicator;
vacuum and pressure; standard);
hand model refractometers model F 1601 for juices, concentrates, jams, etc.
11.7 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. SO2 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.

11.7.1 Manufacturing processing lines for tomato products and tropical fruit products

Flow-sheet of processing operations for tomato products

Figure 11.7.1 Manufacturing processing lines and equipment for canned tomato products and tropical fruit 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.

For the recommended heat processing times for tomato products see Table 11.7.1.

**TABLE 11.7.1 Recommended process times for canned tomatoes by can size, minutes**

<table>
<thead>
<tr>
<th>Can Size</th>
<th>Still retort, 212°F</th>
<th>Agitating cooker, 212°F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water-cool</td>
<td>Air-cool</td>
</tr>
<tr>
<td>303 x 406</td>
<td>45</td>
<td>35</td>
</tr>
<tr>
<td>307 x 409</td>
<td>45</td>
<td>35</td>
</tr>
<tr>
<td>401 x 411</td>
<td>55</td>
<td>45</td>
</tr>
<tr>
<td>603 x 700</td>
<td>100</td>
<td>80</td>
</tr>
</tbody>
</table>

Source: Da Fonseca, J.L.F., Moy, J.H. (1975)

The relationship of direct refractometric readings for natural tomato solids are listed in Table 11.7.2.

**TABLE 11.7.2 Refractometric readings for natural tomato solids**

<table>
<thead>
<tr>
<th>Tomato pulp- purée Concentration</th>
<th>Tomato paste % solids</th>
<th>% solids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>8.0 - 10.1</td>
<td>24.0 - 28.0</td>
</tr>
<tr>
<td>Medium</td>
<td>10.1 - 11.3</td>
<td>28.0 - 32.0</td>
</tr>
<tr>
<td>Heavy</td>
<td>11.3 - 15.0</td>
<td>32.0 - 38.5</td>
</tr>
<tr>
<td>Extra heavy</td>
<td>15.0 - 24.0</td>
<td>over 38.5</td>
</tr>
<tr>
<td>Concentrated tomato juice</td>
<td>20.0 - 24.0</td>
<td></td>
</tr>
</tbody>
</table>

Source: Da Fonseca, J.L.F., Moy, J.H. (1975)

The processing time (spin process) for different packs of passion fruit juice are listed in Table 11.7.3.
11.7.2 Manufacturing equipment for canned tomato products and tropical fruit products factory

The products obtained in this factory would be mainly:

- guava nectar;
- 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.

11.7.3 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.

**Figure 11.7.2 General layout for a fruit and vegetable processing unit/factory for tomato and tropical fruit products**

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.

### 11.7.4 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 system for filling and closing; adapted to bag filling machine model E 104.

**Figure 11.7.3 Mango processing unit - Mango juice in bags "Hot Fill" process (Courtesy of H. Biaugeaud S.A.)**

### 11.8 Overall raw material consumption data / yield for fruit and vegetable
processed products - approximate data

Table 11.8

Table 11.8 (continued)

Table 11.8 (continued)

Table 11.8 (continued)

11.9 Fruit and vegetable processing centre - quality control sheet daily recording sheet finished products defects

Table 11.9

Table 11.9 (continued)

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)
Bibliography

Containing citations from the text and references for further reading


FAO. 1990a. Rural processing and preserving techniques for fruits and vegetables. Rome: FAO.


FARKAS, D.F. 1991. How to describe a process for quality control. PA'91 - Session B-2, Oregon State University, Corvallis, Or.


GROUP 1.1 SIMPLE PROCESSING

PROCESSING OF MANGO BARS

Processing of mango bars

Ripe fruit is used; the mangos are washed, peeled and cut into pieces with a stainless steel knife. Pulp extraction is carried out with a hand-driven or electrical juice extractor. Sugar, lemon juice (or citric acid) and potassium metabisulphite are then added to the pulp so that mixture contains 25% TSS (total soluble solids) as determined by a refractometer.

The composition of ingredients is as follows:

- sugar: 10 to 15% of the weight of the pulp;
- lemon juice: 2 spoons per Kg of pulp;
- potassium metabisulphite (K2S2O5): 2 g per Kg of pulp.

The pulp thus prepared is heated for two minutes at 70-80°C. It is then poured into aluminium trays coated with glycerine (this facilitates the removal of the dried pulp). The prepared pulp should be placed on trays at the rate of 15 Kg per square metre.

The trays are brought to a sun or solar dryer. The drying is completed when the product has the consistency of leather (about 15% moisture content). The yield ratio between raw material and finished product is about 12:1. Two or three layers of dried product are piled one on top of the other and cut into small squares (4 X 4 cm). Each square is wrapped in cellophane paper, packed in cellophane bags then labelled and stored in a dry place.

PROCESSING OF DRIED MANGO SLICES

Processing of dried mango slices

Half-ripe fruits, without fibres, are used.

The mangos are washed, peeled and cut into 6-8 mm thick slices with a stainless steel knife. To obtain finished products with good quality and long storage life, the mango slices are soaked for 18 hours in a solution containing:

* boiling water: 1 litre;

- sugar: up to 40 Brix (7-800 g);
- potassium metabisulphite: 3 g/litre of water;
- lemon juice: 2 spoons/litre of water.

The slices thus prepared are drained and placed on glycerine coated aluminium trays, which are placed in a sun or solar dryer.
The drying is completed when the product has a moisture content of 15%. The dried slices (150 g) are packed in cellophane bags, labelled and stored in a dry place.

Mango bars and mango slices:

Storage life: about 9 months.

Remark: without preservative (potassium metabisulphite), the storage life of the products is relatively short.

PROCESSING OF MANGO JUICE

Processing of mango juice

Fully ripe fruit is used. The mangos are washed, peeled and cut into slices with a stainless steel knife. Pulp extraction is carried out with a hand-driven or electrical juice extractor.

Boiling water, lemon juice and sugar are added to the pulp so that the mixture contains 12% TSS (total soluble solids) as determined by a refractometer and pH of 3.5 to 3.8. The composition of ingredients is as follows:

- boiling water: 1 litre/kg of pulp;
- sugar: 200 g/kg of pulp;
- lemon juice: 2 spoons/kg of pulp.

Bottles are filled and capped with a manual capper. Pasteurization times is related to the size of bottles.

<table>
<thead>
<tr>
<th>Size of bottles in litre</th>
<th>Pre-heating</th>
<th>Pasteurization time in minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.33</td>
<td>YES</td>
<td>20</td>
</tr>
<tr>
<td>0.50</td>
<td>YES</td>
<td>25</td>
</tr>
<tr>
<td>0.75</td>
<td>YES</td>
<td>30</td>
</tr>
</tbody>
</table>

Allow the bottles to cool in the same container till the following morning then wash, label and store them.

Storage time: about 12 months

Processing of mango jam

Both ripe and underripe fruit is used.

The mangos are washed, peeled and cut into small slices with a stainless steel knife. The amount of sugar required represents 60% of the weight of the mangoes prepared.

The cooking is done in two stages:

1ST STEP consists in adding 70% of the amount of sugar calculated, plus 2 spoons of lemon juice per Kg of mango. Stir well
during the entire cooking until 50° Brix of solids by refractometer is reached.

2ND STEP consists in adding the remaining 30% of the sugar plus 2 spoons of lemon juice per kg of mangos. Stir well during the entire cooking, until 67-68° Brix of solids by refractometer is reached.

The jars are filled while the mixture is hot ("hot-fill" process). During the operation the jam must be stirred with the handle of a wooden spoon in order to eliminate the air that has entered the jars. The jars are closed with screw-tops. Jars cooling, washing and labelling are the last stages before storage.

PROCESSING OF PEELED TOMATOES

Processing of peeled tomatoes

For the preparation of peeled tomatoes, fully ripe but still hard, long and/or oval tomatoes are used.

After washing, green tomatoes or those showing mouldy patches, black spots or presence of worms are picked out. The remaining tomatoes are dipped in boiling water for about one minute, then cooled in water at room temperature. Scalding facilitates the bursting of the skin.

The jars, previously washed, are filled by hand. To eliminate the gaps created during filling, tap the bottom of the jar. Then add a small spoonful of lemon juice or vinegar. The filling is completed by adding the hot pulp. The jar is tightly closed with a screw-top. Before counting the pasteurization time, wait till the water comes to the boil.

Pasteurization time is related to the size of the jars.

PROCESSING OF TOMATO PULP

Processing of tomato pulp

For the preparation of tomato pulp, fully ripe but not spoilt tomatoes are used.

After washing, the tomatoes are drained in order to eliminate the water on the surface. Sorting is done before the tomatoes are cut into halves to facilitate crushing and to detect any possible disease or decay inside.

A manual or electrical juice extractor is used to separate the pulp from the seeds and the skin. The pulp is transferred to a pot and heated until 8-90 Brix of solids by refractometer is obtained.

While still hot, the pulp is bottled with the help of a ladle and a funnel (previously "boiled" for few minutes in water). Acid correction is done with a small spoon of lemon juice.

The bottles are closed with a capper. The pasteurization is performed within the same duration as the jars of peeled tomatoes and under the same conditions. Cool overnight. Washing and labelling are the last stages before storage.

Storage life: about 12 months.
GROUP 1.2 - DRYING / DEHYDRATION

PROCESSING OF DRIED CARROTS

Processing of dried carrots

Roots with red cores and not woody are good for drying. Varieties such as "Chantenay Red Core" and "Imperator" are best for drying.

After removing the stalks and tips, wash the carrot, scrape, then cut into slices of about 56 mm thick using stainless steel knives. All green parts, if any, have to be removed.

For blanching, the slices are dipped for 3 minutes in boiling water containing 50 g salt per litre of water, followed by cooling in running water. In some processes, depending on the finished product specifications / customer standards, sulphiting is also carried out. This step is by dipping in a solution containing 3 g potassium metabisulphite per litre of water, during 3 min.

The product is then evenly spread on the trays of a dryer. The carrots are dried when the prepared MW material / dry products ratio is about 12:1 (moisture content about 6%).

Cooling, packing, labelling and storage of dried products are performed according to same recommendations as for the other products.

PROCESSING FLOW-SHEET FOR APRICOT DRYING/DEHYDRATION

Processing flow-sheet for apricot drying/dehydration

In order to obtain a high quality finished product, it is essential, among other points, that raw material characteristics fulfil the following requirements:

- fruit from varieties with kernel not adhering to pulp;
- clean fruit, e.g. not contaminated with dirt, soil, etc.;
- whole and healthy fruit;
- maturity/ripening according to needs for drying technology, e.g. having reached about 90% of the colour of fully ripe fruit;
- fruit with pulp which has a texture that enables it to keep its shape after cutting;
- fruit without physical damages or microbiological attack.

Fruit must be cut in halves with a knife; do not "separate" the two halves by hand.

Conventional sulphuring before drying is performed by exposing fruits on drying trays to fumes of burning sulphur in "sulphuring cells":

2 g of sulphur for each kg of prepared fruits; sulphuring time: 60 to 90 minutes.

In order to reduce SO2 content in finished product and to provide an alternative to sulphuring cells for small scale / farm
operations, dipping apricot halves in various preservative solutions ("wet sulphuring") may be used.

PROCESSING FLOW-SHEET FOR DRIED/DEHYDRATED PLUMS (PRUNES)

The lowest acceptable degree Brix for raw materials is 21 with an average at 24° Bx and a maximum at 30° Bx.

Mechanical drying installation (tunnel) can handle up to 8-11 t/day raw material.

Initial air temperature is 55° C and final air temperature is 72-75° C.

Plums are dried down to 23-24% moisture in the first step.

After storage, commercial practice is to re-process the prunes by immersion in warm water (80° C), containing 2% sodium sorbate, during 10 min and thus rehydrating products up to 26-28% or to 30-32% moisture; this treatment provides a ready-to-eat product which is very appreciated.

PROCESSING FLOW-SHEET FOR DRIED/DEHYDRATED APPLES

After peeling and coring/slicing dip slices in salted water (2% NaCl) before further treatment in order to prevent browning due to contact of tissues with oxygen from air.

Plums should be cut into 8 slices (= cut each quarter in two slices). Peeling is optional and depends upon customer specification or consumer preference.

Sulphuring can be performed by two alternative methods:

a) Wet sulphuring: dipping slices for 10 minutes in a solution containing: 0.5% Potassium metabisulphite (K2S2O5) + 0.2% Citric acid.

b) Dry sulphuring: keeping slices (on drying trays, in sulphuring cells) exposed to fumes of burning Sulphur

2 g Sulphur for each kg of apple; sulphuring time: 30-40 minutes.

- Resulphuring has to be performed by exposing dried apple in bulk to fumes of burning sulphur in order to avoid insect infestation.

PROCESSING FLOW-SHEETS FOR DRIED/DEHYDRATED LEEKS

* It is necessary to separate the white parts of the vegetables from the green ones by cutting manually.
The following step - cutting operation - is then done separately for each colour.

Sorting and sieving steps require elimination of "fines" and a control of adequate separation by colour.

PROCESSING FLOW-SHEET FOR DRIED/DEHYDRATION POTATOES

Processing flow-sheet for dried/dehydration potatoes

- Temporary storage in good conditions is done in darkness, at low temperatures (if possible at 10°C or down to 5°C). Potato peeling could be performed preferably by mechanical or chemical means. After each main peeling step, a manual rectification must be added in order to obtain good final results.

- After cutting, slices or pieces must be immediately dipped in 0.5% solution sodium metabisulphite for 1 minute and then kept in 2 % NaCl water solution until next processing step to avoid contact of tissues with oxygen from air.

- Slices optimal size could be evaluated at 5-6 mm.

* Optimal blanching time is 2-5 min according to variety.

- Treatment after blanching is dipping in water containing 8000 ppm S02 (12 g K2S2O5 to each litre of water).

** Optimal dehydration temperature is 65°C.

An alternative treatment is with slices soaked in a 10-fold weight solution of 5% (w/w) sodium chloride (salt) + 1% K2S2Os for 16-18 h, at ambient temperature (around 20°C) and then dried.

FLOW-SHEET FOR PROCESSING OF DRIED ONIONS

Flow-sheet for processing of dried onions

Varieties with pungent flavour are the most appreciated; both coloured and white onions may be used.

After removing the tops, roots and outer integuments, onions are washed thoroughly and then cut into slices of 3 mm thick. It is preferable to cut at right angles to the core of the onions. After cutting onion slices are carefully washed. Blanching is not practiced (it makes the onion lose its flavour).

The use of preservatives is not necessary; therefore, after washing and draining, the slices are spread evenly on the trays of a dryer. The onions are dried when the ration of prepared raw material to dry product is about 9:1 (moisture content about 5%).

Cooling, packing, labelling and storage follow the same operations as described in other flowsheets.

The dried product may be ground into powder (which tend to agglutinate without any anticaking agent).

The dryer used for onions must be reserved especially for onion (flavour / odour contamination possible to other products).

Storage life: about 12 months.
PROCESSING OF DRIED TOMATOES

Processing of dried tomatoes

For the preparation of dried product, tomatoes should be ripe, of good red colour and should be firm.

Tomato pigments are stable because they are rich in carotene; therefore, pre-processing, such as blanching and sulfiting, is not necessary. Alternatively the slices may be dipped for 3 min in a solution containing 0.7% K2S2O5 plus 10% salt.

Washing and sorting are followed by cutting in halves lengthwise to eliminate the liquid and the seeds. The seeds as well as the ones from tomato pulp processing can be used again as seeds if they have not gone through a heat treatment.

Empty the tomatoes and then cut them lengthwise into slices of 6 to 8 mm thickness and place them in dryers.

The tomatoes are dry when the raw material / dry product ratio is about 25:1. On an average, 40 g of dried products are obtained from I Kg of fresh tomatoes. The yield depends on the dry tomato residue and the degree of drying.

The last operations before storage are: cooling (half an hour at room temperature), bagging (in 100 g cellophane bags, closed to avoid humidity) and labelling.

The product must be kept in a dark place to reduce infestation by photophylic insects.

The dried slices may be reduced to flakes by rubbing through a sieve of about 10 mm mesh. This gives a better looking product which is easy to handle. The product may also be ground into powder but this will tend to cake and the colour is less appealing than the flakes.

NOTE:

Three processing recommendations made in this flow-sheet have to be followed, among others, for all dried/dehydrated products:

1. Let finished products cool down to room temperature for half an hour before packing/bagging;
2. Always store dried/dehydrated products in a dark place.
3. Place dried/dehydrated products in packing materials which have enough barrier effect against moisture transfer and close well.

GROUP 1.3 - JUICES, FRUITS IN SYRUP, SAUCES, JAMS, PULPS AND NECTARS. CANNED PRODUCTS

Flow-sheet for orange juice processing

Fruit to be used for juice production should be from a well run cultivation, freshly picked and well ripened.

The fruit is first sorted to remove rotten and other unfit items. It then passes through a soak tank of disinfectant and water and then to a brush-washer where rapidly revolving brushes and sprays wash the fruit very vigorously and thoroughly. The brush-
washed fruit is again sorted and conveyed to the juice extractor, or halved and juiced.

The pulpy juice flows into the mesh screen finisher for the removal of seeds, heavy pulp and skin portions. The finished juice passes on to the blending, mixing and heating tanks where the requisite amount of sugar syrup is added, if sweetened juice is to be produced. Blended juice is pasteurized and filled into sterilised cans. Filled cans are sealed, cooled, labelled and packaged for marketing.

FLOW-SHEET FOR PROCESSING MANGO JUICE

Fruit to be used for juice production should be factory ripened. Fully mature, unripe mangos are harvested and shifted to the cannery where they are allowed to ripen in a closed atmosphere. Usually it takes about three to four days to ripen the fruit.

Fruit is then sorted and sound ripe mangos are passed to a soak tank of antiseptic and water, and then to a brush washer where rapidly revolving brushes and sprays wash the mangoes. The washed fruit is conveyed to the preparation tables where it is hand peeled. In some cases, the washed unpeeled fruit is steamed and pulped, but for a quality product it should be peeled.

The peeled mangos are steamed and pulped. The coarse pulp thus obtained is sieved with the help of a finisher and conveyed to the blending, mixing and heating tanks where the requisite quantity of sugar syrup is added. The juice is then pasteurized, filled into the steamsterilised cans and sealed. The sealed cans are water-cooled, labelled and packaged for sale.

FLOW-SHEET FOR PROCESSING OF PINEAPPLE JUICE

Canned pineapple juice is now third to canned tomato juice and orange juice in terms of volume (world production). It is an excellent juice for canning, since it retains its fresh flavour and aroma remarkably well and is of an acidity and sugar content such that it is properly balanced in flavour.

Pineapple juice is a by-product obtained during the canning of pineapple slices or rings in syrup. The principal raw materials from which pineapple juice is prepared are the shredded meat obtained from the inner portion of the peels left after the peeling of the pineapple, the small pineapple that is too small for canning, the trimmed cores and the juice drippings from the crushed pineapple.

Small pineapples are peeled. The peeled, small pineapple cores and eradicated meat are shredded; the juice is extracted and then passed through a finisher. The juice thus obtained is blended with sugar syrup, pasteurized and filled into sterilized cans. The cans are sealed hot ("hot-seal" process), cooled, labelled and packaged.

SIMPLIFIED FLOW-SHEET FOR TOMATO JUICE PROCESSING

Simplified flow-sheet for tomato juice processing
A hand-operated or an electrical juice extractor could be used. Refining is an optional step and will be performed if an additional centrifugal refiner is available as equipment.

Citric acid or lemon/lime juice will be added in bottles just before filling. Salt may be added to enhance taste.

Prior to use, empty bottles or jars (and crown-corks or caps) must be washed thoroughly, rinsed and then "sterilised" by keeping in boiling water for 30 min.

* Pasteurization is a very important step for the finished product shelf-life and must be carried out very carefully.

** DO NOT cool recipients after pasteurization in running water - there are risks of breakage; instead, leave recipients to cool down slowly overnight in the pasteurization pot.

* Pasteurization TIMES

<table>
<thead>
<tr>
<th>Recipient countenance</th>
<th>Preheating</th>
<th>Pasteurization times</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.331</td>
<td>60° C</td>
<td>40 minutes</td>
</tr>
<tr>
<td>0.501</td>
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</tr>
<tr>
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</tr>
<tr>
<td>0.751</td>
<td>60° C</td>
<td>60 minutes</td>
</tr>
</tbody>
</table>

FLOW SHEET FOR PROCESSING OF MANGO SLICES IN SYRUP

Flow sheet for processing of mango slices in syrup

Fully mature, unripe mangos are ripened in the cannery to optimum canning ripeness. Mangos high in flavour, with more flesh and low in fibre are always recommended for canning.

Sound ripe mangos are soaked in antiseptic and water, brush washed and then conveyed to the preparation tables and hand peeled. "Cheeks" of the peeled mangos are sliced off and longitudinally cut into two or three slices. Side cuts are packed separately. Slices are then conveyed to the filling tables where they are graded for size, colour and maturity and filled into sterile cans. Filled cans are syruped, steam exhausted, sealed, processed in boiling water, cooled, labelled and packaged.

Stones with the left over flesh are steamed and pulped and the pulp thus obtained is packed as such or converted into mango juice or nectar.

FLOW-SHEET FOR PROCESSING OF PINEAPPLE RINGS IN SYRUP

Flow-sheet for processing of pineapple rings in syrup

Pineapples are harvested when they have reached full maturity in order to obtain maximum flavour and quality. Usually the fruit is harvested when 20 to 25 per cent of bracts have turned orange in colour, and then transferred to the cannery in the shortest possible time. Fruit weighing 1.5-2.0 Kg are the best suited for canning as rings.
Fruit is size graded and the crown removed. It is then washed thoroughly and prepared, which includes peeling, coring, slicing and punching. Slices are then graded for size, colour and maturity. Slices should be free from peels and eyes. Each can is filled with slices of the same size and colour. The filled cans are syrped hot, exhausted, sealed, processed, cooled, labelled and packaged.

FLOW-SHEET FOR PROCESSING OF TOMATO KETCHUP OR SAUCE

Flow-sheet for processing of tomato ketchup or sauce

Tomato sauce and tomato ketchup are popular condiments all over the world. Clean, wholesome tomatoes of intense red colour and of meaty, not watery texture are used for sauce making. High acidity and a rich tomato flavour are additional desirable qualities.

Sound tomatoes are washed very thoroughly, cored, sliced, heat crushed and pulped (through a pulper or juice extractor) to remove seeds and skins. Tomato pulp or paste is then cooked with the requisite quantities of spices, onions, garlic, sugar, salt and vinegar.

The whole mass is concentrated to a final TSS (Total Soluble Solids) of more than 25 per cent. The mass is finally passed through the finisher and filled into clean, dry bottles.

Bottles are cleaned, labelled and packaged for marketing. (Preservation is assured either by use of preservatives or by pasteurization).

SIMPLIFIED TECHNOLOGICAL FLOW-SHEET FOR FRUIT JAMS PROCESSING

Simplified technological flow-sheet for fruit jams processing

Jams may be made from practically all varieties of fruit. Various combinations of different varieties of fruit can be often be made to advantage, pineapple being one of the best for blending purposes because of its pronounced flavour and acidity.

Sound fruit is sorted, washed in running water or, preferably, brush-washed and prepared. The mode of preparation varies with the nature of the fruit. For example, mangos are peeled, steamed and pulped; apples are peeled, cored, sliced, heated with water and pulped; plums are scalded and pulped; peaches are peeled and pulped; apricots are halved, steamed and pulped; berries are heated with water and pulped or cooked as such.

Fruit pulp is cooked with the requisite quantities of sugar and pectin, and finished to 69% Total Soluble Solids (TSS). Permitted food colours and the requisite amounts of citric acid and flavouring are added at this stage. The product is packed in cans or glass jars, and cooled, followed by labelling and packaging.

PROCESSING FLOW-SHEETS FOR MANUFACTURING JAMS FROM BERRIES

Processing flow-sheets for manufacturing jams from berries
Coring is a major limiting factor in the recovery of the fruit and in the whole processing operation. Trimming should be mainly to remove the deep "eyes".

Sugar syrup concentration is adapted to the type of finished products:

- 45-55° Brix for "Fancy" slices
- 30-35° Brix for "Choice" slices
- 20-25° Brix for standard slices

Removal of air is performed in continuous steam exhauster equipment for 7-9 min at 185-212° F or discontinuously in boiling water.

Heat treatment is carried out in continuous rotary cookers at 212° F for 10-20 min.

Cooling is be done in rotary coolers in water for 10 min.
Appendix II - Standards for grades of dried apricots

1. Definition of the product

These standards refer to apricots dried (naturally) or dehydrated, obtained from mature fruits, botanical name: Prunus Armeniaca L.

2. General quality requirements

In all categories, dried apricots must be:

2.1 Whole (with or without kernel) or halves;

2.2 Healthy and especially without mould, without visible evidence of attack by insects or by other parasites and without living insects in any stage of development;

2.3 Clean, without any visible foreign matter;

2.4 Without foreign smell (*) and / or flavour;

2.5 Fleshy, with an elastic and flexible pulp.

The moisture content must not be over 20%. However, at the request of customer, moisture content could be in the range of 20-25% or 25-30%, with the reserve of special processing treatment utilisation (for assuring shelf-life) and mentions in the section "Marks".

The manufacturing and state of dried apricots should be such to enable them to support transport and handling and assure their arrival in good conditions to the delivery point.

3. Grading

The dried apricots are graded as follows:

3.1 "Extra category": Dried apricots shipped under this category must be of superior quality. If the product is whole, it must be without kernel. The colour has to be characteristic to the product and homogenous (colour "apricot") without any part which are black, discoloured or with texture defects. The halves must have a clean / net cutting (by knife).
3.2 "Category I": Dried apricots shipped under this category must be of good quality. If the product is whole, must be without kernel. The colour has to be characteristic to the apricots. Tolerance: slight appearance or colour defects (discoloured) and small cuttings of skin but with the condition that all these defects have no impact on product appearance, quality or shelf life.

3.3 Category II: This category covers dried apricots which cannot be classified in superior categories but are according to the minimum requirements defined in section 2. If the product is whole, it could be with kernel. Appearance and colour defects (spots, brown parts but without darkening of fruits) and slight damages of the skin are accepted with the condition that the finished product keeps its characteristics.

4. Size grading

The size grading is determined by the number of fruits per pound:

<table>
<thead>
<tr>
<th>Category</th>
<th>Wholes</th>
<th>Halves</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very big</td>
<td>Less than 50</td>
<td>Less than 100</td>
</tr>
<tr>
<td>Big</td>
<td>50-65</td>
<td>100-130</td>
</tr>
<tr>
<td>Medium</td>
<td>66-75</td>
<td>131-150</td>
</tr>
<tr>
<td>Small</td>
<td>76-90</td>
<td>151-180</td>
</tr>
<tr>
<td>Very small</td>
<td>More than 90</td>
<td>More than 180</td>
</tr>
</tbody>
</table>

The size grading is mandatory for dried apricots in category "Extra" and "Category I" and has to be mentioned in section "Marks".

5. Tolerances

5.1 Category Extra: 5 % in weight of fruits not answering to the quality specifications for this category but in conformity with those of "Category I".

5.2 Category I: 10% in weight of fruits not answering to the quality requirements for this category but being in conformity with those of "Category II".

A maximum 0.5% in number of fruits having traces of mould or fermentation or containing dead insects or other parasites is also tolerated.

5.3 Category II: 15% in weight of fruits not answering to the quality specifications for this category but being in conformity with the minimum requirements defined in section 2. A maximum 1% number of fruits with moulds or fermentation or containing dead insects or other parasites is also tolerated.
The presence of any living insect or parasite is **NOT** tolerated, in any of their biological cycles.

In all categories, a tolerance is accepted for size grading - 10% in weight of fruits in each pack - in conformity with size from immediately superior and/or inferior size grade identified.

Tolerance in moisture level. - It is accepted a variation of 1% more or less as compared to the level indicated in section "Marks".

6. Homogeneity

The content of each shipping or consumer pack must be homogenous and must contain only dried apricots of same origin, quality and size. The visible part of the pack must be representative of all the content.

7. Packing

The content of each shipping or consumer pack must be protected against any external or internal deterioration/damages. The packing and material must be new, clean, free from any foreign body, according to the specifications, in line with consumer requirements.

8. Marks

All packages of dried apricots must bear:

8.1 Indication as to contents and their origin: (country of origin name) Dried Apricots;

8.2 Indication as to the category: Extra, I or II;

8.3 Indication as to size grade: very big, big, medium, small or very small and type: wholes or halves;

8.4 The packer's mark as specified by local authorities;

These indications must be made clearly and legibly by means of indelible ink or branded outside the package in letters of 2 cm height;

8.5 Indication as to the moisture content, if above 20%, i.e. "Moisture content 20-25 %" or "Moisture content 25-30%";

8.6 Indication as to the net weight of the package.
Appendix III - Recipe guidelines; dried fruit and vegetables

RECIPE GUIDELINES * - FRUIT PRESERVES WITHOUT SUCROSE

1. Strawberry jam with RSunett and Sorbitol

Ingredients:

Strawberries 500 g

Sunett 0.75 g

Sorbitol (powder) 250 g

Gelling agent

Method: Prepare the fruit as usual. Add the Sorbitol powder and the gelling agent and bring to the boil while stirring continuously. Dissolve the Sunett in some water and add it to the other ingredients. Add the additional ingredients which are usually added in producing jams. Let the ingredients boil for approximately 1 minute while stirring constantly. Fill into the prepared jars.

Calorific value: cat 480 kJ/100 g (ca. 115 kcal/100 g)

2. Berry jam with RSunett, cyclamate and sorbitol

Ingredients:

Red currant 100 g

Black currant 100 g

Blackberry 100 g

Sorbitol 150 g

Jelling agent to suit
Sunett 0.45 g
Cyclamate 0.45 g

Method: Prepare the jam in the usual way

Calorific value: cat 480 kJ/100 g (ca. 115 kcal/100 g)

3. Red currant jam with RSunett and Sorbitol

Ingredients:

Red currants 450 g
Sunett 0.9 g
Sorbitol 450 g
Gelling agent

Method: Prepare the fruit as usual. Add the sorbitol and the gelling agent and bring to the boil while stirring continuously. Dissolve the Sunett in some water and add it to the other ingredients. Add the additional ingredients which are usually added in producing jams. Let the ingredients boil for between 2 and 4 minutes while stirring constantly. Fill into the prepared jars.

Calorific value: cat 897 kJ/100 g (ca. 215 kcal/100 g)

DRIED PLUM (PRUNE) PURÉE

I. Ingredients Weight/measures

Soft pitted prunes 3 lbs.
Sugar 1/2 cup
Light corn syrup 1 cup
Boiling water 2 1/2 cups
II. Method

This purée may be made in any commercial-size processor with a 1-gallon capacity work bowl. Lacking a large processor, follow the instructions in the NOTE at the end of the recipe. Purée keeps well, refrigerated, for 6 to 8 weeks. Use directly from the refrigerator. Freeze for longer storage, thaw before using.

Place first three ingredients in work bowl fitted with the metal blade. Start motor and pour boiling water through feed tube. Process about 2 minute, until mixture is completely smooth. Stop motor occasionally to scrape side of work bowl. Cool completely; cover and refrigerate.

NOTE: To make purée without a processor, combine all ingredients in large saucepan. Bring to boil, cover pan, and stew prunes slowly until fruit is very tender. Mash well with large wooden spatula, pressing prunes along side of saucepan. Alternatively, grinding this mixture through the finest blade of a meat grinder. You may multiply this recipe any number of times.

RECIPES

Apricot fruit preserves

1. 1 kg apricot halves (without stones) 0.6 kg sugar 5 g citric acid

   Add 420 g sugar to prepared fruits and bring to boil; boil gently during 15 min

   Add the remaining 180 g sugar and 5 g citric acid

   Continue boiling gently up to required refractometric extract

2. 1 kg apricot halves prepared as above 1.5 kg sugar For all sugar to the fruit; mix gently with a spoon

   Leave the mix overnight

3. Dip apricot halves for 7 min in a solution containing:

   2% sodium metabisulphite and 0.5% citric acid

   Obtain fruit pulp by available means/equipment: a) through a sieve in traditional preparation; b) with a simple juice/pulp extractor in small scale operation; c) with a pulper in other cases).

   Basic recipe is 1 kg fruit pulp + 0.6 kg sugar.

Methods for drying some vegetables and fruits
1. Garlic. - The cloves are separated and the outer skins removed by hand. The skins of individual cloves are not removed. The cloves are cut into pieces not more than 5 mm cube. No blanching nor other treatment are applied.

The product is spread evenly on drying trays. Dry until brittle. The final moisture content should be about 5%. The yield is about 5:1. After completing drying, separate dry skin by winnowing.

The dry product may be ground into powder which should then be protected against moisture pick-up as it is very hygroscopic.

2. Beetroot. - After washing, peeling and trimming the material is cut into slices about 2-3 mm thick. Only steam blanching could be used as water blanching will wash out the colour. The slices are immersed in a solution containing 8000 ppm SO2 for 1 minute.

The prepared material is placed on drying trays and dried to a moisture content of about 6%. Shade drying might also be tried. Overall shrinkage ratio is about 12:1.

3. Turnip. - The material is peeled after cutting off tops and roots then cut into slices 2 to 5 mm thick. The slices are submerged for 4 to 6 minutes in boiling water. Slices are dipped for 1 minute in a solution of metabisulphite containing 8000 ppm sulphur dioxide.

After treatments, material is spread thinly and evenly on standard trays and dried to a moisture content of 6%. Shrinkage ratio is 28:1.

Turnips are white fleshed, and Swede Turnip yellow or orange fleshed. The latter will produce a dried product of better quality.

4. Sweet pepper

The raw material is washed thoroughly and broken up. Cores and interlocular partitions are removed by hand. Defective parts are cut out with knives. The prepared flesh is held under water or a weak solution of sodium metabisulphite (2000 ppm SO2) before being hand cut into strips about 5 mm wide.

The cut pieces are dipped for 1 minute in a solution of 2000 ppm So2 (3 g sodium metabisulphite per litre).

The material is spread in a thin layer on trays and shade dried until crisp or to a moisture content of about 7%. Average shrinkage ratio is about 25:1; drying ratio is about 13:1.
For finishing, pick out any burnt or discoloured pieces; put the material on a sieve of suitable mesh to remove small pieces and "fines". Both green and red peppers may be used for drying.

5. Banana

Both fully ripe and unripe fruits can be dried, but since they are used for different purposes they must not be mixed together.

The fruit is washed, peeled and diced into transverse slices 10 mm thick or lengthwise.

Unripe fruits are blanched in boiling water for a few minutes and then peeled. The ripe fruits are not blanched.

The prepared material is dipped for 1 minute in a solution containing 2000 ppm sulphur dioxide.

The slices are dried on standard trays which have been coated with a very thin glycerin layer to avoid sticking. The final moisture content should be around 12%.

The dried slices prepared from unripe banana may be converted into flour which can be used alone or in combination with other flours.

Dried bananas produced from ripe fruit are usually consumed in the dry state, like dates.

Glossary

Shrinkage ratio: the ratio of unprepared raw material to dry finished product.

Drying ratio: the ratio of prepared raw material to dry product. ppm: parts per million

Carrot dehydration

As an alternative to described method, a double blanch processing was found to give significant increases in firmness.

Lots (6 kg) of whole carrots are blanched by immersion in a large excess of water at 60° C in a steam jacketed kettle for 45 mini then blanched again for 6 min at 100° C in boiling water. The high temperature blanch was designed to inactivate enzymes that have the potential to generate off-flavours during storage in the dry conditions.

The carrots are then immediately peeled by immersion in 10% sodium hydroxide at 90° C for 1 min. passed through a rubber stud roller peeler to remove loose skin, sprayed with cold water and trimmed by
hand. They are diced into 9.5 mm cubes in an Urschel dicer and passed over a vibrating screen to remove small pieces.

The product may be spread on wire mash aluminium trays and conventionally air died in a cabinet dryer with cross-flow air for 1.5 hr at 82°C and then at 66°C for 3.5 hr to obtain a final moisture content of about 6-7%.

TECHNOLOGICAL FLOW-SHEET FOR DRIED/DEHYDRATED MULBERRIES

Technological flow-sheet for dried/dehydrated mulberries

- Treatment before drying is as follows:

** Dipping fruits for 5 minutes in a solution containing

0.5% Potassium metabisulphite and

0.2% Citric acid

- Technological steps and treatment are the same for white and for black mulberries.

PROCESSING OF DRIED GREEN BEANS

Processing of dried green beans

Only stringless varieties should be dried. Suitable varieties are "Contender", "Tendergreen", "Tenderlong". Harvest the pods whilst the seeds are still small.

After washing, snip off the ends of the pods. The material is then cut into pieces 3 cm in length using a diagonal cut.

For preservation purposes and in order to keep the colour of the vegetable, blanching and sulphiting are carried out.

For blanching, the product is dipped in boiling water containing 50 g salt per litre of water, during 3-4 min.
After cooling, sulphiting is carried out by dipping in solution containing 3 g potassium metabisulphite per litre of water, during 3 min.

Then drain and spread the product on the trays of a dryer. The beans are dried when raw material/dry product ratio is about 18:1 (moisture content about 6%).

Storage life: about 12 months.

### PROCESSING OF DRIED OKRA

**Processing of dried okra**

Young tender pods are preferred.

* The pods may be dried whole, in the form of slices (about 6 mm thick) or in halves cut lengthwise.

The pods are washed thoroughly to remove dirt. Both end are trimmed and any discoloured or damaged tissue is removed.

For preservation purposes and in order to keep the green colour, blanching is carried out: the product is dipped for 3 minutes in boiling water containing 50 g salt per litre of water. The blanched okras can then be washed with cold water to remove the slimy material produced by boiling.

The product is then sulphited by dipping for 3 minutes in a solution containing 3 g potassium metabisulphite per litre of water.

The product is then drained and finally placed on the trays of a dryer. The okras are dry when the prepared raw material/dry product ratio is about 12:1 (moisture content 4-5%).

Cooling, packaging, labelling and storage are carried out as recommended for the other finished products.

Storage life: 12 months

### PROCESSING OF DRIED CABBAGES

**Processing of dried cabbages**
After removing the outer leaves, the vegetable is washed and cut into quarters. Cores are removed and cabbages are cut into 5 mm strips. It is then washed to eliminate dust, soil and insects.

To keep the colour of the vegetable and for preservation purposes, blanching and sulphiting are carried out.

Blanching is performed by dipping for 3 minutes in boiling water containing 50 g salt per litre of water. After cooling, sulphiting is carried out by dipping in a solution containing 3 g potassium metabisulphite per litre of water, during 3 minutes.

The product is drained and then evenly spread on the trays of a dryer. The cabbages are dry when the prepared raw material / dry product ratio is around 12:1 (moisture content 5%).

Cooling, packing, labelling and storage are carried out as recommended for other products.
Appendix IV - Complete units and various equipment and material for fruit and vegetable processing

Contents

1. VEGETABLE PROCESSORS
2. AUTOMATIC SIEVES / PULPER
3. SIMPLE PEELING MACHINE BY ABRASION
4. FLOW DIAGRAM OF TRIPLE EFFECT POLYVALENT FRACTIONAL EVAPORATOR FOR TOMATO PASTE UP TO 320 BRIX AND CONCENTRATED CLARIFIED FRUIT JUICE TILL TO 720 BRIX - ING. A. ROSSI
5. SMALL SCALE STERILIZERS - STERIFLOW(r) - BARRIQUAND
6. TECHNOLOGICAL PROCESSING LINE FOR OBTAINING TOMATO JUICE BEFORE CONCENTRATION TO TOMATO PASTE
7. TECHNOLOGICAL LINE FOR TOMATO JUICE CONCENTRATION AND TOMATO PASTE PASTEURIZATION
8. POTATO PROCESSING UNIT - TECHNOLOGICAL LINE FOR POTATO FLAKES DEHYDRATION ON DRUM DRYERS
9. VARIOUS SIZES AND TYPES OF GLASS JARS
10. EQUIPMENT FOR "DRY SULPHURING" OF FRUIT BEFORE DEHYDRATION / DRYING

1. Vegetable Processors

2. Automatic Sieves - Pulper


5. Small-scale Sterilizers - Steriflow(r)- Barriquand

6. Technological Processing Line for obtaining Tomato Juice before concentration to tomato paste

(1) to (6) - WASHING - SORTING EQUIPMENT GROUP

1. INITIAL WASHING
2. DRUM
3. FINAL WASHING
4. AIR COMPRESSOR
5. SORTING BELT
6. RETURN BELT
7. Technological line for tomato juice concentration and tomato paste pasteurization

1. FIRST EFFECT EVAPORATOR
2. SECOND EFFECT EVAPORATOR
3. THIRD EFFECT EVAPORATOR
4. PUMP
5. PUMP
6. PUMP
7. PUMP
8. STORAGE TANK
9. STORAGE TANK
10. CONDENSER
11. VACUUM PUMP
12. PUMP
13. PASTEURIZATOR
14. DOSING AND FILLING MACHINE
15. CLOSING MACHINE

8. Potato Processing Unit - Technological line for potato flakes - dehydration on drum driers
POTATO PROCESSING UNIT - TECHNOLOGICAL LINE FOR POTATO FLAKES
DEHYDRATION ON DRUM DRYERS

(1) Vertical transporter
(2) Separator for soil, stones, etc.
(3) Size grader: whenever possible, potatoes with a diameter of 20 to 80 mm are preferred for processing into flakes. The fresh potatoes with a diameter exceeding 80 mm could be oriented to temporary storage and / or to direct delivery on the fresh fruit and vegetable market.
(4) Storage tank
(5) Washing machine, rotary type
(6) Vertical transporter
(7) Storage tank
(8) Vertical transporter
(9) Weighing device
(10) Vertical transporter
(11) Peeling machine, steam type; for other installations lye peeling equipment could be used.
(12) Rotary washing machine
(13) Transport and control belt
(14) Weighing and distribution system
(15) Vertical elevator
(16) Cutting machine
(17) Equipment for starch removal / washing
(18) Continuous blanching machine: 80-83°C, for 7 min.

(19) Cooler: in a water stream at 14-15°C.

(20) Machine for potato boiling: in water vapour, at 100°C, for 20 min.

(21) Vertical transporter

(22) Press or granulator: change boiled potatoes to a paste; for a good operation at drying stage it is recommended that the paste contain at least 20% dried substances (no more than 80% moisture).

(23) Feeding device for drum dryer; at this processing step, there are various additives that are added to the hot paste (in order to maintain taste, flavour, stability and structure of the finished products - potato flakes).

For 1000 kg paste 120 g of sodium sulphite and 40 g sodium bisulphite are added; in order to facilitate addition and an homogenous distribution, weak sulphite solutions are preferable. Depending on the sanitary regulations in various countries it is also possible to add other antioxidants.

Monoglycerides could be added for flakes texture improvement.

(24) Drying drums: potato purée is dried as a continuous sheet / film having 6% moisture. Rotating speed of the drum should be adjusted according to paste dried substances content; this speed could be between 1.8 and 2.3 rotation per min (RPM). Steam used for heating will have a pressure between 5 and 6 kgf / cm².

It is possible to estimate that a potato paste with 80% moisture could be dried to a 4.5-5% moisture content in about 20 see using the following operating parameters: steam pressure = 6 kgf / cm²; 2 rotations per min (RPM).

(25) Equipment for removal and cutting of potato dried sheets (26) Vertical transporter

(27) Machine for cutting sheets into flakes size / shape

(28) Transport and control belt

(29) Vertical transporter

(30) Vibrating / calibrating machine
(31) Transport belt

(32) Conditioning

(33) Packing: packaging material should be airtight in order to avoid moisture pick-up and enough strong / rigid to protect flakes from breaking. Opaque packaging materials are recommended.

Finished product quality characteristics:

- Colour: white / yellowish;
- Taste and flavour similar to those of purée prepared from fresh potatoes;
- Moisture content: 6%;
- Additives: sulphites = 300 ppm; antioxidant = 0.35%; emulgator = 0.4%;
- Microbiological quality: total plate count = 50000 germs/g;
- Reducing sugar = 3% maximum;
- Summerson calorimetric scale coefficient = less than 150.

9. Various sizes and types of glass jars

9. Various sizes and types of glass jars (continued)

SO2 GENERATOR

SULPHURING INSTALLATION

CONVERSION TABLES - FAHRENHEIT SCALE AND CELSIUS SCALE
electrical data
thermal protection on motor

<table>
<thead>
<tr>
<th>Machine</th>
<th>Speed</th>
<th>Utility</th>
<th>Input</th>
<th>Intensity</th>
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<tbody>
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<td>0.66 CV</td>
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<td></td>
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</tr>
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<td></td>
<td>800</td>
<td>1.5 CV</td>
<td>1100 W</td>
<td>4.2 A</td>
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weight of
net weight gross weight
CL 50 complete 15 kg 18 kg
CL 60 + bulk-feed head + feeding tray 52 kg 63 kg
CL 60 pusher-feed head 7 kg 9 kg
CL 60 hole-feed head 5 kg 7 kg
average weight of one disc 0.5 kg 0.6 kg

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</tr>
<tr>
<td>CL 60 Hole-feed head (1)</td>
<td>Ø 75 mm variable</td>
<td>28025</td>
<td></td>
</tr>
</tbody>
</table>

dimensions (in mm)

<table>
<thead>
<tr>
<th>COMPLETE SELECTION OF DISCS</th>
<th>REFERENCE</th>
<th>PRICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disc</td>
<td>1 mm double blade</td>
<td>27032</td>
</tr>
<tr>
<td>Disc</td>
<td>2 mm double blade</td>
<td>27033</td>
</tr>
<tr>
<td>Disc</td>
<td>3 mm double blade</td>
<td>27034</td>
</tr>
<tr>
<td>Disc</td>
<td>5 mm</td>
<td>27035</td>
</tr>
<tr>
<td>Disc</td>
<td>8 mm</td>
<td>27036</td>
</tr>
<tr>
<td>Disc</td>
<td>10 mm</td>
<td>27037</td>
</tr>
<tr>
<td>Disc</td>
<td>14 mm</td>
<td>27039</td>
</tr>
<tr>
<td>Disc</td>
<td>julienne 2 x 2 mm</td>
<td>27040</td>
</tr>
<tr>
<td>Disc</td>
<td>julienne 4 x 4 mm</td>
<td>27041</td>
</tr>
<tr>
<td>Disc</td>
<td>julienne 6 x 6 mm</td>
<td>27042</td>
</tr>
<tr>
<td>------</td>
<td>-------------------</td>
<td>-------</td>
</tr>
<tr>
<td>Disc</td>
<td>julienne 8 x 6 mm</td>
<td>27043</td>
</tr>
<tr>
<td>Disc</td>
<td>parmesan grater</td>
<td>28435</td>
</tr>
<tr>
<td>Disc</td>
<td>grater 1,5 mm</td>
<td>28270</td>
</tr>
<tr>
<td>Disc</td>
<td>grater 2 mm</td>
<td>28261</td>
</tr>
<tr>
<td>Disc</td>
<td>grater 3 mm</td>
<td>28260</td>
</tr>
<tr>
<td>Disc</td>
<td>grater 5 mm</td>
<td>28261</td>
</tr>
<tr>
<td>Disc</td>
<td>grater 9 mm</td>
<td>28297</td>
</tr>
<tr>
<td>Grid</td>
<td>8 x 8 mm</td>
<td>28379</td>
</tr>
<tr>
<td>Grid</td>
<td>10 x 10 mm</td>
<td>28380</td>
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<tr>
<td>Grid</td>
<td>14 x 14 mm</td>
<td>28391</td>
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<tr>
<td>Grid</td>
<td>20 x 20 mm</td>
<td>28402</td>
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<tr>
<td>Disc header</td>
<td></td>
<td>27258</td>
</tr>
</tbody>
</table>

(1) without disc - * with bulk-feed head

**SUGGESTED PACK A**

* Complete machine + 2 discs: slicers 2 mm / 5 mm - grater 2 mm
* Complete motor base + bulk-feed head + 3 discs: slicers 2 mm / 5 mm - grater 2 mm

**SUGGESTED PACK B**

* Complete machine + 7 discs: slicers 2 mm / 5 mm / 10 mm - grater 2 mm - julienne 2x2 mm - dicing grid 10x10 mm
* Complete motor base + bulk-feed head + 7 discs: slicers 2 mm / 5 mm / 10 mm - grater 2 mm - julienne 2x2 mm / 6x6 mm - dicing grid 10x10 mm
RECEPTION

WASHING

SORTING

PEELING

CUTTING

JUICE EXTRACTION

MIXING ------------

K$_2$S$_2$O$_5$

SUGAR

LEMON JUICE

HEATING

JUICE POURED INTO TRAYS

DRYING

CUTTING

PACKING

LABELLING