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

FRUITS	Drying Conditions			Finished Product	
	Load kg/m	Temperature C	Time	Moisture %	Yield %
Plums	15	I. 40-50	6 H	18-20	25-35
		II. 75-80	14 H		
Apples (Rings)	10	75-55	5-6 H	20	10-12
Apricots (Halves)	10	70-60	10- 15	15-20	10-15
Cherries (w. stones)	10	55-70	6-8	12-15	25
Pears (Halves and quarters)	15	70-65	15-22	18-20	10-15

Pears (Halves and quarters)	15	70-65	15-22	18-20	10-15
	15	70-60	10-15	15-20	10-15

For fruit with a high sugar content drying temperatures have to be lower at initial stage and then increase to the maximum acceptable; for fruit with lower sugar level the temperatures are applied in a reverse order.

Some pre-treatments of fruit and vegetables for sun /solar drying are described in table 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

Fruit or vegetable	Type of cut	Treatment
Banana	5 mm slices	2 hours, 80% sugar
		2000 ppm SO2
		at 70C
Carrots	10 x 10 x 2 mm dices or 5 mm slices	4 hours, 60% sugar + 10%
		salt
		4000 ppm SO2
Mango, green	8 mm slices	2 hours, 25% salt

		8000 ppm SO2
Mango, ripe	8 mm slices	2 hours, 60% sugar
		8000 ppm SO2
Onions	2 mm slices	2 hours, 60% sugar + 10% salt
		4000 ppm SO2
Papaya	8 x 8 mm slices	4 hours, 80% sugar
		2000 ppm SO2 at 70C
Strawberries	Whole	4 hours, 80% sugar
		4000 ppm SO2
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

Products	**Form**	**moisture, %**
Apples	6 nun rings	20
Apricots	Caps	17-20

Banana	Cut pieces	15
Cherries	Whole	12-15
Figs	Whole	23
Guava	Quarters	6
Mango	15 mm pulp sheets	15
Peaches	Caps	15-20
Pears	Halves	23
Prunes	Whole	18-20
Raisins	Whole	17

The moisture contents listed are considered as the best from a technical, practical and commercial point of view for delivery to the market or for shipping and safe for the shelf life needed before buying / consumption by customers / consumers.

All instructions about packing, storage and transport must be followed in order to assure delivery of a safe and high quality product to the market.

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

it drying the fruit pulp after mixing it with suitable ingredients. It can be used to produce mango, banana, guava or mixed fruit bars.

A dual-powered dryer, working by solar energy during the day and by electric or steam power at night and on rainy days, with cross-flow movement of air and controlled temperature (from 55 C at the beginning of processing to a high of 70 C), is well suited for dehydration of the pulp to the desired moisture level of 15 to 20%.

Main raw material quantities to prepare approximately 100 kg of fruit bars are as follows:

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

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/m). 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 pures into leathery sheets. The leathers are eaten as confections or cooked as a sauce. They are made from a wide variety of fruits, the more common being apple, apricot, banana, cherry, blackcurrant, grape, peach, pear, pineapple, plum, raspberry, strawberry, kiwi fruit, mango and papaya.

A description of procedures for mango, banana, guava and mixed fruit bars is given in this document.

Another product with good potential is ciku leather; ciku fruit is grown in Malaysia.

A standard process is carried out using ripe fruits which are washed, peeled, diced and the seeds removed. The fruits are blanched for 1 minute at 80 C and blended into puree in a food processor.

Ciku leather is prepared by mixing ciku puree with 10% sugar, 10% pre-gelatinous rice flour, 150 ppm sorbic acid an 500 ppm sodium metabisulphite ($Na_2H_2SO_4$).

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 Pig. 8.4.1 together with the process parameters regarded as optimal in the light of the published literature.

Figure 8.4.1 Applications of osmotic dehydration

Figure 8.4.2 Sketch of a pilot plant used for detailed stud of process parameters in osmotic concentration of fruit

Figure 8.4.3 Flow diagram for osmotic dehydration and vacuum drying of bananas (Bongirwar and Sreenivasan, 1977)

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

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8.4.4 Apricot processing

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a) Fresh apricot pure.

After washing, cutting and removal of stones, apricot halves are dipped in 2% solution of sodium or potassium metabisulphite for 10 minutes. After draining, the resulting material is passed through a 0.045-in. screen pulper - finisher to produce a fresh apricot puree.

The fresh apricot puree obtained in this way could be further processed in different semiprocessed (i.e. chemically or otherwise preserved products) or finished fruit products (fruit leathers, fruit bars, jams, etc.).

b) Concentrated apricot pulp.

Fresh apricot halves could also be steam blanched for 5 min., passed through a 0.045-in pulper - finisher and transformed in a pure with about 14 Brix depending on the fruit quality. This pure may be concentrated in steam jacketed kettles up to 20 Brix or in other adequate equipment (e.g. a stirred vacuum evaporator) up to 28Brix.

As for fresh apricot pure, the concentrate may be further processed in various semiprocessed or finished fruit products as mentioned above and as will be described below.

c. Dried apricot leather.

- **From fresh fruit pure by drum drying. The fresh apricot pure at about 14 Brix could be dried to 12% moisture apricot sheets, using a double-drum dryer operating at 132 degrees C with a drum clearance of 0.008 in and speed of 45 sec per revolution.**
- **From fruit concentrate by drum drying. The concentrate could also be dried to 12% moisture fruit sheets by the same process as described above.**
- **From fresh fruit pure or from apricot concentrate by sun/solar drying or by dehydration.**

a) Trays. - For sun / solar drying or dehydration of fruit pulp, the trays must have a solid base in order to retain the liquid contents. They may be made of metal, timber or plastic. Stainless steel or plastic trays are most suitable because they are unaffected by acid fruit pulp; they are, however, expensive.

A metal tray could be 75 x 50 cm in size and with side 5 cm high. The trays must keep level during drying; if the tray is not level the pulp will run to the lowest point, giving a layer of irregular depth which will dry unevenly. Any tray which is not made of stainless steel or plastic must be covered inside with a sheet of heavy gauge plastic film to protect the pulp from chemical or bacteriological contamination.

Standard sun/solar trays as described can be used by covering them inside with a sheet of plastic film to create a solid base.

b) Preparation before drying/dehydration. Fresh apricot pure can be directly used for next processing steps. Fruit concentrate needs to be added to potassium metabisulphite to obtain a 0.3% concentration of SO2 in the material.

c) Drying/dehydration. The apricot/fruit pure or concentrate is poured into the trays to a depth of about 1.5 cm. When stainless steel or plastic trays are used they should be coated with a thin layer of glycerine to prevent sticking.

The pulp is then sun/solar dried or tunnel/cabinet dehydrated; moisture content in the dried product should not exceed 14% and the SO2 content should not be less than 1500 pp.

The dried product is wrapped in cellophane to prevent sticking, then put inside polythene bags and stored at best in tight fitting tins and sealed to prevent moisture transfer.

- From fresh fruit pure or from apricot concentrate, with sugar addition, and then processed by sun / solar drying or by dehydration.

In some countries preference is for finished products with added sugar; and this is also interesting from a point of view of energy consumption (concentration is partially achieved by sugar dry matter) and of shelf life. The overall content in SO2 could also be reduced as sugar is a preservation agent, the product will be close to a fruit "paste".

8.4.5 Reconstitution test for dried/dehydrated products

In reconstitution water is added to the product which is restored to a condition similar to that when it was fresh. This enables the food product to be cooked as if the person was using fresh fruit or vegetable.

All vegetables are cooked but many of the dried fruits can be used for eating after they have been soaked in water. The following reconstitution test is used to find out the quality of the dried product.

Reconstitution test

1. **Weigh out a sample of 35 grams from the bulked and packed final product of the previous day's production.**
2. **Put the sample into a small container (beaker) and add 275 ml of cold water (and 3.5 g salt).**
3. **Cover the container (with a watch-glass) and bring the water to the boil.**
4. **Boil GENTLY for 30 minutes.**
5. **Turn out the sample onto a white dish.**
6. **At least two people should then examine the sample for palatability, toughness, flavour and presence or absence of bad flavours. The testers should record their results independently.**
7. **The liquid left in the container should be examined for traces of sand/soil and other foreign matter.**

This test can be used also to examine dried products after they have been stored for some time. Evaluation of rehydration ratio may be performed according to the following calculations.

Rehydration ratio. If weight of the dried sample is 10 g (Wd) and the weight of the sample after rehydration is 60 g (Wr), rehydration ratio is:

$$\frac{Wr}{Wd} = \frac{60}{10} = \frac{6}{1}, \text{ or 6 to 1}$$

Rehydration coefficient. The weight of rehydrated sample is 60 g (Wr); the weight of dried sample is 10 g (Wd) and its moisture is 5% (Wu); raw material before drying had 87% water (A); rehydration coefficient is:

$$\frac{Wr}{\frac{Wd - Wu \times 100}{100 - A}} = \frac{60 \times (100 - 87)}{10 - [10 \times 0.05]} = \frac{780}{9.5} = 82.1$$

A simpler test for eating quality can be carried out without weighing and measuring. The material is placed in a cooking pot with water (and a little salt). The pot is then covered and boiled as described above.

Except for a few products which are eaten in the dry state, most dried fruit and all dried vegetables are prepared by soaking and cooking. Often this preparation is carried out incorrectly and dried products get a bad reputation.

Good quality dried products, after cooking and if properly treated should be similar to cooked fresh produce. In order to get good results, the following methods are recommended:

Quick method. - Cold water, ten times the weight of the dry product, is added to the dried product. The container is covered, brought to the boil and simmered GENTLY until the product is tender. The cooking time may be 15 to 45 minutes after the boiling point has been reached.

Slow method. - This gives better results than the quick method. Cold water is added to the dry food and is left to soak for 1 to 2 hours before cooking. The product is then cooked in the same water as that in which it was soaked. The actual cooking time will probably be shorter than that for the quick method.

Other points to remember are:

- **if too much water is added the cooked product will have little flavour. However, if too little water is added the product may dry and burn. This can be avoided by adding small quantities of water during cooking;**
- **always cook with a lid on the container;**
- **salt, if required, should be added when the cooking is almost complete;**
- **partly used packages of dry products should be reclosed tightly or kept in containers with good fitting lids.**

The composition of some dried fruits is seen in Table 8.5.2.

TABLE 8.5.2 Composition of some dried fruits

Fruit	Moisture content %	Sugar as monosaccharides, %	Other carbohydrates	Vitamin C mg/100 g
Raisins	21.5	64	7	0.0
Dates	12.5	55	7	0.0
Prunes	20.0	45	15	0.0
Apricots	15.0	45	24	4.8
Peaches	15.5	55	14	8.0

8.4.6 Handling, sorting, packing and storage of dried and dehydrated fruit and vegetables.

It is not easy to assess when drying has been completed. In absence of instrumentation, the characteristics of the various products after drying / dehydration can only be assessed by experience. Although this cannot be conveyed adequately on paper, some general indications can be given.

Fruit products. - When a handful of fruit is squeezed tightly together in the hand and then released, the individual pieces should drop apart readily and no moisture be left behind on the

hand. It should not be possible to separate the skin by rubbing unpeeled fruit and the fruit centre should no longer reveal any moist area. Banana should be leathery and not too tough to eat in their dry state.

Vegetable products. - Onions should be dried until they are crisp whereas tomatoes should be leathery.

In general, the lower the moisture content, the better the keeping quality will be, but overdried products generally have an inferior quality. Also the loss in weight from excessive drying cannot be tolerated in a commercial operation designed to run profitably.

It is, however, essential to dry up to an optimum / safe moisture level, related to the type of the product and his designed shelf life, and to avoid running the risk of the products becoming spoiled due to excess water content.

When drying is completed, the material should be sorted either on trays or on a table in order to remove pieces of poor quality and colour and any foreign matter.

Very fine material should be separated from the bulk of the material by using a sieve (12 or 16 mesh per inch). Bad quality products which show poor colour need to be removed from the bulk of finished product.

After selection and grading, dried products should be packed immediately, preferably in polythene bags which must be folded and closed / tied tightly. However, plastic bags are easily

damaged and therefore they must be packed into cartons or jute sacks before they are transported.

8.4.7 Deterioration of dried fruit during storage

Dried fruit must be considered as a relatively perishable commodity in the same category as cereals, pulses and similar stored products. It is subject to deterioration resulting from mould growth, insect and mite infestation and physical and chemical changes.

8.4.7.1 Mould growth

When the moisture content of dried fruit is allowed to exceed the maximum permissible level for safe storage then mould growth may occur. Table 8.4.1 indicates the moisture levels applicable to various types of fruit; and it can be seen that the safe moisture levels for dried fruit are much higher than those for other similar commodities.

At the present time, suitable field moisture meters for use with dried fruit are not readily available, and moisture determinations can only be satisfactorily carried out where laboratory facilities are available.

Various species of drought resisting fungi may develop on dried fruit when the moisture content is just above the safe level, and a number of osmophilic yeasts are quite commonly associated

with spoilage in dried fruit.

Many of the yeasts bring about fermentation with the production of lactic acid or alcohol, and yeasts are frequently present in wart-like crystalline growths which occur in fruit which has become "sugared". In very moist fruit mucoraceous fungi may predominate and are visible as white fluffy growths on and within the fruit.

8.4.7.2 Mite infestation

Severe mite infestations are often associated with the growth of osmophilic yeasts in fermenting dried fruit products. Many of these mites are unable to complete their development in the absence of yeast. They have been reported as occurring on dried fruit, and particularly figs and prunes in Mediterranean countries. Such infestations are difficult to eradicate and affect consumer acceptance of the contaminated products.

8.4.7.3 Insect infestation

Insect infestations may begin in the field before harvest, may continue during bulk storage after drying, and unless measures are taken to prevent it, may occur in the finished packaged product during storage prior to distribution and consumption.

Regular treatments of the stack of dried fruit with a suitable insecticide will be necessary as a routine to combat light insect infestations. Pyrethrins synergised with piperonyl butoxide are commonly used as a surface spray or as an aerosol fog for this purpose. Heavy infestations will

require that the fruit be fumigated.

8.4.8 Equipment for "dry sulphuring of fruit before dehydration/drying

SO_2 generator

(1) SO_2 outlet pipe

(2) Sulphur feeding door

(3) Plate for sulphur burning

(4) Small door

(5) Burner for gas

(6) Metallic sieve

Sulphuring installation

(1) Exhaust pipe

(2) SO_2 pipe

(3) SO2 generator

(4) SO2 distributor

(5) SO2 distribution pipes

(6) Sulphuring cells

(7) SO2 flow regulator

(8) Pipe for removing SO2 from sulphuring cells

(9) Electrical fan

(10) Exhaust pipe for removing SO2 from sulphuring installation

(11) Hole for SO2 coming from cells

8.4.9 Solar dryer with air heater - tunnel type; community or business level

I. Air heaters

1.1 Cover: Transparent 3 mm. plexiglass plate or plastic sheet

1.2 Absorber - bottom - corrugated black painted iron sheets - intermediary - black painted iron sieve

1.3 Insulation: none

1.4 Frames: metallic black painted corner/angle ironR

II. Drying tunnel or room

2.1 Cover: transparent plastic sheets

2.2 Frames: metallic black painted angle iron

2.3 Insulation: for back only on the outside

2.4 Back wall: wood plate, painted black on inside

2.5 Front wall: transparent plastic sheets

2.6 Side doors: - frames = wood

- transparent plastic sheets

2.7 Dimensions of drying tunnel / room

- L = 22 feet

- W= 18 feet

- H = 5 feet

2.8 One range of trolleys

III. Trays

3.1 Frames: wood, black painted

3.2 Bottom: nylon mesh or wood slats

3.3 Dimensions:

- l = 3 feet

- w = 2.4 feet

IV. Trolleys

4.1 Metal platform with wheels

4.2 Number of trays per trolley: 15

4.3 Distance between trays: 3"

4.4 Total height of trolley: 3 x 15 = 45 inch + 4 " (wheel) = 49 inch

V. Capacity calculation; number of trolleys and trays

5.1 Hypothesis: 300 kg fresh apricots received per day

2 days solar drying

5.2 Tunnel / dryer capacity: 2 x 300 = 600 kg fresh apricots

5.3 Number of trolleys and trays calculation:

- number of trays /trolley = 15

- kg fresh apricots per tray = 6 kg

- kg fresh apricots per trolley: 6 x 15 = 90 kg

- number of trolleys needed in drying room: 600 : 90 = 7

- number of trolleys in sulphuring cells = 2

- number of trolleys in "wet preparation section" = 3

- number of trolleys in dry section (after tunnel) = 2

- total number of trolleys needed = 14

- total number of trays needed: 14 x 15 = 200

VI. Sulphuring cell

6.1 Capacity: 2 trolleys

6.2 Dimensions: 1 = 5 feet; w = 3.5 feet; H = 55 inch

6.3 One sulphuring pipe inside the cell, diameter = 15 cm

VII. SO2 generator: diameter = 45 cm; h = 70 cm

VIII. Air heater / heat collector

8.1 DIMENSIONS: L = 5 M; H = 30 CM; Hl = 15 CM; H2 = 20 CM

8.2 Bottom / corrugated black painted iron sheets

8.3 Intermediate heat absorber: iron black painted metallic plate / sieve with holes of

about 3 cm in diameter fixation: at mid-distance between cover and bottom of the

heat collector

8.4 Cover: transparent 3 mm Plexiglas plate (or transparent plastic sheets)

The calculation used in this dryer is based on a real situation in a developing country, within the framework of FAO projects; availability of building materials was confirmed.

For the orientation of the dryer geographical position of the available drying yard and local wind direction were taken into consideration

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8.5 Technology of semi-processed fruit products

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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 "pures-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. "Pures-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 "pures-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 "pures-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 "pures-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 "pures-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 m 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"

Fruit species	Preliminary operations	Preservation means
Apples, pears, quinces	Sorting, washing, coring, cutting	Sulphur dioxide
Prunes, peaches, wax cherries, apricots	Sorting, washing, stone removal (pitting)	Sulphur dioxide or sodium benzoate
Cherries	Sorting, washing	Sulphur dioxide or sodium benzoate, sometimes with calcium bisulphite addition
Strawberries	Sorting, washing	Sulphur dioxide in mix with

		calcium bisulphite
Wild berries	Sorting, washing	Sulphur dioxide or sodium benzoate; in some cases with calcium bisulphite addition

8.5.1.5 Technological flow-sheet for semi-processed "pure-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 "pure-marks" are seen in Table 8.5.2.

TABLE 8.5.2 General technical processing data for semi-processed "pures - marks"

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

Fig. 8.5.1 shows a technological line for the preparation of semi-processed pure-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 SO_2 solutions

Density at 15C	Concentration of solutions % SO_2
1.0168	3.00
1.0181	3.25
1.0194	3.50
1.0206	3.75
1.0221	4.00
1.0234	4.25
1.0248	4.50
1.0261	4.75

1.0275	5.00
1.0289	5.25
1.0302	5.50
1.0315	5.75
1.0340	6.25
1.0353	6.50
1.0365	6.75
1.0377	7.00

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8.6 Fruit sugar preserves technology; jams, jellies, marmalade, fruit paste

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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 8.6.1 Composition of some fruit jams

Type of Jam	Moisture content %	Sugar (as invert sugar, %)	Vitamin C mg/100 g
Jam made from berry fruits: strawberry, raspberry, etc.	29.8	69.0	10 - 25
Jam made from stone fruits: apricot, peach, etc.	29.6	69.3	10 - 35

Source: FAD/WFP, 1970

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:

$$\frac{\text{Total Soluble Solids content of all the raw ingredients}}{\text{Percentage of Total Soluble Solids in the final product}} \times 100$$

In these basic recipes it is assumed that the fruits are poor in pectin content.

Recipe 1. Fruit: sugar = 50:50; desired Brix in the finished product is 68.

Soluble Solids

10 kg of fruit at 10% TSS	1.000 kg
10 kg of sugar	10.000 kg
60 g of pectin (grade 200)	0.060 kg
55 g of citric acid	0.055 kg
	11.115 kg

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

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

	Soluble Solids
d10 kg of fruit at 10% TSS	1.000 kg
2.5 litre of water	-
12.2 kg of sugar	12.200 kg
65 g of pectin grade 200	0.060 kg
60 g of citric acid	0.060 kg
	13.325 kg

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

Recipe 3. Fruit: sugar = 40:60; desired Brix in the finished product is 68.

	Soluble Solids
d10 kg of fruit at 10% TSS	1.000 kg
3.3 litre of water	-
15 kg of sugar	15.000 kg
85 g of pectin grade 200	0.085 kg
80 g of citric acid	0.080 kg
	16.165 kg

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

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.

If container capacity is between:	**Increase pectin by:**

1 kg and 2.5 kg	5%
2.5 kg and 5.0 kg	10%
5.0 kg and 10.0 kg	20%
10.0 kg and 20.0 kg	30%

2. Finishing point: the quantity of pectin is given for a final Brix - Total Soluble Solids (TSS) of 68%.

If the final Brix is 66 increase the pectin by 5%

" " is 65 " " " by 10%

is 64 " " " by 15%

" " is 62 " " " by 20%

" " is 60 " " " by 30%

3. Acidic taste. If the product is too acid, replace the citric acid by tartaric acid (63% of the amount of citric acid).

4. Formation of clots: If batch clots, it is probably due to the pH being too low or the or TSS being too high; correct accordingly.

5. Formation of liquid at the surface: if liquid forms on the surface, it is probably due to too low a pH or too low pectin content.

6. Crystallisation:

a) if liquid forms on the surfaces, then the pH is too low; reduce the acid content;

b) if liquid does not form on the surface, then TSS or pH is too high.

7. Formation of mould: the TSS is probably below 68 deg. Brix. The filling may have been done at a low temperature. If the containers are large, wait until they are cold before closing.

8. Wrong batch: dilute the jam with water to 30% TSS; cook briefly. Add this diluted jam to a new batch but in a ratio not exceeding 10%.

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:

Pineapple pulp	25.0
Papaya pulp	25.0 pounds
Cane sugar	50.0
Apple pectin (150 grade)	6.0 ounces
Citric acid	6.4
Fresh ground ginger	7.5

Processing is carried out in the following way:

The weighed fruit pulp is placed in a stainless steel steam-jacketed kettle and heated to about 110F 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.**
5. **Boil down quickly to 69 deg. Brix (223 deg. F).**
6. **Take off steam, remove foam.**
7. **Add 300 cc citric acid solution 50%.**
8. **Fill hot (180 deg. F).**
9. **Invert receptacles for 3 minutes.**

Check each batch for Brix 68-70 deg.; acidity/pH = 3.2 +/- 0.2.

Evaluate: absence of defects; colour; flavour; consistency.

Various fruit:sugar ratios can be manufactured; some basic recipes are as follows:

	Ratio 50:50	Ratio 45:55	Ratio 40:60
Fruit	55 lb	49.5 lb	44 lb
Water	-	11 lb	13.2 lb
Sugar	55 lb	60.5 lb	66 lb
Pectin (150 grade)	225 g	237.5 g	250 g
Citric acid (50% sol.)	300 cc	320 cc	335 cc

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8.6.8 Gelified sugar fruit preserves

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8.6.8.1 Technology of fruit jellies

Jellies are gelified products obtained by boiling fruit juices with sugar, with or without the

addition of pectin and food acids. Jellies are usually manufactured from juices obtained from a single fruit species only, obtained by boiling in order to extract as much soluble pectin as possible.

Jellies have to be clear, shiny, transparent and with a colour specific to the fruit from which they are obtained. Once the product is removed from the glass receptacles where it was packed, jellies must keep their shape and gelification and not flow, without being sticky or of a too hard consistency.

Technological flow-sheet for jellies manufacturing covers two categories of operations: those to obtain gelifying juices and those related to the manufacturing of jelly itself.

a) Production of gelifying juices:

WASHING & SORTING are carried out in usual conditions;

CUTTING is applied eventually only to pomaces (apples, quinces) and are limited to cutting in halves or quarters;

BOILING IS PERFORMED WITH WATER ADDITION WITH 50-100% water, needed for pectin extraction. The boiling time is 30-60 min., it should not be longer so as to avoid pectin degradation; at the same time boiling must not be too violent.

JUICE SEPARATION is carried out by a simple drain through metallic sieve or cloths; in these cases the yield is lower and the residue can be used for marmalade production. In bigger

productions it juice separation by hydraulic press is preferred, yield being in these cases greater.

JUICE CLARIFICATION is strictly necessary in order to obtain clear jellies. This step can be achieved by sedimentation during 24 hours or by filtration.

b) Manufacturing of jellies

BASIC RECIPE SETTING is done starting with equal parts in weight of sugar and juice (for example 1000 g juice and 1000 g sugar). As final jelly has to contain about 60% added sugar, weight of finished product must be of about 1600 g, by evaporation of about 400 g water.

BOILING is carried out as following: juice is boiled up to removal of about half of the water that has to be evaporated, then the calculated sugar quantity is added gradually; the remainder of the water is evaporated until a concentration in soluble substances (refractometric extract) of 65-67% is reached, in which is incorporated also the sugar from juice.

During boiling it is necessary to remove foam / scum formed. Product acidity must be brought to about 1% (malic acid) corresponding to pH > 3. Any acid addition is performed always at the end of boiling.

For juices rich in pectin, gelification will occur without pectin addition. If at the trial boiling test the gelification has not occurred, because of pectin absence, in this case 1-2% powder pectin will

be added by operating as indicated: pectin is mixed with 10-20 fold sugar quantity and is introduced directly in the partially evaporated juice and then boiling is conducted rapidly up to final point. Evaluation of final point is done not only by refractometry but also by gelifying test.

A rapid test for evaluation of juice pectin content is possible by mixing a small sample of juice with an equal volume of 96% alcohol; the apparition of a compact gelatinous precipitate indicates a sufficient pectin content for gelification.

Boiling of jellies is performed in small batches (25-75 kg) in order to avoid excessively long boiling time which brings about pectin degradation.

COOLING is optional and is carried out up to 85 deg. C, in double wall baths with water circulation.

FILLING is performed at a temperature not below 85 deg. C in receptacles (glass jars, etc.), which must be maintained still about 24 hours to allow cooling and product gelification.

RECEPTACLE CLOSING is done after product gelification.

Usual jelly types are: quinces, strawberries, cherries, wild berries, alone or in mixes with apples.

8.6.8.2 Grading of marmalades

Three categories can be defined:

- **fine marmalade, manufactured from one fruit;**
- **superior marmalade, obtained from a mix of fruit in which 30% are "noble" species (cherries, strawberries, apricots, etc.) and 70% from other species;**
- **marmalade from fruit mixes; apples, pears, plums, quinces, ungrafted apricots and wax cherries may be used, with the optional addition of "superior" fruit which was rejected at sorting but which was sound.**

The content in total soluble substances (refractometric extract) of marmalades must be 64% minimum; the acidity must be between 0.5% and 1.8% expressed as malic acid.

BASIC RECIPE SETTING For a normal composition - marmalade without pectin addition the following is a basic recipe:

100 kg semi-processed fruit product

(10% refractometric extract) …………… 10 kg soluble substances

55 kg sugar ……………………………… 55 kg soluble substances

155 kg 65 kg soluble substances

55 kg water to be evaporated

100 kg marmalade with 65% refractometric extract

This marmalade satisfies many standards and at same time has a good shelf-life since it contains less than 35% water. Semi-processed fruit products must have a minimum 8% refractometric extract; in this case the recipe should use 125 kg of raw material, with 80 kg water to be evaporate.

The use of semi-processed fruit products with a low refractometric extract presents the following drawbacks:

a. **higher water quantity to be evaporated;**
b. **longer boiling times with negative impact of pectin degradation;**
c. **loss of flavour and**
d. **lower equipment efficiency.**

Pectin addition in marmalade manufacture produces the following advantages:

a. **improvement of gelification,**
b. **economy in fruit;**
c. **shorter boiling time; this maintains taste and flavour and produces higher equipment efficiency.**

Pectin addition makes it possible to obtain the "fine" type of marmalade from "noble" fruits which do not contain enough pectin (cherries, peaches, apricots, etc.). In marmalades from fruit mixes, low pectin content can be compensated by addition of semi-processed fruit products which

are rich in this component (for example apples).

When pectin is to be added, the above recipe should be modified as follows:

80 kg semi-processed fruit product

(10% refractometric extract) …………… 8 kg soluble substances

55 kg sugar ………………………………. 55 kg soluble substances

10 kg pectic extract (10 % R.E.) ………. 1 kg soluble substances

145 kg 64 kg soluble substances

45 kg water to be evaporated

100 kg marmalade with 64% refractometric extract

Pectin can be added as pectic extract with about 10% refractometric extract (R.E.) in the recommended proportion or in the form of a powder considered with 100% dry matter (e.g. 100% soluble substances) in a quantity of about 1%.

In some countries it is usual to add 5-12% of corn syrup (calculated to finished product weight) to replace the corresponding quantity of sugar (100 parts corn syrup can replace 80 parts sugar). Corn syrup has to be liquefied by heating before use. Corn syrup addition reduces the too sweet

taste of marmalade, avoids sugar crystallisation and gives a special shine to finished products.

Marmalade manufacturing follows the technological line drawing in Fig. 8.6.1 and covers the following steps:

"MARK" PREPARATION can be achieved from fresh fruits (as indicated in the section related to semi-processed fruit products) or starting from chemical preserved semiprocessed fruit products: "marks" or "pulps". In the latter case, pulps will be processed in marks which then will be desulphitated.

DESULPHITATION is carried out by boiling at atmospheric pressure, under vacuum in specialised equipment or under pressure in special retorts built in acid-resistant material. In any case, the desulphitation must be carried out before sugar addition because sugar will bound to the sulphur dioxide. The desulphitation operation must be conducted so as to be, if possible, fully completed; the finished product must contain less than 0.005% free SO2.

The technological flow for marmalade production according to Fig. 8. 6.1 is the following: fresh fruit after sorting on control belt (1) is washed in a washing machine (2) is brought to the continuous boiling equipment (3) then to the pulper (4); the semi-finished mark is passed on to the storage tank (6). Pulps are boiled and desulphited in continuous boiling equipment (3), then are brought to pulper (4) and to the storage tank (6).

BOILING aims at evaporating the required water quantity, to facilitate the formation of pectin-sugar-acid gel and to partially invert sugar (about 40% from total sugar). The boiling operation

can be carried out in open kettles or in evaporators under vacuum.

In the latter case, the warm "mark" from storage tank (6) is aspirated in a concentrator (7) in a vacuum and submitted to a partial boiling up to removal of half of water quantity which needs to be evaporated; the calculated sugar quantity is then added by aspiration, keeping the boiling on.

After this the pectin extract or powder pectin which has previously been dissolved in warm water, is added; when the final concentration is reached, as indicated by refractometric control, the required quantity of acid is added. Sugar is added in proportion of 55% in finished product, pectic extract (10% refractometric extract) at a level of about 10-15% and the acid (citric, tartaric, lactic) in a quantity needed to obtain a finished product acidity of about 1%.

Boiling at atmospheric pressure affects not only the appearance but also the nutritional value of the products, mainly if these contain proteins, as some albuminoids coagulate even at 60C.

Food products for which flavour is an essential property as for example fruit juices, etc., are also affected by the action of heat. Heat treatment has an impact on vitamin losses, mainly of vitamin C, in the presence of oxygen as is the case at concentration in open vessels.

Figure 8.6.1 Technological line for marmalade production

Sugars are generally less damaged by heat at temperatures below 100 C; as the boiling point is increasing above 100 C, a risk of partial sugar caramelization exists.

In the study of heat effects on products submitted to concentration operation, it is necessary to take into account not only the evaporation surface temperature but also the distribution of the temperature in the whole liquid mass.

The length of the heating period also has a major influence because in many cases it is preferable to concentrate the liquid at a relatively high temperature in a short time avoiding the drawbacks of lower temperatures acting during a long time.

In order to maintain the food value and organoleptic properties, it is necessary that concentration take place at a low temperature which can be achieved by concentration under partial vacuum, taking into account that boiling point decreases when the residual pressure decreases, respectively with the increase of vacuum degree.

Advantage of concentration under partial vacuum are the following:

- **lowering of boiling point;**
- **the total time needed for concentration of food products under a residual pressure of about 200 mm Hg is about half as compared to the that of concentration by boiling at atmospheric pressure;**
- **by lowering the concentration temperature and time, organoleptic properties and of nutritional value are maintained better particularly as far as the vitamins are concerned;**
- **when products are concentrated in a vacuum, it is possible to recover volatile aromatic substances by using adequate installations.**

Technical procedures of concentration by vaporisation can be classified in:

a) concentration at atmospheric pressure: continuous or discontinuous;

b) concentration under partial vacuum: discontinuous (in vacuum equipment with simple or multiple effect) or continuous (in vacuum installations with continuous action or in thin film vaporisation installations).

Even if open kettle equipment is less expensive than evaporators in a vacuum, it is necessary to take into account that boiling under vacuum has the following advantages:

a) low boiling temperature (60-70 C), depending the degree of the vacuum; this give the fruit better taste and flavour-keeping qualities;

b) easy feeding with raw and auxiliary materials;

c) shorter boiling time;

d) better working conditions (vapour elimination in condensed water and not in open air).

There are small size evaporators under vacuum which can be well suited to the needs of medium size operations in developing countries.

COOLING of marmalade to about 50-60C can even be done in a vacuum evaporator by closing

the heating steam and maintaining vacuum degree or by discharge in storage tanks (8).

FILLING in receptacles (boxes, jars, glasses, etc.) is done preferably with filling machines (9) followed by labelling(10). Small packages can be closed warm or after complete cooling; big packages (boxes, etc.) must be closed only after cooling, e.g. 24 hours after processing.

STORAGE of marmalade must be done in dry rooms (air relative humidity at about 75%), well ventilated, medium cool places (temperature 10-20 degrees C), disinfected and away from direct sunlight and heat. These measures are necessary because marmalade is a hydroscopic product and, by water absorption, favourable conditions for mould development are created.

8.6.8.3 Technology of special fruit jams

Special fruit jams are products similar to marmalades but in which fruit partially keep their shape (whole, halves, etc.). Special fruit jams are obtained by boiling fruit with sugar, with or without pectin addition, with acid addition followed by n concentration by evaporation.

Special fruit jams present a pronounced gelification at their cooling and can be considered as fruits included in a pectin-sugar-acid gel.

High quality special fruit jams are obtained only from fresh fruit or possibly frozen and from only one fruit species.

Special fruit jams are classified in:

a) non-pasteurized (min. 68% refractometric extract) and

b) pasteurized (min. 65% refractometric extract); minimum acidity, expressed in malic acid, is 0.5%.

BASIC RECIPE SETTING is done taking into account following elements: - maintenance, as much as possible, of fruit shape, because this is specific to these finished products;

- **added sugar, in relation to finished product, must be at 60-65%; this high percentage is needed in order to obtain a rapid and strong gelification and to facilitate conservation of fruit shape;**
- **a satisfactory gelification cannot generally be obtained without pectin addition, at a level of 1-2%, or respectively 10-20% pectic extract (10% refractometric extract);**
- **partial (about 40%) inversion of added sugar is necessary.**

The basic recipe is: 80 kg fruit + 100 kg sugar + 1.6-2.0 kg pectin powder and 1 kg citric or tartric acid; this will yield about 165 kg of special fruit jam with 60% added sugar; water quantity to be evaporated is about 18 kg. If the finished product has to contain 65 % added sugar, the boiling has to be continued up to evaporation of about 30 kg water, the resulting finished product quantity will be about 153 kg.

Technological flow sheet for manufacturing of special fruit jams is as follows:

FRUIT PREPARATION: sorting, washing, peeling and coring (for apples, pears, quinces), or

removal of quetches and stones/pits (for plums, peaches, apricots, cherries) or of short tails (for strawberries and wild berries). Pomace fruits are then cut in slices or quarters.

BOILING WITH SUGAR is the most important operation in production of special fruit jams and has as objective to evaporate water until gel formation and partial inversion of sugar. Boiling has to be conducted in such a way as to avoid fruit disintegration, but fruits must be well penetrated with sugar.

By boiling an equilibrium is reached, by osmosis, between sugar solution and cellular juice. The initial concentration gap between sugar syrup and cellular juice is very high and if the equilibration process is forced, juice comes out of cells and fruit loses its shape and may even disintegrate.

The boiling process accelerates the equilibration, intensity of which increases with temperature and boiling time.

Pectin addition shortens boiling and thus delays the equilibration; for this reason there are different methods for special fruit jams preparation:

- **maintaining fruit in sugar, at ambient temperature, over 8-24 hours; fruit to sugar ratio is that indicated in recipe. After this sugar impregnation, fruits and resulting sugar syrup are brought together to boil; toward the end of boiling, pectin, dissolved in warm water, and necessary acid quantity are added.**

- **preparation of a very concentrated sugar syrup (at least 75%), in which fruit is introduced in order to be boiled.**

The rest of the operations are similar to those described in the previous method.

- soft fruit (strawberries, wild berries) can be mixed with sugar directly in evaporating open kettles, without added water and then heated gradually up to boiling, which is continued as in previous method.

Boiling is preferably carried out in small open kettles (50-100 kg) in order to avoid too long a boiling and fruit disintegration.

Gelification corresponds generally to the reaching of a concentration of 65% soluble extract, respectively 68% refractometric extract. Practical test for gelification is done as for jellies and marmalades.

COOLING is a technological step strictly necessary in order to avoid fruit rising to the surface in preservation receptacles. Cooling is done in a double bottomed water bath in which water circulates at about 80 C.

FILLING of receptacles (jars, boxes, glasses, etc.) is carried out and it is necessary to assure at this stage that the finished product is homogeneous (equal quantities of fruits and gel).

Pasteurization is only applied to special fruit jams with 65 % refractometric extract packed in

jars or boxes and is performed at about 100 C for about 20 min.

GELIFICATION is carried out during product cooling and intensifies during storage.

STORAGE must follow the same conditions as for marmalades.

8.6.9 Non gelified sugar fruit preserves

8.6.9.1 Technology of fruit jams

Fruit jams are products obtained by boiling of fruits (whole, halves, etc.) with sugar syrup until the reaching a viscous consistency. Jams can be defined as fruits included in a concentrated syrup.

Jams are only prepared from fresh fruits; the usual product range covers the following species: strawberries, cherries, apricots, wild berries, peaches, plums, raisins, quinces, rose petals, etc.; manufacturing of jams from fruit mixes is not an accepted practice. Standards indicate that fruit jams have to conform with following conditions:

- **fruit or fruit pieces content 45-55%;**
- **soluble substances, refractometric degree min. 72%;**
- **acidity (expressed in malic acid) min. 0.7%.**

BASIC RECIPE SETTING is presented below as an indication:

100 kg fruits

150 kg sugar

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250 kg

35 kg water to be evaporated

---

215 kg jam at about 72% refractometric extract

FRUIT PREPARATION is similar to special fruit jams with the difference that stone / seed removal is mandatory for all species.

BOILING FRUITS WITH SUGAR can be achieved by the same three methods described above for special fruit jams. By boiling a sugar content equilibration is foreseen and the operation must be conducted in such a way that texture, flavour and colour of fruits be preserved. Foam/ scum has to be removed during boiling.

Generally boiling in concentrated sugar syrup (at least 75%) after a previous diffusion during 2-4

hours is in practical use. Boiling must to be carried out in small portions (about 15 kg) in order to avoid fruit disintegration.

For some fruit species, boiling has to be conducted in many phases / steps with "stops" to enable sugar diffusion. At the end of boiling, vanillin at a ratio of 125 g for 100 kg jam may be added for some fruits (white cherries, raisins, etc.). At the same time, it is also possible to add citric or tartric acid in order to avoid the "sugaring" defect.

COOLING of jams, necessary in order to avoid fruit rising to the surface, is carried out as for special fruit jams.

FILLING of receptacles and STORAGE for jams are performed in same way as for special fruit jams.

8.6.9.2 Technology of special non gelified fruit marmalades

Special non gelified fruit marmalades are products resulting from fruit without stones or seeds, sieved or squashed, concentrated by boiling, without sugar added and non gelified. Their consistency results from a low water content (about 35%) and a high percentage of insoluble substances (5-10%). Sugar the from fruits acts as a preserving agent.

Plum special non gelified fruit marmalade is the product representative of this category. Other fruit is used very rarely, because they have a reduced sugar content as compared to plums; though there are some countries producing special non gelified fruit marmalade from pears or

sweet apples.

For plums, the finished product in this category must contain minimum 55-60% soluble substances (refractometric extract), rising up to 70% for a high quality product.

BASIC RECIPE SETTING for plums is done in relation with sugar content of fruits; when this is higher, the product quality is better and the yield is higher. Thus, if plums with 18% refractometric extract are used, 300-350 kg of fruits are needed for 100 kg finished product.

At the same time, concentration of sugar by boiling, also increases by three fold acidity and astringency of this special plum non gelified marmalade; for this reason it is recommended to use only sweet and completely mature plums.

WASHING is performed in usual conditions.

PRE-BOILING of fruits can be carried out in water or vapour, preferably with continuous running and has as its objective the softening of tissues.

DE-STONING is performed in a pulper.

BOILING of the sieved mass is done in double bottom open kettles with a big evaporation surface or in vacuum evaporators.

Boiling in open kettles enables production of a more tasty slightly caramelized, product; boiling in

vacuum evaporators has the technological advantages indicated in marmalade production.

At the end of boiling and once of necessary concentration is reached, the product is poured directly into receptacles (drums, etc.) and left to cool in order to form a hard surface layer (crust).

STORAGE of well closed receptacles is carried out as for marmalade.

Special non gelified fruit marmalade can also be prepared from chemically preserved semi-processed fruit products, but the quality is lower than that obtained from fresh fruits.

Sometimes dried prunes in a mix with preserved semi-processed products can be used for plum special non gelified marmalade preparation.

In some countries plum finished products in this category are sweetened by the addition of maximum 30% sugar, calculated in relation to the finished product.

8.6.9.3 Technology of fruit pastes

These products are obtained in a similar way to marmalades and special non gelified marmalades, but have a lower water content (about 25%). Reduction of water content can be achieved by continuing the boiling of the product or by natural or artificial drying.

A typical example of fruit paste without sugar added is the apricot paste - "pistil", etc. which is a

concentrated special non gelified fruit marmalade poured in thin layers and sun dried.

An example of fruit paste with sugar added is quince paste which is a marmalade concentrated by evaporation. Sugar content must be 65%; soluble substances content, 7075 % refractometric extract and acidity at least 0.5% expressed as malic acid. Packing is done usually in polyethylene sheets and then in boxes or tins; storage conditions are similar to those for marmalade.

8.6.9.4 Technology of fruit syrups

Fruit syrups are products obtained by dissolving sugar in juices obtained from direct pressing of fruits. Sugar dissolving can be done at room temperature or by heating.

Syrups have to contain 68% soluble substances (refractometric extract) and minimum 1 g/100 ml malic acid. Up to a maximum 10% of sugar can be replaced by corn syrup. Syrups must be manufactured from the juice of only one fruit species.

JUICE PREPARATION is carried out at room temperature as described above.

SUGAR DISSOLVING IN FRUIT JUICE can be performed by one of the following methods:

a) Boiling in open kettles, done by using the basic recipe:

350-400 kg fruit juice;

650-660 kg sugar;

max. 10 kg citric or tartric acid.

The juice is brought to boiling and the sugar is dissolved; the total time has to be as short as possible in order to avoid flavour loss and a too high sugar inversion degree (optimum inversion degree is 40%). Acid is added preferably towards the end of boiling.

During all boiling processes it is necessary to remove foam / scum. In order to avoid caramelization, the syrup has to be cooled rapidly, and this can be carried out in baths with double bottoms through which are circulated water.

One alternative to this method is to boil syrup in closed vessels to avoid flavour losses.

b) Boiling in a vacuum. The basic recipe is the same as above. Sugar and fruit juice are mixed previously in a pre-heating kettle and then transported to vacuum equipment.

Boiling is performed at 50 C and at the end the temperature is raised slowly up to 65-70 C. The syrup can be cooled directly in vacuum equipment by closing the steam inlet and by increasing the vacuum. In this boiling method it is possible to incorporate a flavour recuperation device.

c) A continuous process for syrup preparation can be carried out by dissolving components with heat while passing them through a horizontal cylinder with a screw inside.

In the methods where sugar is dissolved by heat, it is also possible to use chemically preserved juices.

In this case it is necessary to first perform the desulphitation of juices preserved with SO2. This can be performed by boiling juice with optional water addition (and before any sugar addition). High quality syrups are obtained however from fresh juices.

d) Sugar can also be dissolved at room temperature by using continuous flow percolators. These are similar to those used for salt solution preparation in vegetable canning processes. The juice goes over a sugar layer and is concentrated progressively until saturation (about 65 %). The syrup is then passed through a filtration section in the bottom of the percolator.

SYRUP FILTRATION is needed in order to clarify crystals; the filtration of syrup is done in warm conditions through cloth.

FILLING of syrup in bottles is done in aseptic conditions as much as possible in order to avoid syrup infection with osmophile yeasts.

Syrup preservation is assured by the high sugar content with respect to a low water activity [unclear].

STORAGE takes place in well ventilated storage rooms; avoiding sunlight at 10-15 C.

The usual product range is: strawberries, cherries, wild berries, citrus fruits.

8.6.10 Technology of "fruit in syrup" products

This type of product is represented by fruit (whole, halves or pieces) covered by a sugar solution and preserved by pasteurization. In these products sugar does not have a preservation effect but only a sweetening role.

Technological general flow-sheet covers the following steps:

SORTING is necessary in order to choose mature fruit, whole, unblemished, undamaged and with a specific texture. Fruit of good quality but with a texture not compatible with this type of finished product are used for the production of semi-processed products, marmalades, etc. This step is done manually on a sorting belt.

WASHING is performed in equipment with fan and sprays.

CLEANING covers removal of leaves, etc., skin removal by one of the described methods for some fruits and coring / pitting for others.

CUTTING is applied only to pomace fruits and is performed preferably by mechanical means.

PRELIMINARY HEAT TREATMENT depends very much upon the fruit types and can be as different as a light blanching up to a real boiling; this step is aimed toward softening of tissues for

hard fruits, elimination of waxy pruin layer (plums, etc.) or enzyme inactivation for pomace fruits.

This treatment has to be reduced to the minimum necessary in order to avoid sugar losses. Some fruit (for example apricots, black cherries, grapes, etc.) does not undergo preliminary heat treatment.

COOLING is carried out in water (as cold as possible) and should not be too long to avoid soluble substances loss.

RECEPTACLE FILLING Fruit is introduced manually or sometimes mechanically (filling tables, etc.) in receptacles and then sugar syrup is added.

SUGAR SYRUP PREPARATION is performed by dissolving crystal sugar in hot water (90100 C). After the sugar has been dissolved, the syrup is boiled briefly; removal of impurities and coagulated substances is then performed by foaming / scumming. An addition of about 0.3% citric acid helps syrup clarification, followed by filtration through cloth.

PREHEATING/EMPTYING of open receptacles has as its objective to eliminate air from fruit tissues and this step is largely replaced today by receptacle closing under vacuum. Preheating may be done in steam or in water in such a way that syrup temperature reaches 8090 C and is maintained for 10-15 min.

HERMETIC SEALING is performed according to the type of receptacle and of cover/cap.

Pasteurization is carried out at 100 C and may be performed in continuous installations or in normal water baths. In some countries fruits in syrup are pasteurized at 80-90 C; this contributes to a greater flavour retention.

COOLING should be intensive in order to avoid discolorations and colour modifications and to reduce corrosion in metal cans.

Refractometric extract is to be measured 30 days after manufacturing. In order to establish exact concentration of sugar syrup to be added in each individual case it is possible to use the following formula:

C = 1.5 x [(2 x E) - F]

C = added syrup concentration;

E = refractometric extract needed in finished products, according to Table 8.6.3.

F = fruit refractometric extract.

Hot syrup is put into receptacles with a minimum temperature of 80 C in order to enable a corresponding vacuum after cooling.

It is possible to add in the syrup 0.3-0.5% citric or tartaric acid for fruit with a low acidity. Adding ascorbic acid in proportion of 0.8% assures colour maintenance and taste improvement

based on its reducing action.

Avoidance of excessively soft texture in finished products may be achieved for soft fruit (strawberries, apricots, etc.) by dipping fruit in a solution of calcium chloride (5% $CaCl_2$ in water).

Finished product defects and production "accidents" for "Fruit in syrup" and the means of preventing them

- **Change of colour in red fruit (red cherries, plums, etc.) to violet; to avoid this it is necessary to use glass jars or varnished/lacquered tinplate;**
- **Colour change to red for pears and quinces (pink shade) could arise in products which are over-pasteurized and insufficiently cooled;**
- **Change of colour of whole peaches peeled by chemical means is due to an incomplete inactivation of oxidative enzymes; to avoid this it is necessary to boil fruit after chemical peeling followed by washing with 0.5% citric or tartric acid solutions or by adding ascorbic acid in syrup;**
- **Softening of strawberries tissues can be prevented by a pre-treatment with warm syrup and also by addition of calcium salt.**

Some technical data for processing are seen in Table 8.6.2.

TABLE 8.6.2 Technical data for "Fruits in Syrup"

Type of fruit/product		Minimum fruit	Soluble substances (in syrup), RE** at 20C,
name	Size/shape	content, %	minimum
Apricots	Halves	55	25
Strawberries	Whole	47	25
Cherries	Whole	53	22
Quinces	Slices, 30 mm	50	26
Apples	Halves or quarters	47	25
Pears	Halves or quarters	57	22
Plums	Whole	45	25
Melon	Pieces	55	26
Wax cherries	Whole	53	27
Wild cherries	Whole	47	27
Pineapple	Slices	55	26
Mangos	Pieces	50	25
Papaya	Pieces	55	27

Fruit mixes	According to the	50	25
	conditions indicated		
	above, for each fruit		

** RE = Refract metric extract

TABLE 8.6.3 Quality in fruit products preserved with sugar and means to prevent them

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8.7 Fruit juice technologies

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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 CO_2 pressure may be done at a concentration of 1.5% CO_2 under a pressure of 7 kg/cm². At the distribution step, proceed at CO_2 decompression and the juice is then submitted to a sterilising filtration and aseptic filling in receptacles.

Preservation by freezing is carried out at about -30° C, after a preliminary de-aeration; storage is at -15 to -20° C.

Production of concentrated juices by evaporation is performed under vacuum (less than 100 mm Hg residual pressure) up to a concentration of 65-70% total sugar which assures preservation without further pasteurization. Modern evaporation installations recover flavours from juices which are then reincorporated in concentrated juices.

Additional operations for juice manufacturing are the vacuum de-aeration and mixing with other fruit juices or with sugar.

For the production of non clarified juices the centrifugation is the only specific step, enzyme clarifying and subsequent filtration being eliminated.

The optimum sugar/acid ratio for the majority of fruit, mainly for pomaces, is 10/1 to 15/1.

Fruit which is rich in carotenoids (apricots, peaches, etc.) is only processed as juices with pulp ("nectars").

Technological 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.

8.8.2.2.2 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.

8.8.2.2.3 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%.

8.8.2.2.4 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.

8.8.2.2.5 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-blanched in a 28-in Hg vacuum which ensures disintegration and enzyme inactivation. The pulp is then conveyed to a screw press, the resulting purée diluted in the ratio 1:3 with water, and the pH adjusted by further addition of citric acid to 4.2 to 4.3, which yields an attractive drink when this is centrifuged and sweetened.

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.

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8.9 Mango and guava processing technologies

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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, pure, 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:

Mango pieces	250 g	**Tumeric powder**	2 to 4 g
	60 g		2 to 4 g

Salt		**Fenugreek seeds**	
Mustard powder	30 g	**Bengal gram seeds**	2 to 4 g
Chili powder	20 g	**Gingelly oil**	20 to 30 g

The ingredients are mixed together and filled into wide-mouthed bottles of 0.5 kg capacity. Three days later the contents are thoroughly mixed and refilled into the bottles. Extra oil is added to form a 1-2 cm layer over the pickles.

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 pure, 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 Pure.

Mangoes are processed into pure for re-manufacturing into products such as nectar, juice, squash, jam, jelly and dehydrated products. The pure 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 pure 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 pure 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 pure. In one process, pure is pumped through a plate heat exchanger and heated to 90C for 1 min and cooled to 35 C before being filled into 30 lb tins with polyethylene liners and frozen at -23.50 C.

In an other process, pulp is acidified to pH 3.5, pasteurized at 90C, 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 pure, 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 (pure) 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% pure can be prepared using the following procedure.**

	Brix of pure		
Nectar components	15	17	20
Pure	100	100	100
Sugar	45	43	40
Water	255	257	260

Commercial processing conditions may require the use of a preservative.

The pH is adjusted to approximately 3.5 by adding citric acid as a 50% solution.

The time of heat processing will vary with filling temperature, can size and viscosity of the juice or nectar.

Mango squash may be prepared according to flow-sheet described below; the finished product may contain 25% juice, 45% TSS and 1.2 to 1.5% acidity and may be preserved with sulphur dioxide (350ppm) or sodium benzoate (1000 ppm) in glass bottles.

Mango squash simplified flow-sheet.

Ingredients

Mango pulp	900	900
Sugar	900	1100
Citric acid	18	15
Water	900	900

Mangoes are washed, stored, peeled with stainless steel knives. The pulp is prepared by using a pulper with fine sieve (0.025-in); Sugar is mixed with water and citric acid = syrup; The pulp is added to the syrup and mixed well; The mixture is strained trough cloth; The squash is heated at

85 C and bottles are filled and closed.

For additional heat treatment bottles may need to be maintained at a product temperature of 80C for 30 minutes if the product is to be processed without preservatives. The bottles are then left to cool in water and stored at room temperature.

Two negative points must be avoided: presence of air bubbles (which is a source of quick deterioration) and separation of squash solids (giving an undesirable appearance). The means to avoid these two phenomena are described in the fruit juices section.

A type of "squash type" beverage may also be manufactured with '/a pulp + '/a water + i/a sugar and pH adjusted to 3.7 by addition of citric acid. Using different sieve sizes affects the quality and reduces air bubbles to a certain extent but homogenisation and de-aeration of pure 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 pure 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 pure

Guava pure 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 pured 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 pure 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 pure and this can be accomplished by heating the pure 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 pure that is depectinised enzymatically. About 0.1% pectin-degrading enzyme is mixed into the pure 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 pure 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 pure 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

	1990	1991	1992 Jan-June
Frozen vegetable products	66	95	21
Chilled vegetable products	76	81	78
Heat processed vegetables	51	60	38
Heat processed fruits	13	14	5
Fruit juices and drinks	73	83	46
Potato crisps	32	33	16

Source: C. Dennis (1993)

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 then 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 amygdalin, from which cyanide is released by enzymic action when the kernels of cherry and apricot are crushed. Amygdalin was found to be absent from the cherry and apricot kernel oils.

The ACNFP is satisfied that there are no food safety reasons why the use of cherry and apricot kernel should not be acceptable provided there is compliance with the specifications shown in Table 8.10. 3.

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

	Cherry	Apricot

Contaminants limits:		
Heavy metals (total)	0.5 mg/kg	0.5 mg/kg
Aflatoxins (total)	4.0 g/kg	4.0 g/kg
Cyanide	0.15 mg/kg	0.15 mg/kg
Pesticide residues	0.01 mg/kg	0.01 mg/kg
Tocopherols:		
alpha/delta/gamma (mg/kg)	356-886	569-899

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.

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Chapter 9 Vegetable specific processing technologies

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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 %

	Peeling methods		
Vegetables	**Manual**	**Mechanical**	**Chemical**
Potatoes	15-19	18-28	-
Carrots	13-15	16-18	8-10
Beets	1416	13-15	9-10

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

Vegetables	Temperature, C	Time, min.
Peas	85-90	2-7
Green beans	90-95	2-5
Cauliflower	Boiling	2
Carrots	90	3-5
Peppers	90	3

Steam heat treatment can also be applied instead of water blanching as a preliminary step before freezing or drying, as long as the preservation method is only used for enzyme inactivation and not to modify consistency.

For drying, the vegetables are conveyed directly from steaming equipment to drying installations without cooling. Vegetable steaming is carried out in continuous installations with conveyer belts made from metallic sieves.

Cooling of vegetables after water blanching or steaming is performed in order to avoid excessive softening of the tissues and has to follow immediately after these operations; one exception is the case of vegetables for drying which can be transferred directly to drying equipment without cooling.

Natural cooling is not recommended because is too long and generates significant losses in vitamin C content. Cooling in pre-cooled air (from special installations) is sometimes used for vegetables that will be frozen

Cooling in water can be achieved by sprays or by immersion; in any case the vegetables have to reach a temperature value under 37 C as soon as possible. Too long a cooling time generates supplementary losses in valuable hydrosoluble substances; in order to avoid this, the temperature of the cooling water has to be as low as possible.

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, pured, 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 cm of 96% ethylic alcohol and then this preparation is brought to 100 cm with the same solvent);**
- **peroxide solution 0.3% (1 cm perhydrol is brought to 100 cm with distilled water.**

b) Sampling. From various parts of the material samples are taken (about 20-30 pieces, etc.); the material is then crushed in a laboratory bowl in order to obtain an average sample.

c) Check. Prom the average sample, 10-20 g of material is taken in a medium capacity test tube; on this sample are poured: 20 cm distilled water; 1 cm of 1% guaiacol solution; 1.6 cm of peroxide solution.

The contents of the test tube is shaken well. The gradual appearance of a weak pink colour indicates an incomplete peroxidase inactivation - reaction slightly positive. If there are no tissue colour modifications after 5 minutes, the reaction is negative and the enzymes have been inactivated.

As an orientative check it is also possible to simply pour a few drops of 1% guaiacol solution and 0.3% peroxide solution directly on blanched and crushed vegetables. A rapid and intensive brown-reddish tissue colouring indicates a high peroxidase activity (positive reaction).

Catalase test

In order to identify the catalase enzyme activity, 2 g of dehydrated vegetables are well crushed and mixed with about 20 cm of distilled water. After 15 min softening, 0.5 cm 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

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The vegetables can be stored, in some specific natural conditions, in fresh state, that is without significant modifications of their initial organoleptic properties. Fresh vegetable storage can be short term; this was briefly covered under temporary storage before processing. Also fresh vegetable storage can be long term during the cold season in some countries and in this case it is an important method for vegetable preservation in the natural state.

In order to assure preservation in long term storage, it is necessary to reduce respiration and transpiration intensity to a minimum possible; this can be achieved by:

a. maintenance of as low a temperature as possible (down to 0 C),
b. air relative humidity increased up to 85-95 % and
c. CO_2 percentage in air related to the vegetable species.

Vegetables for storage must conform to following conditions: they must be of one of the autumn or winter type variety; be at edible maturity without going past this stage; be harvested during dry days; be protected from rain, sun heat or wind; be in a sound state and clean from soil; be undamaged.

From the time of harvest and during all the period of their storage vegetables are subject to respiration and transpiration and this is on account of their reserve substances and water

content. The more the intensity of these two natural processes are reduced, the longer sound storage time will be and the more losses will be reduced.

For this reason, vegetables have to be handled and transported as soon as possible in the storage conditions (optimal temperature and air relative humidity for the given species). Even in these optimal conditions storage will generate losses in weight which are variable and depend upon the species.

Some optimal storage conditions are shown in table 9.3.1

TABLE 9.3.1 Optimal conditions for fresh vegetable storage

Vegetables	Storage conditions	
	Temperature, C	Relative humidity, %
Potatoes	+1…+3	85-90
Carrots	0 … +1	90-95
Onions	0 … +1	75-85
Leeks	0 … +0.5	85-90
Cabbage	-1 … 0	90-97
Garlic	0 … +1	85-90

Beets	0 … +1	90-95

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 pures 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 pure to be dried are placed on them. Process conditions are at low residual pressure (about 10-20 mm Hg) and a product temperature of 50-70 C. This equipment is discontinuous but easy to operate.**
- **Drum dryers have one or two drums heated with hot water or steam as heating elements. Feeding is continuous between the two drums which are rotating in reverse direction (about 2-6 rotations per minute) and the distance of which is adjustable and determines the thickness of layer to be dried. he product is dried and removed by mechanical means during rotation.**
- **Drying installations by spraying in hot air; the product is introduced in equipment and sprayed by a special device in hot air. Drying is instantaneous (1/50 s) and therefore can be carried out at 130-15O C.**

TABLE 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

Product	Form/cut	Moisture %	Weight kg/m
Bean (green)	20 nun cut	5	1.6
Bean (lima)	5	3.3	
Beet	6 mm strips	5	1.6-1.9

Cabbage	6-12 mm shreds	4	0.7-0.9
Carrots	5-8 mm strips	5	3-5
Celery	Cut	4	
Garlic	Cloves	4	
Okra	6 mm slices	8	
Onion	Slices	4	0.4- 0.6
Pea (fresh)	Whole	5	3.4
Pepper (hot)	Ground	5	
Pepper (sweet)	5 mm strips	7	
Potato (Irish)	5-8 mm strips	6	2.9-3.2
	Diced	5	3.3-3.6
Tomato	7-10 mm slices	35	

Selection and storage

It is important to select potatoes of high specific gravity since this characteristic indicates superior yield and lower oil absorption. It is even more important to select potatoes with low reducing sugar contents or to store them at temperatures conducive to the minimising of these substances.

Sprouting and fungal damage must also be minimised by the storage conditions.

Peeling

The ideal peeling operation should only remove a very thin outer layer of the potato, leaving no eyes, blemishes, or other material for later removal by hand trimming. It should not significantly change the physical or chemical characteristics of the remaining tissue.

Preferably peeling should use small amount of water and result in minimal effluent; compromises will have to be made in all of these aspects of peeling.

First, the potatoes are thoroughly washed, not only for sanitary reasons, but also to prevent dirt of grit from abrading the equipment the tubers will dater contact. Washing may take place in streams, as the potatoes are being conveyed by water streams, or in equipment provided with means for scrubbing the potato with brushes or rubber rolls.

Figure 9.4.3 Plate vacuum dryer

Figure 9.4.4 Drum dryer

Figure 9.4.5 Drying installation by spray in heated air

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. I the crisps are allowed to cool before packaging, better adherence of salt and flavour powders is obtained.

Some consumers prefer the hard, curled-up crisp that is characteristic of the hand-kettle type of operation. The special flavour of the hand-kettle crisp is said to be due, at least partly, to the starch retained on the cut surfaces of the potato slices as a result of the omission of a washing process after slicing. Starch-covered slices tend to stick together in the fryer so it is necessary to use devices to prevent clumping.

The principal factors affecting potato crisp acceptability are piece size, colour, and of course, flavour. These factors are controllable primarily by selection of the raw material, adjustment of processing conditions, and packaging.

Storage stability

If the frying oil is stabilised and has not deteriorated through use, and if the packaging is opaque and has a low moisture vapour transmittance rate (MVTR), a shelf-life of 4-6 weeks should be achieved when crisps are stored at temperatures of about 70 F.

Once potato crisps are in the bag, the three forms of quality loss which have the greatest effect on consumer acceptance are breakage, absorption of moisture with loss of crispiness, and fat

oxidation leading to development of rancid odours.

The mechanical abuse causing breaking of the crisps can be partially prevented by using stiff packaging material, making the package "plump" with contained air, and avoiding crushing in the shipping case.

Absorption of moisture is prevented largely by proper choice of packaging material. Cellophane coated with various moisture barriers has proved to be a satisfactory pouch films for the relatively short shelf-life expected (generally stated to be 4-6 weeks).

Light (especially fluorescent light) accelerates oxidation, so that opaque packaging material must be used to obtain maximum shelf-life.

Potato crisps are considered commercially unacceptable when they have a moisture content above 3%, which is in equilibrium with a relative humidity of about 32%. The containers should have a high degree of resistance to moisture-vapour transfer.

If pouches are used, foil-containing films are preferable, since they not only resist moisture-vapour transfer but reflect light.

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. Modem technology is oriented to a maximum maintenance of organoleptic properties and of vitamin content.

At same time, it is important to assure juice uniformity by avoiding cellulosic particle sedimentation. Juice stability is assured by a flash pasteurization which assures the destruction of natural micro-flora, while keeping the initial properties.

The modern technological flow-sheet covers the following main operations:

PRE-WASHING is carried out by immersion in water, cold or heated up to 50 C (possibly with detergents to eliminate traces of pesticides). This operation is facilitated by bubbling compressed air in the immersion vessel/equipment.

WASHING is performed with water sprays, which in modern installations have a pressure of 15 at or more.

SORTING/CONTROL on rolling sorting tables enables the removal of non-standard tomatoes - with green parts, yellow coloured, etc.

CRUSHING in special equipment.

PREHEATING at 55-60 C facilitates the extraction, dissolves pectic substances and contributes to the maintaining of vitamins and natural pigments. In some modern installations, this step is carried out under vacuum at 630-680 mm Hg and in very short time.

EXTRACTION of juice and part of pulp (maximum 80%) is performed in special equipment / tomato extractors with the care to avoid excessive air incorporation. In some installations, as an additional special care, a part of pulp is removed with continuous centrifugal separators.

DE-AERATION under high vacuum of the juice brings about its boiling at 35-40 C.

HOMOGENISATION is done for mincing of pulp particles and is mandatory in order to avoid future potential product "separation" in two layers.

FLASH Pasteurization at 130-150 C, time = 8-12 see, is followed by cooling at 90 C, which is also the filling temperature in receptacles (cans or bottles).

ASEPTIC FILLING

CLOSING OF RECEPTACLES is followed by their inversion for about 5 to 7 minutes.

COOLING has to be carried out intensely.

Full cans do not need further pasteurization because the bacteria that have potentially contaminated the tomato juice during filling are easily destroyed at 90 C due to natural juice acidity.

For bottles, it may be possible to avoid further sterilisation if the following conditions can be respected: washing and sterilising of receptacles, cap sterilisation (with formic acid), filling and capping under aseptic conditions, in a space with UV lamps. In so far as this is quite difficult to achieve it may be necessary to submit bottles to a pasteurization in water baths.

The main characteristics of high quality tomato juice are:

- **natural red colour;**
- **taste and flavour of fresh tomatoes;**
- **uniformity (without pulp sedimentation);**
- **total soluble solids: 6% minimum;**
- **total soluble substances (by 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 mini**

- **add salt and lemon juice to the prepared receptacles just before filling;**
- **pasteurize closed glass receptacles (bottles or jars) according to conditions recommended in technological flow-sheets and which is summarised as follows:**

Receptacle size	Pre-heating	Time of pasteurization
0.33 1	60 C	40 minutes
0.501	60 C	45 minutes
0.66 1	60 C	55 minutes
0.751	60 C	60 minutes
1.0 litre	60 C	70 minutes

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)

AIRTIGHT SEALING

Pasteurization at 100 C for 30 minutes.

The main characteristics of a good quality carrot juice:

- **uniformity (no separation in layers occurs during storage);**
- **good orange colour;**
- **pleasant taste, close to fresh carrot taste;**

- **total soluble solids: 12 %;**
- **total sugar content: 8%;**
- **beta-carotene: 1.3 mg/100 ml;**
- **soluble pectin: 0.4 %.**

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 0.700.75 (minimum limit of mould growing), it is necessary to take special measures (e. g pasteurization, cold storage or salt addition).

Salt is not a preservative in itself but contributes to the lowering of water activity.

In drums, the preservation of tomato paste with minimum 30% refractometric extract is carried out in two ways:

- the hot paste (about 90 C) flows directly from pasteurization equipment into drums that have been previously steamed;

- the paste is cooled down to 30 C through a heat exchanger and is introduced into drums that have been previously steamed.

For preservation purposes, it is possible to add 3-8% salt.

Preservation with 3% salt must be carried out respecting the following criteria:

a) processing of a healthy raw material;

b) thorough washing and control;

c) pasteurization of concentrated paste and use of well prepared drums. Paste in drums has to be stored in cold storage rooms during the hot season.

Preservation in big metal cans of 5 and 10 kg capacity of tomato paste with a minimum of 30% refractometric extract can be achieved without sterilisation if the following conditions are respected:

a) sterilisation by steam of cans and covers;

b) filling of paste at 92-94 C;

c) airtight sealing/ closing of cans;

d) invert cans and then

e) air cooling.

For small packages (tinplate cans of 1/10-1/1 or glass jars of same capacity) it is usual to use pasteurized paste, as hot as possible (92-94 C). The receptacles are first sterilised by steam.

After airtight sealing, the receptacles are kept in boiling water for a short time in order to sterilize their inner surface and the paste in contact with inner receptacle surface. In some countries small receptacles are not further sterilised if the manufacturing is carried out in perfect hygienic and sanitary conditions.

Packing in small tinned aluminium tubes is carried out with concentrated paste, pasteurized and hot.

Good quality tomato paste is an homogenous mass, with a high density, without foreign bodies (seeds, peel, etc.), with a red colour, and an agreeable taste and smell, close to those of fresh tomatoes.

There are usually three types of tomato paste: 36, 30 and 24 which have refractometric extracts of respectively 34-38%, 28-32% and 24-26%. Paste of good quality must have a volatile acidity of maximum 0.15% as lactic acid. An 8% salt addition is accepted.

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.**

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9.6 Pickles and sauerkraut technology

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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 be preferable to obtain a fairly light pressure on cabbage just after salt addition with some simple mechanical means. This is important in order to:

- **create an anaerobic medium for fermentation;**
- **facilitate external diffusion of cellular juice;**
- **assure a rational use of the fermentation space.**

FERMENTATION. The maximum acidity level obtained is generally of about 1.5% lactic acid (and very rarely 2.5%); this is obtained in 4-6 weeks. Optimal acidity is 1.0-1.8% and pH value 4.1 or lower.

Fermentation temperature is at 20-25 C in the first phase and needs to be lowered then to 14-18 C. During fermentation, the brine from each storage / fermentation silo cell is periodically circulated with a pump in order to uniformise the fermentation process.

STORAGE is performed in same silos used for fermentation, or the finished products is removed from silos and packed in drums and other receptacles according to distribution schedule.

These silos are usually made of reinforced concrete and coated with gritstone plates or with an acid-resisting material layer.

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)

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 120C, 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 curse, be frequently checked.

Heat Processing

After seaming, the cans are heated for a definite time at a definite temperature to kill or inhibit organisms which may cause spoilage. This operation is termed "heat processing".

The times and temperatures required for "heat processing" of various packs have been determined experimentally to ensure that spores of the most heat resistant food poisoning organisms known, Clostridium botulinum, are destroyed.

There are other organisms, however, whose spores are more heat resistant than those of Clostridium botulinum and which although they will not cause food poisoning may cause spoilage and for this reason the minimum heat processing time is often exceeded by recommendations made by laboratories.

At the same time there is a limit to the amount of heating which a canned food may be given without spoiling its flavour, texture and colour and this also has to be taken into consideration when process recommendations are made.

Bacterial spores have a greater resistance to heat when the growth-medium is neutral or near neutral, and neutrality is normally required for bacterial growth to commence. Because of this, canned foods have been broadly divided into two groups:

a) "acid" foods having a pH of 4.5 or lower and

b) "non-acid" foods having a pH of more than 4.5.

"Non-acid" foods (vegetables) must, therefore be "heat processed" at high temperatures using steam under pressure, whereas "acid" foods (fruit) may be processed at the (lower) temperature of boiling water, since this will kill moulds and yeasts and if any bacterial spores survive the combination of acid and heat, they will be inhibited from growth by the acid environment.

The rate of destruction by heat follows a definite pattern, the same proportion of the surviving bacteria being destroyed in successive units of time. The more bacteria there are in a pack, the more time will be need to reduce their numbers. For this reason, it is essential that the initial number of bacteria be kept low, and this may be achieved by ensuring fast and hygienic handling at all stages in the cannery.

Pressure gauges and retort temperature control equipment must be checked frequently for accuracy. Processing times and temperatures must be strictly adhered to, and complete removal of air from the retort during processing must be achieved by adequate venting. Failure to remove the air completely will result in their being cold spots in the retort and intermittent spoilage 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 pressurecooling, 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")

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

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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, package and transport products to meet the mandatory requirements of importing countries;**
- **lack of awareness by food exporting countries of the mandatory requirements of importing countries, including certification;**
- **lack of adequate export control programmes and related agencies in food exporting countries, preventing them from exercising the necessary product surveillance and giving reliable and credible certification, and**
- **a lack of communication, between food control authorities and agencies in exporting and importing countries.**

All four can be remedied by governments if they possess sufficient political will and take the necessary steps to do so.

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 keep in a sanitary condition through frequent cleaning and, when necessary, sanitizing. If necessary, such equipment must be taken apart for thorough cleaning.**
b. **It is necessary to process, package and store food under conditions that will minimize the potential for undesirable microbiological growth, toxin formation, deterioration or contamination. To accomplish this may require careful monitoring of such factors as time, temperature, humidity, pressure, flow rate, etc. The object is to assure that mechanical breakdowns, time delays, temperature fluctuations or other factors do not allow the foods to decompose or become contaminated.**
c. **Food shall be held under conditions that prevent the growth of undesirable microorganisms as follows:**

- **Refrigerated foods shall be maintained at 45 F or below;**
- **Frozen foods shall be maintained in a frozen state;**
- **Acid or acidified foods to be held in hermetically sealed containers at ambient temperatures shall be heat-treated to destroy mesophyllic microorganisms;**

d. **Measures such as sterilizing, irradiating, pasteurizing, etc., shall be adequate to destroy or prevent the growth of undesirable microorganisms;**
e. **Work-in-process shall be protected against contamination;**
f. **Finished food shall be protected from contamination;**
g. **Equipment, containers and utensils shall be constructed, handled and maintained to protect against contamination;**
h. **Measures, e.g., sieves, traps, metal detectors, shall be used to protect against the inclusion of metal or other extraneous material in food;**
i. **Food or materials that are adulterated shall be disposed of in a manner that prevents other food from being contaminated;**
j. **Mechanical manufacturing steps such as washing, peeling, etc., shall be performed to protect against contamination by providing adequate protection from contaminants that may drip, drain or be drawn into the food, by adequately cleaning and sanitizing all food-contact surfaces and by using time and temperature controls at and between each manufacturing step;**
k. **Heat-blanching should be done by heating the food to the required temperature, holding it at this temperature for the required time, and then either rapidly cooling the food or passing it to the next manufacturing step without delay;**
l. **Filling, assembling, packaging, and other operations shall be performed in such a way that the food is protected against contamination by:**

- **Use of a quality control operation in which the Critical Control Points are** identified and controlled during manufacturing;

- Adequate cleaning and sanitizing of all food-contact surfaces and food containers;
- Using materials for food containers and food-packaging materials that are safe and suitable;
- Providing physical protection from contamination, particularly airborne contamination;
- Using sanitary handling procedures.

m. Food such as, but not limited to, dry mixes, nuts, intermediate moisture food, and dehydrated food, that relies on the control of aw for preventing the growth of undesirable microorganisms shall be processed to and maintained at a safe moisture level by:

- Monitoring the aw of food;
- Controlling the soluble solids / water ratio in finished food;
- Protecting finished food from moisture pickup, by use of a moisture barrier, or by other means, so that the Aw of the food does not increase to an unsafe level;

n. Food such as, but not limited to, acid and acidified food, that relies principally on the control of pH for preventing the growth of undesirable microorganisms shall be monitored and maintained at a pH of 4.6 or below by: - Monitoring the pH of raw materials, food in process, and finished food; - Controlling the amount of acid or acidified food added to low-acid food;

o. If ice is used and comes in contact with food products, it must be made from potable water

and be in a sanitary condition;

p. **Areas and equipment that are used to process human food should not be used to process non-human food-grade animal feed, or inedible products unless there is no possibility of contaminating the human food;**
q. **A coding system should be utilized that will allow positive lot identification in the event it is necessary to identify and segregate lots of food that may be contaminated.**

- **Records should be kept for a period of time that exceeds the self life of the product, except that**
- **Records need not be kept beyond two years.**

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