FRUIT PRESERVES AND JELLIES

1. Introduction

The fruit preserve and jelly categories are certainly a major milestone in food evolution. Their history dates back to ancient times, when a confection or a dessert has been documented as a part of the meal. The use of sugar widened the possibilities for preserving fruits. In fact, during colonial times, a jam sometimes formed while fruit was being boiled. This jam or gel formed when the correct proportions of pectin, sugars, and acids occurred. Jam and jelly production was once considered an art; now it is a science. More is known about the components necessary to produce this kind of gel. This knowledge has led to other applications such as stabilized fruit fillings and sauces, processed fruit juices, canned fruits, and frozen desserts and confections.

2. Definitions and Standards

The name preserves covers a broad range of products, including jams, butters, marmalades, and conserves, as well as ordinary preserves. Preserves contain the largest fruit pieces, whereas jams contain smaller pieces that are crushed or chopped with added acid. Fruit butters are made of fruit pulp cooked to a smooth consistency. They are pressed through a coarse strainer and are more concentrated than jams. Scorching can be a problem because of their high viscosity. Marmalades have the characteristics of both jellies and preserves. They contain thin citrus peel or fruit pieces and are chiefly made from citrus fruits, alone or in combination with other fruits. Conserves are similar to jams, except that two or more fruits are cooked together and raisins and nuts can be added. Jellies are in a class by themselves. They are clear sparkling spreads in which fruit juices as the source of flavor, and, in some cases, the thickening agent.

The Federal Standards and Definitions do not differentiate between preserves and jams (1,2). A preserve is minimally 45 parts prepared fruit with 55 parts of sugar and is concentrated to 65% or higher solids, resulting in a semisolid product. Jellies are similar to preserves, with 45 parts of clarified fruit juice and 55 parts of sugar, resulting in a minimum of 65% solids. Both categories can utilize a maximum of 25% corn syrup for sweetness as well as pectin and acid to achieve the gelling texture required. Fruit butters are prepared from mixtures containing not less than five parts by weight of fruit to two parts of sugar.

3. Gelation-Pectin Mechanism

3.1. Typical Gel Formations. Gelation, the formation of the polymer network that gives commercial fruit preserves and jellies their texture, depends on four essential ingredients—pectin, sugar, acid, and water—added in the correct proportions. A pectin gel is a system resembling a sponge filled with water. This polymer is in a partially dissolved, partially precipitated state. The chain molecules are locally joined by limited crystallization, forming a three-dimensional network in which water, sugar, and other solutes are held. Some fruits such as tart apples, red and black raspberries, oranges, and cranberries have enough pectin and acid present. Still others, such as ripe apples and plums, contain sufficient pectin but lack enough acid. Pectin or acid must be added when using most fruits. Sugar is always needed when high-methoxyl pectin is used.

Since fruits vary widely with regard to maturity, climatic conditions, and storage, it can be difficult to ensure the proper composition. Fruit should be picked just before processing to ensure taste and texture. It should be picked as ripe fruit in the early morning to ensure quality. Overripe fruit will have reduced sugar quality, and the pectin will suffer molecular breakdown from enzyme activity. If fresh fruit is not available, frozen, cold-pack, or canned fruit can be used for jams and preserves.

The juice of grapes, currants, lemons, sour oranges, and grapefruits contains sufficient pectin and acid for jelly manufacture. Strawberries, rhubarb, and apricots usually contain sufficient acid but may lack pectin. On the other hand, sweet cherries and quinces may lack acid yet have enough pectin. Commercial pectin, either liquid or powder, can be added as a supplement. The viscosity of a fruit juice is an index of its gelling power.

Pectin is found in the flesh, skins, and seeds of most fruits. It can be extracted when fruit is boiled. Pectin is a complex carbohydrate consisting of polygalacturonic acid chains having a wide variety of molecular weights. The chains contain some carboxyl groups that are partially methylated, forming the ester known as pectin.

Generally, a degree of methylation (DM) of 50% divides commercial pectin into two main groups: high-methoxyl (HM) pectins and low-methoxyl (LM) pectins. The LM-pectin group includes both conventional and amidated versions. The HM pectins are the predominate choice for the standard jellies and preserves. The LM pectins can be utilized in low-sugar fruit spreads.

The degree of methylation of pectin has a critical influence on the solution and gelation characteristics of preserves and jellies. The highest DM that can be achieved by extraction of the natural raw material is about 75%. Pectins of DM ranging from 0 to 70% are produced by de-methoxylation in the manufacturing process.

The DM of HM pectins controls their relative speed of gelation; hence, the terms slow-set and rapid-set HM pectin. If a higher degree of methylation of pectin is used, the higher will be the pH required for a fast set. A fast set is necessary to suspend fruit pieces and prevent fruit flotation or sinking. A slow set is necessary for a clear jelly, so that air bubbles are removed. The pectin's quality is standardized on the basis of its 150° standard, which means that, under controlled conditions, 1 lb of 150-grade pectin will gel 150 lb of sugar. This method is known as SAG.

Another method for testing pectin gels is the Voland-Stevens LFRA texture, analyzer in which the gel's elasticity is exceeded. The Tarr-Baker gelometer was the original jelly strength tester. However, after it was discontinued in 1965, the Voland-Stevens analyzer was declared an acceptable replacement because of its operational similarity, portability, compactness, reproducibility, and ease of use and calibration (3). This flexible instrument can be attached to a printer to measure elasticity and other attributes of a gel. This method is comparable to the SAG method.

Jellies are usually produced at a pH of 3.1 and jams at 3.3. HM pectin can gel sugar solutions with a minimum of about 55% soluble solids within a pH range of approximately 2.0 to 3.4. For any soluble solids with a value above 55%, there is a pH value at which gelation is optimal for a particular HM pectin and a pH range within which gelation can be controlled.

Sugars have a general dehydration effect on HM-pectin solubility. At higher solids values, there is less water available to act as a solvent for the pectin. Hence, there is an increased tendency to gel. Because gelation relies on the proper balance of soluble solids and pH in the medium, it is possible to compensate for a reduction in soluble solids by reducing the pH. Any HM pectin can gel rapidly or slowly and the rate can be controlled by the soluble solids and pH.

An attempt was made to quantify fruit content in jams by combining chemical, composition data, particularly the inorganic elements that are stable to processing such as ash, magnesium, and potassium, with the rheological forces such as yield stress and flow index in a regression analysis that could explain 90% of the variability in fruit content (4).

3.2. Novel Gel Systems. The typical manufacturing methods for jams and jellies use the four necessary components: fruit, pectin, sugar, and acid. Some combination pectin sources have been devised. In one (5), an emulsifier is added to the sugar surface and blended with the bulk of the sugar. A very fine pectin is then mixed with acid and combined with the emulsifier-sugar complex. The emulsifier acts not only as a glue, causing the fine pectin particles to adhere to the sugar surface, but it also acts as an antifoaming agent and a dispersing agent in the final gel production.

Another convenient product, one-step pectin gelling composition, has been developed (6). Pectin particles are mixed with moistened coarse sugar particles. Acid may be added in a dry form and will adhere to the sugar, or it can be predissolved in water and sprayed onto the mix. Much less pectin can be used in this method as compared with dry blending fine pectin, acid, and sugar. This is due to the use of larger sugar particles and smaller pectin particles, so that the pectin dissolves faster while the concentration of dissolved sugar solids is retarded.

Instant pectins are technologically optimized pectins with better dispersion and solubility properties. They dissolve rapidly even at low temperatures and work into jam mixes without prior mixing with sucrose or corn syrup (7).

The LM pectin offers another gel formation method for preserves and jellies. However, the gel formed does not conform to the federal standard of identity. The use of this pectin does result in reduced-sugar jams, jellies, and preserves, the LM-pectin group includes both conventional (acid demethuylated) and amidated types. These pectins require calcium ions for gelation, not sugar or acid.

The gelation of LM pectin is controlled primarily by the reaction of a divalent cation with the acid groups of the pectin chains. LM pectin can be used at solids levels as low as 10%. The pH range for LM pectin is 3.0 to 6.0

because the role of acid is minimized. For successful gelation to occur, 50 to 100% of the acid groups must be complexed with calcium. The amidated pectin, which has fewer free acid groups, requires less calcium for gelation and relies on hydrogen bonding between the amide and free acid groups. Amidated pectins form gels that are more rigid than those formed with conventional pectins. Conventional pectins produce a thickening effect and are aptly used for jams and preserves; amidated pectins are used for jellies.

4. Carbohydrate Sweeteners

In HM-pectin systems, sugar accounts for more than 50% of the total weight and 80% of the total solids in a jam. It contributes solids; maintains microbiological shelf life; provides sweetness, body, and mouth-feel; contributes to gelation; and adds color and shine to the jam.

Other sugars that can be used are glucose syrup, dextrose, invert sugar syrup, and honey. When other sugars are substituted for sucrose in jam, the effects on the HM-pectin gelation are as follows:

- Inversion of sucrose reduces gel strength and lowers the gelling temperature.
- Glucose syrup usually reduces the gel strength. High-dextrose-equivalent (DE) glucose syrups decrease gelling temperature; regular-DE syrups increase it.
- Sugar alcohols such as sorbitol and xylitol are used in dietary products. Sorbitol jams can be made with HM pectin, soluble solids of 65%, and a pH of 3.0 Xylitol has limited solubility. At the 39% limit of solubility, gelatin with HM pectin can be obtained when the pH is lowered to 2.7.
- Maltitol syrups are used in the manufacture of sugar-free jellies. Suitable selection of the maltitol content needs to complement the acidified and nonacidified gelatin to deliver the appropriate applications (8).

A study was developed to compare some effects of gelling agents and sweeteners in high- and low-sugar-content carbohydrate gels (9). HM pectin, LM pectin, carrageenan, and alginate gels were the gelling agents, while sucrose and high-fructose corn syrup (HFCS) were the sweeteners. Soluble solids ranged from 35 to 65% with polydextrose as the bulking agent. The properties compared were bound water, water activity, syneresis (35% soluble solids), closely simulated HM-pectin gels because of the comparable spreadability properties. The water-binding property of sucrose exceeded HFCS with most gel systems, except where a combination of LM pectin and carrageenan was used. The water binding served as an index for predicting syneresis, or weeping; spreadability; and shear. However, a synergy of carrageenan with pectin or alginate with pectin resulted in increased bound water compared with individual gums.

Another study to improve nonsugar jam systems used the addition of xylitol or saccharin to veltol to improve the color and taste of apricot jam with minimal changes during storage (10). The use of aspartame in fruit spreads was minimally documented until its stability and effectiveness were measured in 1986 (11). A high-performance liquid chromatographic method was the quality control tool for monitoring levels of aspartame. This study predicted an average half-life of 168 days for aspartame in a fruit spread kept at 25°C. It occurs only at higher temperatures.

Studies on the preparation of acceptable low energy jams using different formulas of sucrose substitutes have been ongoing. The main focus of some studies was in the use of these low energy jams for diabetic foods (12). One study showed that it was technologically possible to prepare acceptable, high nutritional diabetic and low energy apricot, guava, and strawberry jellies and jams using xylitol–sorbitol–aspartame and xylitol–fructose (13).

Gel strength and gelling temperatures of both amide and conventional LM pectins are influenced by the type of sugar used in the gel. Gels prepared with HFCSs have significantly lower gel strengths at all calcium levels than gels prepared with sucrose. However the use of 42- and 62-DE corn syrups give higher gel strengths than sucrose in LM-pectin formulations.

5. Processing Techniques

5.1. Traditional Process. The traditional process used for preserve and jelly manufacture is the open kettle, batch boiling technique. The boiling process, in addition to removing excess water, also partially inverts the sugar, develops the flavor and texture, and destroys yeast and mold. In jelly manufacture, the fruit is boiled to extract the pectin and destroy the pectin-hydrolyzing enzymes. The juice is then separated by straining or pressing, and the press cake is boiled with more water to obtain more pectin. Pectin deficiency is remedied by the addition of commercial pectin. Added pectin needs to be dispersed with sugar to ensure uniform distribution. Either liquid or dry sugar is added.

A second boiling step is necessary to concentrate the juice to the critical point for gel formation of the particular pectin–sugar–acid system being used (14). Extended boiling causes acid volatilization, pectin breakdown, and losses in flavor and color. Vacuum concentration (50–60°C) produces a higher-quality jelly than atmospheric pressure boiling (105°C). Small vacuum pans are used since there is a more favorable heat transfer area to reduce heat (15). A refractive index reading indicating soluble-solids content is the point at which the concentration stops. A flow diagram for these processes can be found in Reference 16.

The pH of the jelly will determine the set temperature of the pectin. The setting temperature of a jelly at pH 3.0 can be lowered approximately 10°C with rapid-set pectin or 20°C with slow-set pectin by decreasing the acidity to pH 3.25 (17).

For preserves and jams, the same procedure is used except that the fruit pulp is not strained. Rapid-set pectin is preferred to suspend the fruit more evenly and to minimize setting out.

Both products are packed hot, at about 85°C, into containers that are then sealed. Hot sterilized jars with hot sterilized lids and caps can also be used. Once filled, the jars are turned over to heat the lids and then returned to the upright position. The hot water bath technique can be a water bath and boiled from 5 to 15 min, depending on the fruit. This is a better method for deterring mold growth for fruit preserves and jellies. The U.S. Department of Agriculture (USDA) sanctions the use of paraffin or a two-piece metal lid and screwband for sealing jellies, but it highly recommends processing them for extra safety precaution. Recent literature states that jelly jars and paraffin are no longer recommended. An incomplete seal could lead to contamination (18).

The continuous process utilizes a premix for its efficiency. The APV system uses a plate evaporator for jellies. The Alfa-Laval system uses a scraped-surface heat exchanger for preserves because of the fruit pieces involved. The soluble-solids content or Brix degree is monitored by either an in-line unit or an automatic unit with electrical feedback to control the evaporator (19,20).

The filling temperature for these processes should be 85 to 95°C. This will ensure proper setting, fruit distribution, and a sterile product. A rotary multiple-piston displacement machine is used for filling. Speeds range from 100 to 600 jars per minute. Jars are washed and preheated before filling. Capping occurs immediately afterward, ensuring a vacuum seal.

The pack will be sterile in most cases if it is filled at not less than 85°C and capped using a steam flow closure. If a steam flow closure is not used, the sterile pack will require the use of a steam-sterilizing unit to cool it. Jars can be cooled continuously using water sprays of about 60°C to avoid thermal shock. Subsequently, 20°C water is used to finish this process. The jar temperature should be above ambient. The vacuum seal is check by a nonvacuum detector to ensure a hermetic seal. Jars are passed through a visual inspection point to locate and remove jars with unfavorable attributes such as foreign material, floating fruit pieces, and bubble formation. The jars are then passed to labeling machines, packed in cases or trays, and shrink-wrapped.

The order of addition of ingredients is very important. As in vacuum cooking, a slow-set pectin is preferred to limit the change of preset with the pectin. Most manufacturers use pectin solutions that are easily prepared and dissolve much more effectively than powder. The pectin solution can be added before or after concentration of the batch. Addition of the pectin after concentration results in a faster cooking rate due to the lower viscosity of the batch during concentration. For jelly manufacture, it is best to add the pectin solution before cooking is completed. The addition of 15 to 25% corn syrup deters crystallization from occurring due to sugar inversion resulting from low-temperature vacuum cooking (21). Low-sugar jams require less cooking than jellies and can use larger quantities of HM pectin to improve gel quality.

5.2. Modern Processing Techniques. A process to replace canning has been developed in Sweden by Alfastar (19). This multitherm process is said to preserve food for several months without chemicals as well as to achieve a fresher-tasting product. The process is rapid, with even heating through the product. The processing temperature is 150°C and can be reached in less than a minute.

The use of enzymes has made the process more efficient. Serum separation can be reduced by using an effective amount of pectin esterase to the aqueous phase and incubating it in the presence of divalent cations (22).

Another modern technique being used today includes extraction of pectin by pretreating the fruit in an electromagnetic field of superhigh frequency (23).

The microwave oven is the latest method for processing jams and jellies for the homemaker (16). An oversized container must be used for this process to avoid boiling over. Fruit, sugar, and some butter are mixed and allowed to stand for 30 min. The butter will help to deter the frothiness that may develop. The mixture is microwaved until it boils, with frequent stirring. It is then cooked for 10 to 13 min more in the microwave. Jams produced from this mixture keep well in the refrigerator for several months. They can also be canned for greater safety.

The no-cooked freezer jams are by far the easiest of these processing techniques. The fruit is mixed with an appropriate amount of sugar. This technique does not rely on pectin as much, because pectin is not heated to form the gel bonding that cooking at high temperatures creates. Lemon juice, if any, is added to the pectin, and then stirred into the sugar–fruit mix. The mixture is placed in sterilized containers and covered with two-piece metal lids and kept at room temperature for 24 h before placing in the freezer. Once opened, it can be stored up to three weeks in the refrigerator.

6. Quality Parameters

The overall quality of fruit preserves and jellies has increased because of improvements in processing techniques, increased knowledge of fruit characteristics, and competitive situations. Fruit quality control is most important because it affects flavor, odor and color of the preserves and jellies.

The following criteria are important for manufacturing a quality product:

- Fruit appearance, ripeness, and solids must be optimized.
- Fruit juice must be clarified properly to ensure a clear jelly.
- Appropriate pectin grade, 120 to 200, must be used.
- Sugar assay and appearance must be appropriate.
- Corn syrup buffering capacity, solids, and appearance must meet minimum specifications.

Processing must be monitored in the areas of appearance, flavor, color, viscosity, pH, and solids. Powder pectin use results in a dark, rich color and stiff gel. In contrast, liquid pectin, which is less concentrated, makes a less stiff product. Typically, high-DM pectin must be conditioned to increase its set time and to optimize the DM. This pectin follows first-order kinetics in its stability.

Jelly quality attributes are similar to those of jam except that jelly is clear and bright, does not contain fruit pieces, holds its shape when unmolded, and cuts easily with a spoon. A stiff jelly is so firm that the mold will retain the mold shape.

Some problems that can occur are the following:

Cloudy jelly. Unclarified juice, underripe fruit, or pouring so slowly into containers that gelling occurs can result in a cloudy jelly.

Color changes. Darkening at the top of the jars can be caused by storing them in too warm a place or by an imperfect jar seal.

Color fading. Fading can occur with red fruits if they are stored in too warm and too bright areas or stored too long. The natural colorants in the fruit are highly susceptible to high temperatures and light. Another possible cause of color fading could be that the processing was not sufficient to either destroy the enzymes that can affect color, or that the processing time elevated the temperature, causing color destruction. Trapped air bubbles can also contribute to the chemical changes caused by oxidation.

Crystal formation. An excess of sugar can "seed" the jelly when HM pectin is used. This excess sugar comes from overcooking, too little acid, or from undercooking the recipe. Tartrate crystals can form in grape jelly, if juice is left to stand in the cold for several hours before being used. Moreover, if the glass interior is scratched, seeding can occur.

Floating fruit. This can result either from undercooking or from not driving off enough water to create the viscous gel necessary to maintain even fruit distribution. Fruit pieces not properly cut or not ripe enough can also lead to floating fruit.

Gummy jelly. Gummy jelly can result from overcooking and creating invert sugar.

Mold. The appearance of mold can be the result of imperfectly sealed jars and airborne contamination, if the full sugar complement was not used. The water activity created makes a favorable environment for contamination from the jars if they were not properly sterilized or simply underprocessed. A change in the appearance and off-odor or fermented smell will not necessarily occur. However, mold is often seen before taste is affected.

Weeping jelly. Syneresis in jelly can be overcome by not overcooking, not storing in a warm place, and using the appropriate amount of pectin or acid.

Stiff or tough jelly. Overcooking or using too much added pectin delivers a tough jelly.

Jelly failures. An improper balance has occurred when a gel is not formed. Inaccurate measurement, insufficient cooking, overcooking, or increasing the recipe prevents the pectin from building its network.

In a study (24), reduced boiling time improved both the aroma and flavor of fruit preserves. However, it was noted that the retention of flavor and color can be protected during the shelf life by means of modified packaging and appropriate storage practices, thus eliminating light and oxygen and storing at 15°C.

7. Trends

Economic data for jams and jellies is not reported on a regular basis since it is such a small part of the huge fruit and nuts market. However, the jam, jelly and preserve sales in supermarkets reached $\$1.6 \times 10^9$ in 2001, which was a 4.6% increase than the previous reporting period (1999) (25).

The upscale market shows the greatest potential for growth. Gourmet fruit spreads, pre-serves, jams, and jellies, including more imports and exotic flavors, are the new products. The nutritional and health benefits take the forms of less sugar and more fruit; no sugar is added because high-sugar fruit juice is used instead of 100% fruit (22,26). A more convenient packaged powdered pectin has sugar added to it to be used as a sugar and pectin mix for preparing jams and jellies at home.

Newer products reported in the literature include a fruit spread using a pre-served powder that can be stored at room temperature, and comes in low fat and low sugar version (27); and a squeezable fruit sauce that contains less 50% fruit, water, sweetener and pectin plus thickeners (28).

Food safety overseers in several U. S. states are cited as saying that more people are dabbling in selling homemade food products, including jams. Rules vary from state to state. Homemade jams are considered low risk, but overall food safety is gaining more attention as recent highly publicized food poisonings have been reported (29).

The packaging revolution has also affected this market in the form of squeezable plastic containers for convenience, trays and containers of layered foil materials that add longer shell life to products, and contemporary designs, plastic jelly jars and lids featuring.

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