Module 5. Jam, jelly, marmalade and glazed and crystallized fruits

Lesson 17

ROLE OF SUGAR AND OTHER INGREDIENTS IN FRUIT PRESERVATION

17.1. Introduction

The fruit are perishable in nature and so are the juices expressed out of them. Preparation of sugar preserves like Jams, Jellies, Marmalades, Conserves, etc. are one means to extend the shelf life of fruit juice at the same time enable the consumers to enjoy the body and texture of a gel – a mouthfeel that is relished by all. The high osmotic pressure of sugar creates conditions that are unfavourable for the growth and reproduction of most species of bacteria, yeasts and molds.

17.2 Preservation of Fruit Solids by Sugar

Food preservation if the process of treating and handling food to stop or greatly slow down spoilage (loss of quality, edibility or nutritive value) caused or accelerated by microorganisms. A sugar concentration of about 60% in finished or processed fruit product generally increases their preservation. Preservation is not only determined by the osmotic pressure of sugar solutions, but also by water activity 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 the products from mould and osmophilic yeasts. Maximum saccharose concentration that can be achieved in liquid phase of product is about 67.89%.

In the case of jellies and preserves, the water is withdrawn from the microorganisms toward the concentrated sugar syrup through osmotic gradient. The microorganisms become dehydrated and incapacitated, and are unable to multiply and bring about food spoilage. In jellies, jams and preserves, a concentrated sugar solution of at least 65% is necessary to perform this function. Since the sugar content naturally present in fruits and their juices is less than 65%, it is essential to add sugar to raise it to this concentration in jellies and preserves.

17.3 Fruit Products Based on Sugar Preservation

17.3.1 Preserves

They are whole fruits or large pieces of fruit in thick sugar syrup, often slightly jellied. Preserves are made from practically all fruits including peaches, pears, plums, aonla, strawberries, grapes, muscadines, quinces and tomatoes.The fruit for preserving should be in a firm-ripe rather than a soft-ripe stage. By using up to 25% of firm-ripe fruit, the tartness is increased and less pectin is required in the formula. The fruit should be uniform in size or uniform pieces so as to cook evenly. Examples include fig preserve, watermelon rind preserve, etc.

17.3.2 Jam

It is essentially a gel or semi-solid mass containing pulped or whole fruit, made by boiling the fruit pulp with sugar solution. It is made from crushed or macerated (ground) fruit and generally is less firm than jelly. They may be made from a single fruit or mixture of fruits. It may contain small particles of fruit as against preserves, which may contain whole or large pieces of fruit.

17.3.3 Jelly

It is made from fruit juice. A perfect fruit jelly has a clear colour and a flavor characteristic of the fruit used. It is transparent and sparkles, quivers but does not flow when removed from its mould. The jelly should be tender enough to cut easily and is so firm that angles produced retain their shape.

17.3.4 Conserves

Conserves are similar to jams with chopped nuts (pecans, walnuts or others) and raisins added for texture and flavour. Conserves are mixtures of two or more fruits usually including citrus fruits. The chief ingredient in specific conserves being figs, peaches, pears, plums, oranges or carrots.

Conserves contain higher proportion of fruit than preserves or marmalades.

17.3.5 Marmalades

They have the characteristics of jellies and preserves combined. It is a semi-viscous jelly which contains the fruit pulp and may contain the peels suspended evenly throughout the jellied juice.
They are made from under ripe fruit, rich in pectin and acid, chiefly citrus fruits – alone or in combination with other fruits. Popular marmalades are combination citrus, orange-peach, orange-pear, ginger-pear, pear-pineapple and grape. The pectin and acid contents of the marmalades should be kept slightly higher than what has been recommended for jellies.

17.4 Prerequisites for Preparing Gelled Fruit Products

17.4.1 Selection of fruits

They maybe from under ripe, undersize and off-grade fruit or even from peels, cores and wind-fall fruit. The fruit should be sufficiently ripe (not overripe); mixture of under-ripe and ripe fruits is advantageous. Combining fruits rich in acid with those rich in pectin is less expensive than using acid or commercial pectin to supplement the deficiency. The juices of different fruits may be mixed.

17.4.2 Principle

The preparation is based on the gel making power of pectins which are present naturally in the products or added to them. Fruits that are low in pectin and acid components can be used to make jams and jellies, provided the pectin and acid content is adjusted to levels that make them gel.

17.4.3 Pectin in jelly formation

Protopectin is a component of the cementing material between plant cell walls; also a part of cell walls themselves. These are most abundant during the immature stage of fruit and are converted to pectin as the fruit matures. The chemical structure of pectin is shown in Figure 17.1.

When fruit are heated, the protopectin that has not turned to pectin is partially hydrolyzed or converted to pectin. To increase the amount of pectin extracted, some acid has to be added to the extraction solution and heat has to be applied.

When fruit are very ripe, other enzymes break up the pectin into pectic acid and alcohol. Pectic acid does not form a gel, except in the presence of added calcium molecules.

Jellies made with additional commercial pectin are usually bright and more transparent with no lessening of colour.

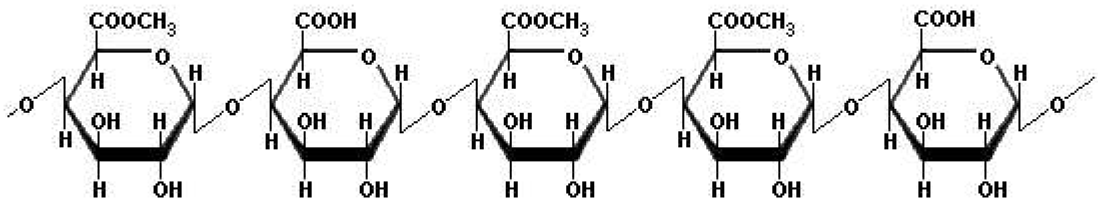

Fig. 17.1 Chemical structure of Pectin

17.5 Commercial Production of Pectin

Plant materials are used. Most frequently culled or rejected apples, apple pomace or the pulp (together with peel and core wastes) remaining after apple juice extraction are used. Lemon rejects are also a good source. Extract all pectin substances including protopectin, pectinic acid, pectic acids and pectin related compounds.

17.5.1 Pectins are classified into two groups:

(a) those with a high methoxyl content (HMP) ~ 11% methoxyl
(b) those with low methoxyl content (LMP)

HMP is extracted with higher temperature, acidic solutions. Pectins with high methoxyl content forms gels in presence of high sugar and acid concentration. Most commercial pectins are HMP.

LMP containing pectic acids are extracted with lower temperatures with less acidic solutions, but in presence of other chemical compounds. LMP are pectin derivatives which do not need sugar to gel. If used, they need to react with a calcium salt (dicalcium phosphate), which has to be added during jam making.

17.5.2 Pectin extraction method

The fresh fruit tissue or separated parts, including the peel and core are heated in 95% alcohol or 0.05N HCl (pH 2.0) for 10-20 min at 70^{o}C to inactivate pectic enzymes. After the pretreatment, the materials is ground in an electric blender and placed in water. Versene or Na-EDTA is added at 2.0%. The pH is adjusted to 6.0. The mixture is heated for about an hour at 90-95^{o}C. The slurry formed is rapidly filtered and the pectin is precipitated from the solution using acidified alcohol. The precipitate is centrifuged and repeatedly washed with 70% alcohol. Acetone is used for dehydration and the pectin produced is vacuum-dried. It may also be dried in a hot-air oven at 50^{o}C for 4 h.

17.5.3 Household extraction of pectin

A pectin solution of maximum strength can be obtained with about 30 min of boiling. When this period is divided into two, each of 15 min period of extraction, maximum amount of pectin can be extracted.

Other jellying agents include agar, arrow root, tapioca flour or cassava starch.

17.6 Other Ingredients

Successful jelly formation requires correct proportion of sugar, acid and pectin.

17.6.1 Sugar

Pectin-sugar gel formation occurs as a result of the precipitation of a part of pectin present in solution. Precipitation takes place in such a way so as to develop high binding forces at the surface. These hold the solution of other ingredients with sufficient strength to confer on the whole system the rigidity and texture associated with a jelly.

The addition of sugar is essential to produce an ideal jelly texture, appearance, flavour and yield. The sugar reduces the stability of the system by removing water from the pectin particles and affects the strength of the acidity.

The sugar content influences (a) the pH optimum or maximum acidity, and (b) maximum gel strength.

A sugar content of between 60-65% is usually preferable. The proportion of sugar added to extract should be appropriate to pectin concentration; depends on the acid present in the extract.

Smaller percentage of sugar gives lower jelly strength at all acidity levels. This may be made up by use of larger amount of pectin or acid or both.

Too little sugar added when pectin is over-concentrated results in tough jelly.

The principal cause for failure in gel formation is addition of too much sugar.

17.6.1.1 Inversion of sugar

The maximum solubility of sucrose at 86^{o}F is 68.7 %.

Inversion is desirable since (a) it lowers the concentration of sucrose, and (b) it reduces the possibility of sugar crystallization.

$$\text{Sucrose} \xrightarrow{\text{Heat + Acid}} \text{Glucose} + \text{Fructose}$$

The degree of inversion depends on:
(i) Hydrogen ion-concentration
(ii) Duration of boiling

For sufficient inversion, boil the pectin extract for 10 min at pH 3.0 or for 30 min at pH 3.5 (i.e. boil sugar with 0.05% H_2SO_4 for 15 min).

In the finished jelly, 30-50% invert sugar/glucose should be present.

If < 30% invert sugar – chances of crystallization.
If > 50% invert sugar - development of a honey-like mass.

17.7 Estimation of Pectin Strength of Fruit Extract

The following methods can be employed to determine the pectin in fruit juices:

1. Testing amount of pectin by precipitating it with alcohol or methylated spirit.
2. Finding the viscosity of pectin solution using a jelmeter. The temperature of pectin solution should be between 70-100oF. Close the bottom end and fill juice in the tube; allow dripping for 1 min. and close the bottom. The figure (i.e. 11/4, 1, ¾, ½ etchings) nearest (< or >) the level of the juice in the tube of jelmeter is noted. The data shows the cups or parts of cups of sugar to be added to each cup or part of the juice extract.
3. Making actual test jellies from the fruit extract.

17.7.1 Alcohol test

Place 1 teaspoon (5 ml) of liquid in a saucer. Allow it to thoroughly cool down. Three teaspoonfuls (15 ml) of alcohol (95%) are added and the mixture is gently shaken and allowed to stand for 3-5 minutes (Table 17.1).

Table 17.1 Alcohol test to estimate the pectin strength of fruit extract

Observation	Inference	Quantity of sugar
A firm jelly-like mass forms	Extract is rich in pectin	¾ - 1 cup of sugar to 1 cup of fruit extract.
Pectin precipitates in form of several lumps	Extract is medium in pectin	½-2/3 of a cup of sugar to 1 cup of extract.
Few small stringy lumps	Low pectin concentration	Extract should be concentrated.

17.8 Acid

For any given pectin-sugar combination under given conditions of temperature, there is a maximum hydrogen-ion-concentration or acidity which just permits the completion of jelly formation within the time limit of the system.

The acid concentration affects the final structure through the alteration of the rate of setting, but does not show an optimum when the setting time is made sufficiently long by diminishing the sugar content.

Given a certain proportion for a particular pectin level, the sugar and acidity controls the strength of the jelly formed; the sugar through its dehydration of the pectin particles, and the acid by its own destabilizing action and its effect on the speed at which sugar-pectin equilibrium is attained.

High quality product is associated with a sugar content of ~ 65% and this is related to a pH of 3.4 - 3.1. The rheology of jelly as influenced by the acidity of the system is depicted in Table 17.2.

Table 17.2 Rheology of jelly based on the acidity of system

Quantum of acid	Rheology of jelly
Small amount of acid	Weak fibrillar structure; unable to support sugar solution adequately.
At higher acidity or lower pH	Jelly is somewhat stiffer.
Acidity further increases	Acid tends to hydrolyze pectin fibrils. Fibrils lose elasticity and jelly becomes syrupy. Syneresis is likely to occur.
Less acid (sugar normal)	Add more pectin.

The final jelly should contain a minimum of 0.5% (preferably 0.75%) total acidity and not exceeding 1.0% acidity.

Weak jellies can be improved by adding a little acid.

When fruit extracts are deficient in acid, either characteristically or because they are obtained from over-ripe fruit, it is possible to improve their jellying capacity by addition of acids viz., citric, tartaric or malic acids (usually found in fruits); tartaric acid gives best results. Lemon juice may be added, or other fruit juices which are sour can be blended with them.

The acid should be added near the finishing point. If external pectin is used, acid should be added just before the jellies are poured into containers.

17.8.1 Proportion of ingredients

The desired proportion of ingredients required to obtain good jelly is as follows:

Table 17.3 Desired proportions of ingredients for jelly making

Pectin	Sugar	Fruit acid	Water
1.0	60-65	1.0	33-38

17.9 Acid

For jelly containing 1.0% pectin, the optimum pH and sugar requirement is as follows:

Table 17.4 pH of jelly mass based on the sugar content used

Optimum pH	3.0	3.2	3.4
Sugar (%)	60	65	70

17.10 Theory of Jelly Formation

17.10.1 Fibril theory

When sugar is added to pectin solution, it destabilizes the pectin-water equilibrium and pectin conglomerates forming a network of fibrils through the jelly. The network of fibrils holds the sugar solution in the inter-fibrillar spaces.

The firmness of network depends on (a) the concentration of sugar, and (b) acidity.

The fibrils of pectin become tough in presence of acids. Small amount of acid gives a weak fibrillar structure. Large amount of acid tends to hydrolyze pectin; the fibrils lose elasticity and the jelly becomes syrupy.

17.10.2 Spencer's theory

Sugar acts as a precipitating agent; the presence of acid helps it. Greater the quantity of acid, lower is the sugar requirement.

17.10.3 Olsen's theory

Sugar acts as a dehydrating agent which disturbs the equilibrium existing between water and pectin. The negative charge on pectin is reduced with help of hydrogen-ion-concentration. Pectin precipitates and coalesces in the form of a fine network of insoluble fibres, provided sugar is present in sufficient concentration. As the system reaches equilibrium, the jelly strength becomes the maximum.

17.11 Pectin – A Prized Ingredient in Jam/Jelly making

17.11.1 Raw materials for Pectin

Apple pomace and Citrus peel (Lime, lemon and orange) serves as raw material for extraction of pectin
.

17.11.2 Types of Pectin

High methoxyl (HM) pectins are defined as those with a Degree of Esterification (DE) above 50, while low methoxyl (LM) pectins have a DE of less than 50. LM pectins can be acid or alkali-treated. LM pectins can be either amidated (LMA) or non-amidated (LM).

17.11.3 Pectin in jelly formation

Protopectin is a component of the cementing material between plant cell walls; also a part of cell walls themselves. These are most abundant during the immature stage of fruit and are converted to pectin as the fruit matures.

When fruit are heated, the protopectin that has not turned to pectin is partially hydrolyzed or converted to pectin. To increase the amount of pectin extracted, some acid has to be added to the extraction solution and heat has to be applied.

When fruit are very ripe, other enzymes break up the pectin into pectic acid and alcohol. Pectic acid does not form a gel, except in the presence of added calcium molecules.

Jellies made with additional commercial pectin are usually bright and more transparent with no lessening of colour.

17.5 Concentration of Pectin and Jelly characteristics

1.0% pectin	Firm and tough jelly
< 0.5% pectin	Jelly fails to set

17.11.4 Commercial production of pectin

Plant materials are used. Most frequently culled or rejected apples, apple pomace or the pulp (together with peel and core wastes) remaining after apple juice extraction are used. Lemon rejects are also a good source.
Extract all pectin substances including protopectin, pectinic acid, pectic acids and pectin related compounds.

Pectins are classified into two groups:

(a) those with a high methoxyl content (HMP) ~ 11% methoxyl content
(b) those with low methoxyl content (LMP) – lower methoxyl than mentioned above

HMP is extracted with higher temperature, acidic solutions. Pectins with high methoxyl content forms gels in presence of high sugar and acid concentration. Most commercial pectins are HMP.

LMP containing pectic acids are extracted with lower temperatures with less acidic solutions, but in presence of other chemical compounds. LMP are pectin derivatives which do not need sugar to gel. If used, they need to react with a calcium salt (dicalcium phosphate) which has to be added during jam making.

17.11.5 Pectin extraction method

The fresh fruit tissue or separated parts, including the peel and core are heated in 95% alcohol or 0.05N HCl (pH 2.0) for 10-20 min at 70^{o}C to inactivate pectic enzymes. After the pretreatment, the materials is ground in an electric blender and placed in water. Versene or Na-EDTA is added at 2.0%. The pH is adjusted to 6.0. The mixture is heated for about an hour at 90-95^{o}C. The slurry formed is rapidly filtered and the pectin is precipitated from the solution using acidified alcohol. The precipitate is centrifuged and repeatedly washed with 70% alcohol. Acetone is used for dehydration and the pectin produced is vacuum-dried. It may also be dried in a hot-air oven at 50^{o}C for 4 h.

17.11.6 Household extraction of pectin

A pectin solution of maximum strength can be obtained with about 30 min of boiling. When this period is divided into two, each of 15 min period of extraction, maximum amount of pectin can be extracted.
Other jellying agents include agar, arrow root, tapioca flour or cassava starch.

17.11.7 Manufacture of different types of Pectin

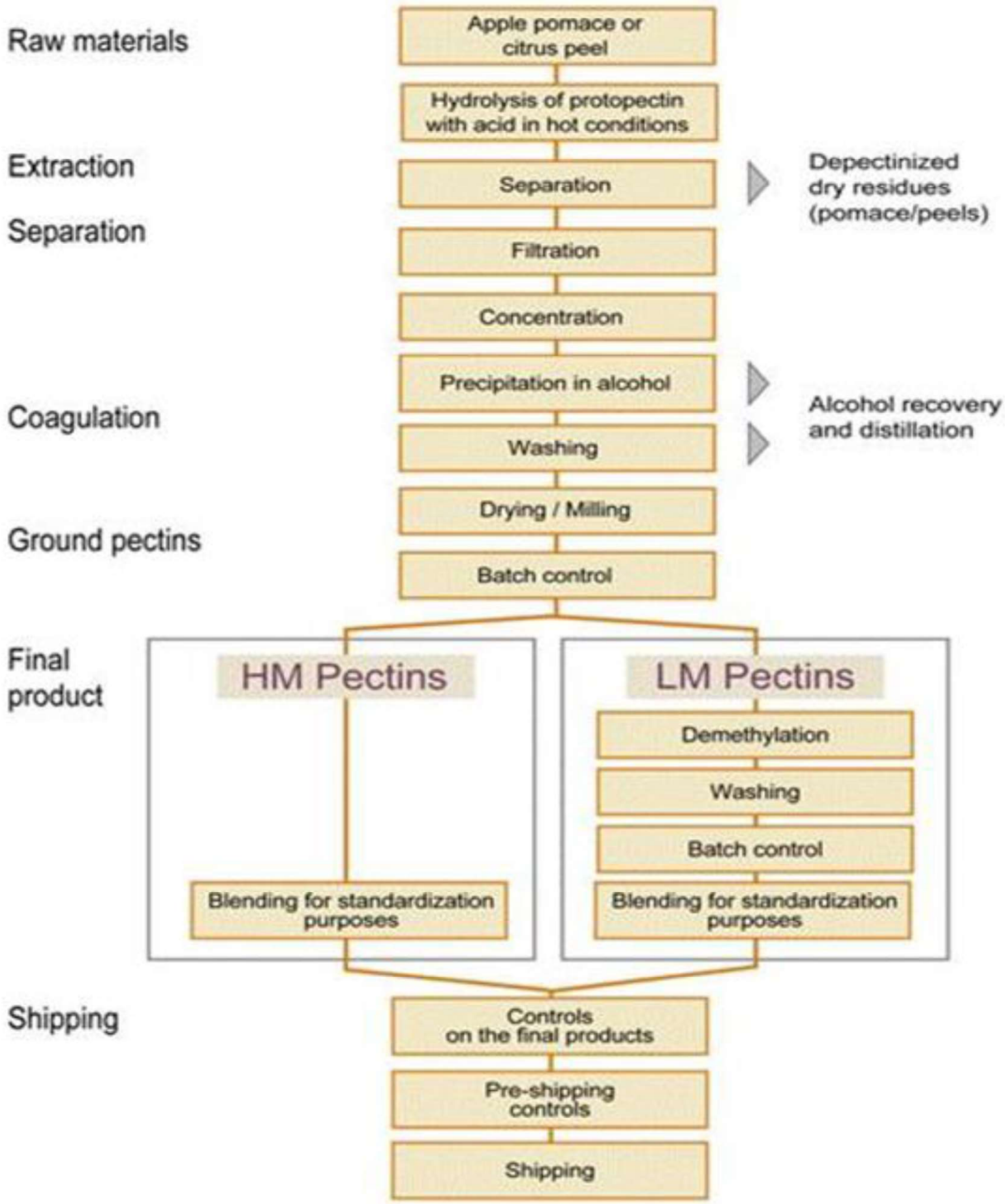

Fig. 17.2 Flow diagram for manufacture of Pectin

****** ☺ ******