**7. Jam Production Technology**

Jam is a viscous product with a porridge-like consistency and spread ability, which is generally obtained as a result of chopping whole, half or small pieces of fruits, grating them and boiling them by adding sugar[7,15].

The fruits used in jam production can be grouped as follows:

* Pome fruit: apple, quince, pear
* Stone fruits: peach, apricot, plum
* Cherry and cherry varieties
* Berries: berries, strawberries, blackberries, raspberries
* Dried fruits: dried apricots, damsons

In recent years, with the effect of local uses, jam making from vegetables and varieties has become widespread. Commonly known vegetable jams are eggplant, carrot and tomato.

Rose jam can be given as an example of the most common flower jams that are known and consumed fondly. Types of jam made from the peel are citrus, watermelon, orange peel, bergamot and green lemon.

**7.1. Preparation of Raw Materials**

The raw material of jam and similar products is fruit and sugar. Although fresh vegetables and fruits are generally used in jam production, sometimes different applications can be made. For example, fresh vegetables and fruits can be processed by various methods (freezing, applying heat, with preservatives) and used later in order to ensure the continuity of production out of season. It is extremely important for the quality of the product to be processed that the fruits and vegetables to be used in jam production are suitable for the purpose, fresh, healthy, high quality and reliable. It is an important detail that the vegetables and fruits to be used in production are harvested in the appropriate period for their intended use[7,15].

The fruit, vegetable, flower or shell to be used in jam production is first washed and prepared for processing. Then they are made ready for cooking by pre-processing such as sorting and separating stems, removing seeds and chopping.

**7.2. Preparation of Additives**

**7.2.1. Pectin**

Pectin, a colloidal carbohydrate compound from the group of pectic substances, is a substance found between cells or in the cell walls of higher plants. It is generally found in most plant tissues and in all unripe fruit in the form of water-insoluble protopectin. As the fruit matures, protopectin becomes water-soluble. Pectin is important in jam and marmalade technology due to its gel-forming properties. Generally, citrus peels (orange, lemon, grapefruit, etc.) and a small amount of apple pulp and skin, and quince are used as raw materials in the production of pectin in the food industry. Liquid or powder pectin is obtained from processed raw materials. Approximately 85-90% of the annual production is used in jam production[85].

There is a wide variety of gum ingredients, but only pectin is used in jam production. The reasons for this are that pectin is the natural component of fruits, forming a characteristic gel and helping to increase dry matter.

All of these products contain pectin-acid gel. In jams made using only low methoxyl pectin, there is a pectin-calcium gel. The texture and mouthfeel of the gel depend on the pectin ratio, pH, sugar type and amount, and gel formation temperature[86].

The following factors are important in forming pectin gel[26,86]:

* Amount and quality of pectin used: In order to form a good gel, 1% pectin should be present in the medium, and the esterification degree of the pectin should be high. The formation of long chains of pectin molecules is necessary for a good gel formation. In addition, it should be soluble in water.
* The pH level of the medium: In the formation of pectin gel, the pH level of the medium must be between 2.8-3.2 for a good gel formation. For this reason, the pH level should be controlled in production, and acid should be added when necessary. If the pH falls below 2.8, the pectin gel is diluted and a sluggish state called syneresis is observed.
* Sugar concentration (dry matter concentration of the medium): In order to ensure a good gel formation, the amount of dry matter in the medium, i.e. sugar, must be kept around 65%.

Some fruits naturally contain high amounts of pectin and acid. When these fruits are cooked with sugar, gel formation is achieved. In order to obtain gel formation from fruits that do not have enough pectin in their structure, additional pectin addition is required[6].



Figure 8 Chemical structure of pectin

Pectin contains galactronic acid linked by an α (1-4) glycosidic bond (Figure 8). In some of these galactronic acids, the hydrogens in the COOH group have been esterified with methyl alcohol and this group has transformed into the COOCH3 form. Depending on the level of this esterification (DE), the gelling properties of pectin differ. This ratio can be changed between 0-100% by modifying the structure of pectin. While DE is 55-80 in high methoxyl pectins, DE is <50 in low methoxyl pectins. Commercial low methoxyl pectins usually have a DE of 20-50 and extremely low esterified pectins precipitate rather than form gels. High methoxyl pectins form gels only in acidic conditions and sugar content above 55%[85-87].

Commercial high methoxyl pectins are divided into groups according to their gelation time[26]:

* Fast gelling: 20-70 seconds (72-75 DE)
* Medium speed gelling: 100-150 seconds (68-71 DE)
* Slow gelling: 180-250 seconds (62-67 DE)

Fast gelling pectins are preferred in jams filled at high temperatures. In this way, the fruits are dispersed throughout the product and form a gel. These pectins can be used if the fruit floats in the syrup. Slow gelling pectin is preferred when the cooked product is cooled to a certain degree and packaged. These pectins can also be used if the fruit is not floating. Type of pectin type also has a relation with taste. At similar consistency, high methoxyl pectin reduces the intensity of flavor more than low methoxyl pectin[15,26,88].

High methoxyl pectins also form gels with sugars and sugar alcohols other than sucrose. For this reason, maltose, high fructose corn syrup, especially starch syrup can be used instead of some sucrose. Thus, cost is reduced, flavor is enhanced and susceptibility to crystallization is reduced[88].

**7.2.2. Acid**

Another substance required for gel formation is acid. Although there are different amounts of acid in the composition of the fruits, the amount of acid coming from the fruit is not sufficient in the production of jam. Therefore, for a good gel formation in jams, acid addition is necessary to keep the pH of the medium within certain limits. Acid is not only used for pH adjustment in jams and similar products. The use of acid is also necessary for the formation of a balanced and pleasing flavor. Generally, citric, tartaric, malic and lactic acid varieties are used in jams. In production, acid is usually added to the product as a solution. When it is added as a solution, it is dissolved by mixing water and acid at a ratio of 1:1. Acid should be added to the product as late as possible so that acid and pectin are not adversely affected by each other during cooking. If inversion is to be performed by adding acid, it can also be added first[7,15].

pH is critical in the formation of pectin gel, especially in high methoxyl pectin. Pectins with a high degree of esterification, that is, fast gelling, gel at higher pH than pectins with a low degree of esterification[85].

* The optimum pH for slow-set pectin is 3.1.
* The optimum pH for rapid-set pectin is 3.4.

In order for pectin to form a gel, the pH must be within certain ranges. This range is 2.8-3.2 for 60-72° brix. Acid is used in jam production to maintain both the pH and the required invert sugar ratio in open cooking. Acid also affects flavor. Acid is usually added at the end of cooking. However, if it is desired to perform inversion with acid addition, it can be added earlier. Acid is usually added to jam as a 50% solution, sugar as powder or syrup, and pectin dissolved in water and added as a 5% solution[7,15].

**7.2.3. Sugar**

It is used in the production of jam, marmalade and jelly to balance the taste and increase the dry matter content. Sugar in the jam recipe[26];

* It increases the amount of dry matter.
* Improves the color and aroma of the product.
* It provides resistance against the microbiological deterioration of the product.

The most commonly used sugar in jam production is sucrose, that is, tea sugar. When only sucrose is used in production, it undergoes inversion by breaking down into glucose and fructose under the influence of heat and acid, and crystallization (sugar) may occur. For this reason, the sugar used in production consists of sucrose and invert sugar, and even the use of some glucose syrup is necessary for the prevention of sweetening and the formation of taste balance. Invert sugar is a mixture of glucose and fructose that is formed in equal amounts by breaking down sucrose (inversion). In jam or marmalade containing a total of 68% dry matter, when invert sugar is 30-35% of the available sugar, no crystallization is observed in the product[7,15,26]. Presence of invert sugar in jam can be achieved by inverting sucrose with acid used during cooking, by pre-inverting and using sucrose, or by using starch syrup containing invert sugar directly[89].

Today, since the cooking process is done under vacuum in modern enterprises, the cooking temperature does not exceed 60-70°C and inversion does not occur at this temperature. Invert sugar must be used in vacuum cooking. Corn syrup is mostly used as invert sugar and its use is increasing due to low cost. Corn syrup is obtained by acid or enzyme hydrolysis of corn starch. Starch has a certain "dextrose equivalent" value, depending on the level of exposure to glucose (or its equivalent)[90-92].

For example, starch;

* Low conversion if 20-28% converted
* Medium conversion if 39-58% converted
* High conversion if 59-73% converted
* If 74-99% is converted, it qualifies as very high conversion.

Regardless of the conversion rate of starch syrups, it is generally 20% water and 80% dry matter. Dry matter consists of different degradation products of starch. The dry matter of a syrup with a dextrose equivalent of 65:

* 65% glucose
* 19% maltose
* 13% triose
* 33% are high molecular polysaccharides.

Of these, only glucose has the property of crystallization. By using starch syrup instead of a portion of sucrose in jam making, dry matter is increased with carbohydrates that do not tend to crystallize[92].

**7.3. Cooking, Filling and Packaging**

Heat treatment is applied with cooking and in this way, the water in the mixture is evaporated and the desired consistency is reached. The positive effects of cooking and post-cooking processes on the product are as follows[7,15]:

* With cooking, the water in the content is evaporated and a viscous product containing the desired level of dry matter is obtained.
* It is ensured that the sugar penetrates the fruit pieces by cooking.
* Inversion of sucrose is provided in cooking.
* Most of the microorganisms are killed by heat and enzymes become inactive.
* Sulfur dioxide removed by heat when processing fruit that has been preserved with sulfur dioxide.

Adverse effects are as follows[7,15]:

* Heat treatment causes some fruits to turn brownish color and accelerate the hydroxymethylfurfural formation.
* Sugar may caramelize with overcooking.
* Loss of aroma can be observed with heat treatment.
* Deterioration may occur due to filling that is not done under appropriate conditions.
* Product quality may deteriorate as a result of not filling at the desired temperature.

Cooking can be done in an open boiler or under vacuum. Modern plants prefer the latter one. In cooking under vacuum, sensory qualities, especially color, are at a high level. In particular, the fruit does not disintegrate and the color does not darken, the amount of hydroxymethyl furfural does not exceed the permitted limits. The main disadvantage of this technique is the high investment cost. In addition, inversion cannot be achieved, the transition between fruit and sugar is low, microbial inactivation cannot be achieved[85,93].

In open boiler cooking, fruits, water and half of the sugar are put in the boiler and mixed. When it boils, the rest of the sugar is added. Pectin solution and acid are added last. If pectin is added at the beginning, the gel-forming power decreases with the effect of heat, and if the acid is added early, inversion occurs more than necessary. Jams cooked in this way are immediately cooled to 85-88 °C.

In vacuum cooking, 5-10% less pectin is required, as pectin degradation does not occur during cooking. The pectin used here should not be fast-gelling pectin because it gels in cooking, or the pectin should be added at the end when the temperature rises above 80 °C. In cooking, fruit, sugar, acid and water are mixed in the pre-mixing vessel. The temperature is increased to 60-65 °C. Then it is taken into a vacuum boiler, cooked in a vacuum of 650-675 mm Hg at 60 °C until the final brix. When the cooking is finished, the vacuum is removed and the temperature is increased to 85-88 °C while adding the pectin solution.

**7.4. Production Defects in Jam and Causes**

Some defects that can be seen in jams and their causes are as follows[7,15,26]:

* Extremely hard structure: Fluidity is important in jam production. An excessively hard structure may occur as a result of the product losing its fluidity. The reasons for the formation of an extremely hard structure are the excessive amount of pectin used, the increase in the amount of dry matter due to the prolonged cooking time and the low pH level.
* Extremely soft structure: If the product is more fluid than it should be, it is expressed as an extremely soft structure. The reasons for the formation of excessive soft structure are the less amount of pectin used or it does not dissolve well, the amount of dry matter is insufficient, the use of stale pectin, the incorrect pH level, the filling made at a very low level, the packaging too shaken without sufficient gelation in the filled product, and the hot filling to large packagings.
* Bleary liquid structure (sineresis): It is the case where the product fluidity is excessively watered and liquid. The reasons for the formation of watery liquid structure are low dry matter ratio due to insufficient evaporation, insufficient use of pectin or incomplete dissolution of the used pectin, low pH level, pectin fragmentation due to long cooking, pectin being stale and excess calcium in the product.
* Crystallization: It can be seen in the product in the form of crystallization (sweetening) over time. The reasons for the formation of crystallization are the formation of glucose crystals due to excessive inversion, excessive addition of glucose, higher brix than normal, keeping the product in extreme cold, and the delayed sucrose crystallizing in package because the low inversion at the beginning.
* Separation of fruits: As a result of weak gel formation due to various reasons, use of pectin that forms a slow gel, filling at a very high temperature and keeping the pH level high, the fruit pieces in the product may be collected at the bottom or the top.
* Color change: The reasons of darkening after production are sugar caramelization due to long cooking time, low quality of the fruit or pulp used in the production, metallic contamination and darkening in the center parts as a result of incorrect filling in large packages.
* Hardening of the fruit pieces: As the water used in pre-cooking is hard, especially in jams made from citrus peels, the fruit pieces get a hard structure as a result of not or unsufficient pre-cooking peels in water.
* Microbiological deterioration: Molding or fermentation may occur in the product due to less dry matter amount, filling made at low temperature, poor quality of the fruit, faulty sealing and contamination for any reason.