

6 Fruit Preserves and Jams

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6.1 INTRODUCTION

Historically, jams and jellies may have originated as an early effort to preserve fruit for consumption in the off-season. As sugar for their manufacture became more affordable, the popularity and availability of these fruit products increased (Anon., 1983). Jellies, jams, preserves, and marmalades are primarily distinguished by the form in which their fruit component is incorporated. In jellies, only strained fruit juice is used, while jams are made with crushed or ground fruit material. Preserves are made with whole fruit (if sufficiently small) or large pieces of fruit (Ahmed, 1981). Marmalades are basically clear jellies in which slices or shreds of (usually) citrus peel are suspended. Regardless of their form, all are sugar–acid–pectin gels or low-methoxyl pectin–calcium gels. Their structure, appearance, and mouthfeel result from a complex interaction between pectin level and functionality, PH, sugar type and content, setting temperature, and, in the case of low-methoxyl pectin gels, calcium content.

Originally, jam or jelly production relied on the native pectins of incorporated fruit for gel formation. Fruit was cooked with sugar, extracted acids, and pectins, and if the proper balance of sugar level, pH, and pectin content were achieved, a satisfactory jelly was obtained; however, modern manufacturing requirements for uniform gel strength and appearance preclude reliance on fruit component pectins, which may vary in content and quality, depending on fruit maturity and variety. In spite of the current availability of other gelling agents, pectin remains the universal

choice for jams and jellies, in part because of its presence as a natural fruit ingredient and also because of the characteristic consistency that pectin imparts to a gel. Pectins of known quality and gelling capacity (usually derived from citrus or apple by-products) are added to jelly and jam formulations to achieve a desired gel strength. It is estimated that 80 to 90% of commercial pectin production, which totals 6 to 7 million kg, is used in the production of jellies and jams (Crandall and Wicker, 1986).

Although the basic steps in the production of jams remain the same, there is a continuous demand for improvement in processing performance and product quality. Important aspects to consider include close cooperation between preserve manufacturers and engineers to meet changing consumer preferences (e.g., preserves with higher fruit content or low-sugar jams), optimization of the preserve and jam manufacturing process, new developments in processing equipment and automatic controls, and strict sanitation controls.

The next section gives an updated account on pectin and gelation.

6.2 PECTIN

6.2.1 PECTIN STRUCTURE

An understanding of pectin structure is a prerequisite to defining its role in gel formation, and much research has focused on elucidating the finer points of this molecule's primary, secondary, and tertiary structures. Pectin is a plant cell-wall polysaccharide consisting of a linear chain composed of D-galacturonic acid residues linked via $\alpha(1-4)$ -glycosidic bonds. At intervals in this homogalacturonan chain are regions in which the polymer backbone consists primarily of alternating units of galacturonic acid and rhamnose (Toman et al., 1976). Such regions are described as "hairy," because, within these areas, short side chains of xylose occur, interspersed with larger, more elaborately branched side chains of arabinose and galactose. Approximately 95% of pectin's galacturonic acid residues are located in the "smooth," or homogalacturonan, regions (de Vries et al., 1986). Xylose residues in the hairy regions are primarily attached to galacturonic acid residues, while most galactose side chains are attached to rhamnose residues of the backbone (Schols et al., 1990). These arabinogalactan-rich regions are located at regular intervals along the pectin chain, but this regularity may vary depending on the pectin source. Recent work suggests that the hairy regions of apple pectin comprise, at least in part, smaller repeating units (Colquhoun et al., 1990). In commercial pectins, rhamnose and pentose linkages of these hairy regions may be partially hydrolyzed by acids used in extraction (de Vries, 1988; Mort, 1993a).

As a long-chain polymer, pectin's molecular weight (MW) may vary widely, depending on source and method of extraction. Its MW is also susceptible to reduction by chemical, enzymic, and even physical treatments. Average MWs of commercial pectins may range from 5×10^4 to 1.8×10^5 (Ahmed, 1981; Fishman et al., 1991; Smit and Bryant, 1969), but milder extraction procedures can yield pectins of considerably higher MWs (Kontominas and Kokini, 1990; Miyamoto and Chang, 1992). In addition, pectin is an association colloid and can aggregate to form even larger macromolecular-sized units (Fishman et al., 1992).

Galacturonic acid residues of the pectin backbone are esterified to varying degrees, usually with methanol; the extent to which this occurs is referred to as the degree of esterification (DE) or methoxyl content. There is some evidence of a repeating structure in the distribution of these sites as well, with a suggested repeating unit of five esterified galacturonate residues and one free acid residue (de Vries, 1988). This would imply a DE of 83% for unaltered intercellular pectin; however, extraction and processing of pectins alter these *in situ* ratios, such that commercial pectins may range from 20 to 70% DE. Certain pectins may be naturally low in ester content, such as those from cotton cell cultures (Mort et al., 1993b) or sunflower head residues (Miyamoto and Chang, 1992).

Recent studies have claimed that esterified residues in pectin are randomly distributed (Garnier et al., 1993; de Vries et al., 1986) or nonrandomly distributed (Mort, 1993a, 1993b). Using liquid hydrofluoric acid (HF) solvolysis to cleave cultured cotton cell pectin at the rhamnose inserts of the pectin backbone, Mort (1993a, 1993b) isolated two homogalacturonan fractions, one approximately 40% esterified and the other 10 to 15%. Isolation of residues differing in esterification suggested a nonrandom distribution in the original pectin. However, ion-exchange chromatography showed a random distribution of charge in a citrus pectin that had undergone acid-catalyzed deesterification (Garnier et al., 1993). Such disparate findings may, in part, be due to the length of galacturonate residues being examined or to differences in pectin source.

From the above discussion, it should be apparent that pectin is an extremely heterogeneous material and any discussion of pectin's molecular weight or degree of esterification refers only to the average for the molecular species present in solution. Such average values alone will not define the functionality of a particular pectin. Different methods of preparation may result in pectins identical in average MW or DE but with differing MW and DE distributions, which will, in turn, confer entirely different properties (Baker, 1979).

6.2.2 PECTIN AND GELATION

Pectin gels have been aptly described as intermediate between a solid and a liquid state, consisting of a three-dimensional network of pectin immobilizing the aqueous component (Oakenfull, 1987). The solvent water, pH, and accompanying cosolutes (usually sugar) influence the intermolecular forces contributing to gel structure; conversely, the gel structure prevents the aqueous phase from separating. In high methoxyl pectin solutions, gelation occurs via noncovalent bonding between adjacent polymer chains, with both hydrogen bonding and hydrophobic interactions between juxtaposed chains contributing to formation of junction zones (Oakenfull, 1987). Bonding between adjacent pectin chains occurs primarily at these junction zones, which can range from 18 to 250 galacturonic-acid units (Oakenfull and Scott, 1984). Although hydrogen bonding in a higher methoxyl (70% DE) pectin is approximately double that of the hydrophobic contribution, hydrogen bonding alone is insufficient to initiate gelation. Thus, hydrophobic interaction between adjacent ester methyl groups, which is enhanced by cosolutes such as sucrose, is essential to gel formation (Oakenfull and Scott, 1984). More recent work with high-methoxyl pectin gels utilizing ethanol, 1-butanol, and dioxan as cosolutes confirmed the dependence of junction-zone formation on hydrophobic interactions (Brosio et al., 1993). Although formed by noncovalent bonds, these junction zones can be of sufficient strength to prevent gel melting without polymer breakdown (May and Stainsby, 1986).

6.2.3 EFFECT OF METHYLATION ON FUNCTION

Of the features influencing pectin gelation, the degree of esterification may arguably be the most significant. Pectins can be modified chemically to produce a continuum of esterification levels, from 0% (pectic acid) to almost 100%. In practical terms, for food use, the upper limit of esterification in commercial pectins is set by the naturally occurring ester content of pectin in the raw material source. Although raw material origin may provide an upper bound to esterification levels, both DE and gel-forming capacity of pectins can be altered by extraction time, temperature, and pH (Woodmansee and Baker, 1954; Aravantinos-Zafirios and Oreopoulou, 1992). Pectin functionality is altered by changes in DE, and a broad distinction is made between high-methoxyl pectins (DE values from 55 to 80%) and low-methoxyl pectins (DE values below 50%); however, it should be understood that this is an arbitrary distinction, and pectins with DE values near 50% will display features intermediate between those of high and low DE values. Commercial low-methoxyl pectins usually have DE values ranging from 20 to 50% because pectins with excessively low DE will precipitate rather than gel.

High-methoxyl pectins gel only under acidic conditions and when the sugar (sucrose) content is at least 55% (Oakenfull and Scott, 1984). Low pH suppresses dissociation of free carboxylic acid groups, reducing their electrostatic repulsion (Watase and Nishinari, 1993), whereas sugars stabilize hydrophobic interactions between the methyl ester groups (Oakenfull and Scott, 1984; Brosio et al., 1993; Rao et al., 1993). Junction-zone size and the standard free energy of gelation increase as the degree of esterification increases, being proportional to the square of the DE (Oakenfull and Scott, 1984). As pectin ester content is lowered to 50%, jelly strength increases, but only at progressively lower pH values (Smit and Bryant, 1968).

Commercial high-methoxyl pectins are further divided into rapid set (20 to 70 sec), medium set (100 to 150 sec), and slow set (180 to 250 sec) categories, depending on the time required for a gel to form under standard conditions. Gel-setting time is a function of DE, with rapid-set pectins possessing a DE of 72 to 75, medium-set pectins a DE of 68 to 71, and slow-set pectins a DE of 62 to 66 (Crandall and Wicker, 1986). Such distinctions are of value in processing where speed of gelation can influence product quality. Rapid-set pectins are useful in the manufacture of jams and ensure uniform dispersal of fruit pieces and prevent floating. When flotation of fruit is not a problem, such as in clear jellies, then slow-set pectins are preferable because they allow entrained air bubbles to rise before gelation.

Esterification levels of pectins can also have an effect on the flavor perception of jellies. For a substance to be tasted, it must contact the taste buds; therefore, if a gel delays diffusion of the substance (flavor) to the taste bud surface, taste perception may be controlled not by the taste reaction but by diffusion. Guichard et al. (1991) found that, at similar gel consistencies, high-methoxyl pectin reduced taste intensity more than low-methoxyl pectin.

6.2.4 LOW-METHOXYL PECTINS

Low-methoxyl pectins, those with DE of 50% or less, are also able to form gels but by an entirely different mechanism than that described previously. These pectins do not require high levels of sugar or low pH to initiate gelations, but gel in the presence of divalent cations such as calcium. Such divalent cations form associations between sequences of charged species on adjacent chains. As stated earlier, pectins with DE in the upper range of this class (45 to 50% DE) exhibit properties intermediate between high- and low-methoxyl pectins; that is, they can also form acid-sugar gels (Smit and Bryant, 1968). However, the low pH requirements for such gels preclude their use in most foods. Low-methoxyl pectins with DEs near the upper limit of the range require some sugar for gelation, a further indication of their intermediate properties (Oakenfull, 1987). Low-methoxyl pectin's ability to form gels with less sugar content allows the production of dietetic jams or jellies, whereas their ability to gel with calcium at higher pH enables them to produce gels in acid sensitive foods such as milk.

The free carboxyl groups available on the galacturonic acid residues of low-methoxyl pectin may form calcium bridges (Figure 6.1) with adjacent pectin polymers. This results in a stronger gel network and firmer structure, and less occurrence of syneresis.

Low-methoxyl pectins can be generated from high-methoxyl pectins by various treatments, including acid-, base- or enzyme-catalyzed deesterification. Acid-catalyzed deesterification can be done simultaneously with initial extraction of pectin from the raw material source (Woodmansee, 1954). Such treatment tends to lower the MW of pectin, but methods have been developed to produce high-MW, low-DE pectins (Wiles and Smit, 1971). In addition, some sources of pectins (e.g., sunflower) are naturally low in DE, and careful extraction of these pectins provides high-MW, low-DE pectins (Chang and Miyamoto, 1992; Miyamoto and Chang, 1992). While acid- and base-catalyzed deesterification tends to randomly remove methyl esters, enzyme-catalyzed deesterification with pectin methyl esterase cleaves esterified sites nonrandomly, producing blocks of completely deesterified galacturonic acid units interspersed with unmodified original material. Activation energies for low-methoxyl pectin gels are much lower than for high-methoxyl pectin

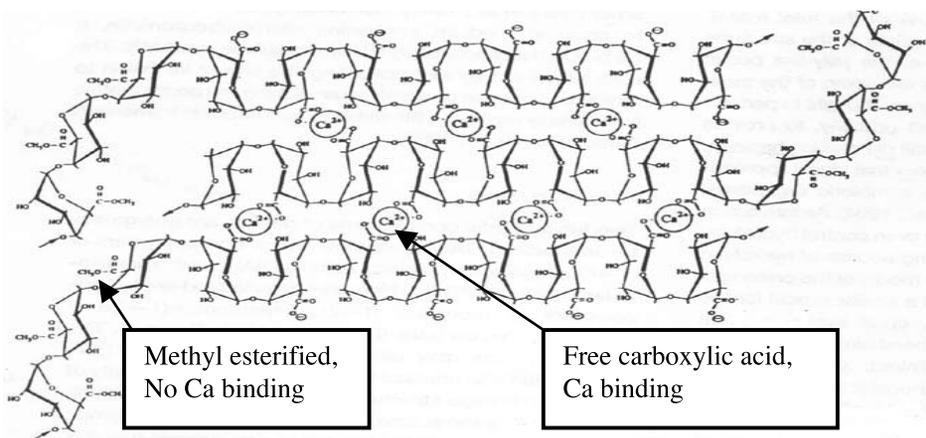


FIGURE 6.1 Pectin polymers indicating methylation (left) which prevents calcium binding or free carboxylic acid (right) that may bind calcium.

gels, suggesting that shorter sections of the polymer backbone are involved in the gelation process in low-methoxyl pectin gels (Garnier et al., 1993).

6.2.5 INTERACTION WITH SUGAR COSOLUTE

As stated earlier, high-methoxyl pectins will not form a gel with less than 55% sugar as cosolute. As pectin DE levels drop below 50%, the amount of sugar becomes less significant because low-methoxyl-calcium gelation becomes the predominant gelling mechanism; however, even in low-methoxyl pectin gels, the addition of sugar can increase gel strength and reduce syneresis (Axelos and Thibault, 1991). For high-methoxyl pectin gels, any of a number of other sugars, alcohols, and polyols will permit gelation. From a practical standpoint, it may be advantageous to substitute other sugars for sucrose, either because of cost, to reduce the likelihood of crystallization, or for flavor modification (Ahmed, 1981). Partial replacement of sucrose with other sugars such as maltose, glucose syrups, or high-fructose syrups altered the setting times and certain rheological properties of model gels (May and Stainsby, 1986). For example, addition of maltose reduced the setting time and extended the pH range of gelation, whereas fructose delayed setting time. Partial or complete replacement of sucrose with other sugars alters the water activity of the system and can modify the hydrophobic interactions contributing to gelation.

The use of dietary fiber as a thickener was evaluated in peach jam (Grigelmo-Miguel and Martin-Belloso, 2000). Commercial amidated pectin was either partially or totally substituted by peach dietary fiber, and jams with soluble solids contents of 40, 45, 50, and 55° Brix were produced. Jam color was unaffected because both the dietary fiber and puree originated from peaches. The rheological behavior of the jams with substituted dietary fiber was pseudoplastic in nature, similar to that of conventional jams. The sensory characteristics of the high peach dietary fiber jams were also deemed as acceptable as conventional jams. Therefore, the authors concluded that such a jam might serve as a dietary supplement with no adverse effects.

6.2.6 EFFECT OF pH

Control of pH is critical to successful gel formation with pectins, particularly high-methoxyl pectins. Low pH increases the percentage of unionized carboxyl groups, thus reducing electrostatic repulsion between adjacent pectin chains. High-DE, rapid-set pectins will gel at higher pHs than lower-DE, slow-set pectins; however, this difference is slight, with the optimum pH for slow-set pectins being

about 3.1 and for rapid set pectins 3.4 (Crandall and Wicker, 1986). Substitution of other sugars for sucrose, by modifying hydrophobic interactions between chains, allows gels to be formed at somewhat higher pHs (May and Stainsby, 1986). Because they rely on calcium bonding to effect gelation, low-methoxyl pectins can form gels at higher pHs than high-methoxyl pectins. Gels can be made at pH values near neutrality (Chang and Miyamoto, 1992; Garnier et al., 1993), an advantage in producing dairy-based products.

6.3 PROCESSING TECHNOLOGY

6.3.1 GENERAL CONSIDERATIONS

This section concerns the manufacture of jams. The four necessary ingredients in manufacturing jams include fruit, pectin, sugar, and acid. Optional ingredients include spice, buffering agents, preservatives, and antifoaming agents.

The exact process selected will depend upon the type of product to be manufactured, raw materials available, and scale of production. Essentially, the main stages in jam manufacture are as follows:

- Blending together of ingredients
- Evaporation to the desired total solids level
- Heat treatment to pasteurize the product

Traditionally, all of the ingredients were blended together at the first stage of the process; however, with modern demands for high consistency of quality, it has been common to add some critical ingredients at later stages in the process. Thus, for example, citric acid may be added at a late stage to give precise pH control. Volatile flavoring may also be added after the evaporation stage to avoid evaporative loss.

While it is possible with a simple atmospheric batch evaporation to carry out the whole process in one vessel, the requirements for consistent, economic, high-speed production and improved product quality mean that this technique has been generally superseded, except for very small-scale manufacture.

Most modern plants are based on low temperature or vacuum evaporation, which may necessitate the addition of an extra pasteurizing stage to give a product of suitable microbiological quality to allow prolonged storage.

In general, the main factors to be considered when selecting process are as follows:

- What is the required total solids (TS) level in the finished production?
- What is the required fruit percentage?
- What requirement is there for fruit particle integrity?
- What will the fruit content be?
- What are the required production rates?
- What will the range of ingredients be?

Although it is not possible to discuss in detail all of the possible process variables, the following two processes cover the main needs of the larger scale jam manufacturer.

6.3.2 PLATE EVAPORATION PROCESS

This process is particularly suitable for jams that do not have any large particles in suspension but where there is a need for a high-quality product and good process economy. It may be used for

PLATE EVAPORATION PROCESS

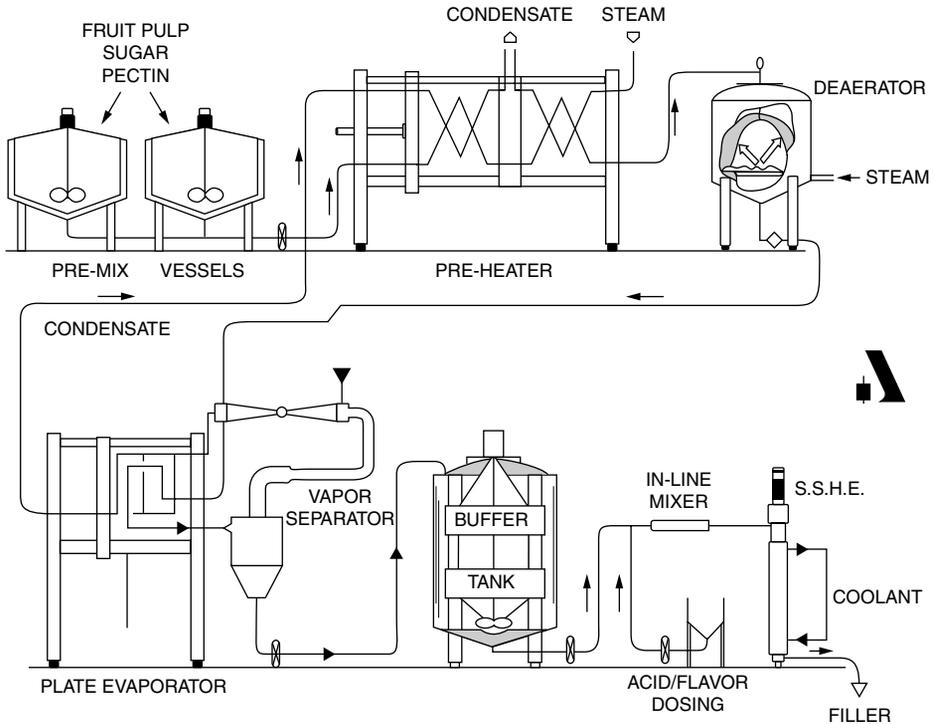


FIGURE 6.2 A typical processing plant.

the production of standard consumer products and is particularly suitable for special bakery and confectionery jams with very high solids levels and for jams for portion packing.

Figure 6.2 shows a typical plant. The first stage is the mixing together of ingredients that would normally include fruit pulp, sugar, pectin, and possibly corn syrup (liquid glucose). The various ingredients may be weighed or metered into the batch premix vessels. Two vessels are provided so that one may be used for the recipe preparation while the other is feeding the process. Thus, with flip/flop operation, a fully continuous feed is possible. Although in most cases this type of batch premix system is used, where long runs on a single recipe are likely, a continuous inline metering and blending system may be more appropriate.

The premix then goes through a Paraflow plate heat exchanger where it is heated by condensate and steam. If sulphited fruit pulp is included in the recipe, the hot mix enters a desulphiting column. At the top of the column is a variable orifice spray device. This allows the production of a good spray pattern with large surface area exposure to steam, which rises up the vessel to give effective stripping of sulphur dioxide. The opening of the nozzle may be adjusted to take into account both the velocity and viscosity of the feed. A second trimming stage of desulphiting takes place in the premix held in the bottom of the vessel by steam being sparged up through the mix. A level-control device allows the residence time in the vessel to be controlled according to the particular recipe's sulphite content. Where nonsulphited pulps are used, this stage may be omitted.

The hot mix is now fed to the APV plate evaporator, which is held under vacuum. This is a rising and falling film-type evaporator. Flashing occurs, giving good distribution in the wide gap plates, and further heating by steam passing through alternate plates ensures that very rapid evaporation takes place, minimizing loss of fruit volatiles and giving a product with a good natural fruit color. Typically, the temperature of evaporation is 60 to 65°C (140 to 149°F).

A vapor recompressor (thermoc compressor) may be used to recompress the product vapor with incoming high-pressure steam. This reduces the evaporation steam requirement by almost 50%. Further steam economy is achieved by utilizing the steam condensate in the Paraflow for the partial preheating of the premix.

The concentrated jam and resulting vapor are discharged through a large rectangular port to a snail shell separator where jam is separated from the vapor. The vapor passes to the condenser, which may be of the spray or surface type.

The jam is extracted by a rotary pump and passes through an inline refractometer. This is used to monitor the solids level, and may be used to control the steam rate to the evaporator and thus accurately control the finished product concentration. Inline pH metering allows control of citric acid solution addition to give the desired acidity level. Postprocess addition of any flavorings avoids volatile loss during the evaporation. The product now passes through a scraped surface cooler before passing to buffer storage and on to filling. This type of process may also be used for certain types of particulate-bearing products where the particulate material is presyruped in a strong sugar syrup. With this technique, it is possible to manufacture products with very good particle identity and a surrounding liquid phase of sparkling clarity.

6.3.3 VACUUM BATCH PROCESS

Figure 6.3 shows the general details of this process, which is suitable for the production of high-quality jams containing fruit pieces or whole fruit. Evaporation is carried out at low temperature, reducing thermal degradation. Postprocess pasteurization allows the process to be used for jams of a wide range of TSs with or without preservatives. It is ideal for linking to aseptic or ultraclean filling equipment.

The various ingredients are metered or weighed into the premix vessel, which is jacketed for the preheating of the mix and dissolution of sugar. A scraped surface agitator and baffle combination in this vessel gives both good heat transfer and rapid but gentle blending together of the various ingredients.

After mixing, the premix is drawn under vacuum into the vacuum cooking vessel. This has zoned dimple panel heating elements so that there is efficient heat transfer using the low-speed scraper agitator without problems of burn-on even in preparing part batches. Rapid vacuum evaporation takes place at 60 to 65°C (140 to 149°F), and the vapor is separated in a cyclone separator with any product carryover being returned to the vessel.

Normally, the vapor is condensed in a surface and may be recovered for use in recipe makeup, in-place cleaning, and so on; however, where required, a partial condensation volatile recovery system may be added for recovery of volatile flavorings.

After completion of this rapid low-temperature cooking process, the product is transferred using top-filtered air pressure to the buffer tank. From here, it is pumped to an APV scraped-surface heat

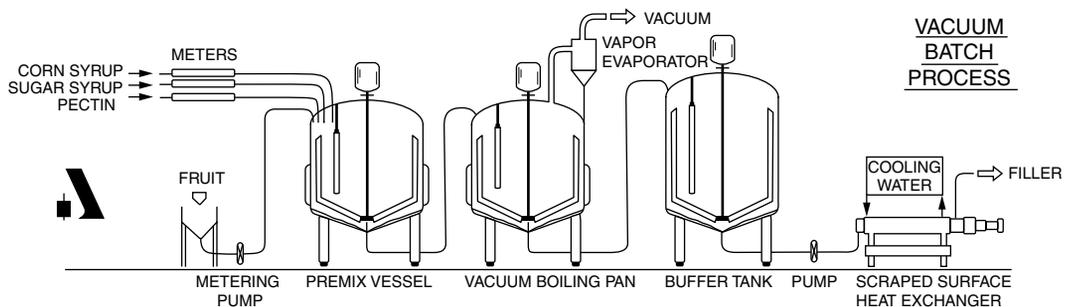


FIGURE 6.3 Processing details.

exchanger flash-pasteurizing plant prior to filling. This stage is necessary because the low-temperature vacuum evaporation may not be effective in killing any spoilage microorganisms present in the ingredients. The rapid pasteurization usually takes place at 85 to 95°C (185 to 203°F), depending on the TS and acidity of the recipe. Pasteurizing is under pressure to avoid any volatile loss and, after a short hold time, is followed by rapid cooling to the required filling temperature.

This process may also be adapted for use during the fruit harvesting period for the pasteurization of fruit pulp or fruit in syrup, which can then be filled into aseptic tanks or containers for later use in recipes.

While the two systems described above may not be suitable for every circumstance, they have proved effective for a wide range of applications throughout the world. As mentioned at the beginning, it is important to carefully analyze the requirements and then select the most appropriate process accordingly.

6.3.4 HIGH-PRESSURE-TREATED FRUIT PRESERVES AND JAM

Jam preparation using a new method (e.g., the application of high pressures) has been studied extensively in Japan in recent years. In a study by Horie et al. (1991), the use of high pressure (4000 to 6000 kg/cm²) resulted in a fresh fruit jam of superior color and flavor. In addition, vitamin C retention of fresh strawberries was 95% in pressure-treated jam. The authors reported that these pressure levels resulted in reduced levels of *Zygosaccharomyces rouxii*, *Saccharomyces cerevisiae*, *Staphylococcus* and *Salmonella*. In addition, a taste panel preferred the high-pressure-treated jam over the heat-processed product. Due to the presence of residual enzymes, refrigeration of the jam is required. Pressure-treated jam and preserves are commercially available in Japan and offer the consumer a more colorful, flavorful, and perhaps nutritionally sound product.

6.4 FEDERAL STANDARDS

U.S. federal standards and definitions do not differentiate between preserves and jams. 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 5 parts by weight of fruit to 2 parts of sugar.

The following is the 1994 U.S. Food and Drug Administration standard of identity for fruit preserves and jams (21 CFR 150.160).

6.4.1 21 CFR 150.160 FRUIT PRESERVES AND JAMS

(a) The preserves or jams for which definitions and standards of identity are prescribed by this section are the viscous or semisolid foods, each of which is made from a mixture composed of one or a permitted combination of the fruit ingredients specified in paragraph (b) of this section and one or any combination of the optional ingredients specified in paragraph (c) of this section which meets the specifications in paragraph (d) of this section, and which is labeled in accordance with paragraph (e) of this section. Such mixture, with or without added water, is concentrated with or without heat. The volatile flavoring material from such mixture may be captured during concentration, separately concentrated, and added back to any such mixture, together with any concentrated essence accompanying any optional fruit ingredient.

(b)(1) The fruit ingredients referred to in paragraph (a) of this section are the following mature, properly prepared fruits that are fresh, concentrated, frozen, and/or canned:

Group I: Blackberry (other than dewberry), black raspberry, blueberry, boysenberry, cherry, crabapple, dewberry (other than boysenberry, loganberry, and youngberry), elderberry, grape, grapefruit, huckleberry, loganberry, orange, pineapple, raspberry, red raspberry, rhubarb, strawberry, tangerine, tomato, yellow tomato, youngberry

Group II: Apricot, cranberry, damson, damson plum, fig, gooseberry, greengage, green-gage plum, guava, nectarine, peach, pear, plum (other than greengage plum and damson plum), quince, red currant, currant (other than black currant)

(2) The following combinations of fruit ingredients may be used:

(i) Any combination of two, three, four, or five of such fruits in which the weight of each is not less than one fifth of the weight of the combination; except that the weight of pineapple may be not less than one tenth of the weight of the combination.

(ii) Any combination of apple and one, two, three, or four of such fruits in which the weight of each is not less than one fifth and the weight of apple is not more than one half of the weight of the combination; except that the weight of pineapple may be not less than one tenth of the weight of the combination.

In any combination of two, three, four, or five fruits, each such fruit is an optional ingredient. For the purposes of this section the word "fruit" includes the vegetables specified in this paragraph.

(c) The following safe and suitable optional ingredients may be used:

(1) Nutritive carbohydrate sweeteners

(2) Spice

(3) Acidifying agents

(4) Pectin, in a quantity which reasonably compensates for deficiency, if any, of the natural pectin content of the fruit ingredient

(5) Buffering agents

(6) Preservatives

(7) Antifoaming agents, except those derived from animal fat

(d) For the purposes of this section:

(1) The mixture referred to in paragraph (a) of this section shall be composed of not less than:

(i) In the case of a fruit ingredient consisting of a Group I fruit or a permitted combination exclusively of Group I fruits, 47 parts by weight of the fruit ingredient to each 55 parts by weight of the saccharine ingredient, and (ii) in all other cases, 45 parts by weight of the fruit ingredient to each 55 parts by weight of the saccharine ingredient. The weight of the fruit ingredient shall be determined in accordance with paragraph (d)(2) of this section, and the weight of the saccharine ingredient shall be determined in accordance with paragraph (d)(5) of this section.

(2) Any requirement with respect to the weight of any fruit, combination of fruits, or fruit ingredient means:

(i) The weight of fruit exclusive of the weight of any sugar, water, or other substance added for any processing or packing or canning, or otherwise added to such fruit.

(ii) In the case of fruit prepared by the removal, in whole or in part, of pits, seeds, skins, cores, or other parts; the weight of such fruit, exclusive of the weight of all such substances removed therefrom.

(iii) In the cases of apricots, cherries, grapes, nectarines, peaches, and all varieties of plums, whether or not pits and seeds are removed therefrom, the weight of such fruit, exclusive of the weight of such pits and seeds.

(iv) In the case of concentrated fruit, the weight of the properly prepared fresh fruit used to produce such concentrated fruit.

(3) The term "concentrated fruit" means a concentrate made from the properly prepared edible portion of mature fresh or frozen fruits by removal of moisture with or without the use of heat or vacuum, but not to the point of drying. Such concentrate is canned or frozen without the addition of sugar or other sweetening agents and is identified to show or permit the calculation of the weight of the properly prepared fresh fruit used to produce any given quantity of such concentrate. The volatile flavoring material or essence from such fruits may be captured during concentration and

separately concentrated for subsequent addition to the concentrated fruit either directly or during manufacture of the preserve or jam, in the original proportions present in the fruit.

(4) The weight of any optional saccharine ingredient means the weight of the solids of such ingredient.

(5) The soluble-solids content of the finished jam or preserve is not less than 65%, as determined by the method prescribed in *Official Methods of Analysis of the Association of Official Analytical Chemists*, 13th ed. (1980), section 22.024, under “Soluble Solids by Refractometer in Fresh and Canned Fruits, Jellies, Marmalades, and Preserves — Official Final Action,” which is incorporated by reference, except that no correction is made for water-insoluble solids. Copies may be obtained from the Association of Official Analytical Chemists, 2200 Wilson Blvd., Suite 400, Arlington, VA 22201-3301, or may be examined at the Office of the *Federal Register*, 1100 L St. NW, Washington, D.C. 20408.

(e)(1) The name of each preserve or jam for which a definition and standard of identity is prescribed by this section is as follows:

(i) If the fruit ingredient is a single fruit, the name is “Preserve” or “Jam,” preceded or followed by the name or synonym whereby such fruit is designated in paragraph (b) of this section.

(ii) If the fruit ingredient is a combination of two, three, four, or five fruits, the name is “Preserve” or “Jam” preceded or followed by the words “Mixed fruit” or by the names or synonyms whereby such fruits are designated in paragraph (b) of this section, in the order of predominance, if any, of the weights of such fruits in the combination.

(2) Each of the optional ingredients specified in paragraphs (b) and (c) of this section shall be declared on the label as required by the applicable sections of Part 101 of this chapter, except that:

(i) The name(s) of the fruit or fruits used may be declared without specifying the particular form of the fruit or fruits used.

(ii) When the optional ingredients listed in paragraphs (c) (3), (4), and (5) of this section are declared on the label, the declaration may be followed by the statement “used as needed” on all preserves or jams to which they are customarily, but not always, added to compensate for natural variations in the fruit ingredients used.

6.5 PHYTONUTRIENT PROPERTIES OF FRUIT PRESERVES AND JAMS

Fruits are widely revered for their macronutrient properties; indeed, they serve as a primary source of vitamins and minerals in the diets of many people. Recent attention has focused on the phytonutrients naturally present in many fruits. These compounds include flavonoids (including polyphenolics and anthocyanins), carotenoids, and other antioxidant compounds that epidemiological studies show play a role in prevention of cancer and heart disease. Many of these nutritional components are also responsible for the color of fruit crops; for example, the flavonoids may be yellow, red, blue, and purple colors whereas carotenoids are typically yellow, orange, and red.

Jams have been determined to contain flavonoid profiles similar to those of the natural fruit. Tomas-Lorente et al. (1992) analyzed the phenolic compounds in a number of commercial jams as a means of determining the authenticity of the fruit jam. They compared between three and six commercial preparations of apricot, peach, plum, strawberry, sour orange, apple, and pear jam for both total phenolics and specific phenolic compounds. It was interesting to note that, even when there were significant differences in total phenolics content, a single pattern of individual phenolics was determined. The total phenolic content was influenced by cultivar of fruit, maturity stage of fruit, and the industrial process utilized.

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