Chapter 8
Yogurt

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8.1 A Brief History of Yogurt

Yogurt has been consumed since recorded time. It is not exactly known how yogurt was discovered, but it is assumed that it was by accident, perhaps by Mesopotamians in about 5000 BC (Kosikowski and Mistry, 1997). During this time, herdsman would milk goats and sheep and carry the milk with them in pouches made from an animal's stomach. These stomachs contained a natural enzyme, called chymosin, which forms a gel or coagulum when added to milk. Given (1) the warm climate in this part of the world, (2) the storage conditions available at the time, and (3) "natural starter culture" in the milk – either yogurt or cheese was made. Fermentation probably began within a few hours. Most likely, these people noted that this soured milk product tended to keep longer and they grew to prefer the flavor of yogurt to that of fresh milk. These people also eventually realized the health benefits of eating yogurt, and much later, some observers wrote about living a longer and healthier life as a direct result of frequent consumption of the fermented products (Andrews T. 2000).

Yogurt also traces its roots to the Caucasus Mountain region of Russia. The people of this rugged region were commonly nomadic – and as subsistence used both the milk and meat of cows, sheep, goats, and yaks. The fermented milk product traditional to this region, kefir, is a liquid cultured product whose name translates to "good feeling". It also earned the reputation as being a healing drink and was considered a "gift of the gods". Kefir was widely consumed by all families, and the bacteria culture that was used to ferment this product was prized and guarded most closely.

Cultured dairy products history also reports that Genghis Khan loved the taste of cultured products and mandated that all of his soldiers consume them on a regular basis. By the year 1215, Genghis Khan had conquered Mongolia, and Khan personally believed that part of his military success could be attributed to the fact that his army stayed strong and healthy by consuming the nutritious product, Kumiss. Reportedly, his official orders required that his

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entire army, from the top generals to the lowly slaves, were to eat this particular form of yogurt.

In 1542, a Jewish physician introduced yogurt into France from Constantinople. The King of France, Francois 1, suffered from acute depression and had undergone every possible therapy known at that time. The “Ambassador to the Sublime Porte” told him about this doctor from a distant land who made a concoction derived from soured sheep milk. This particular fermented milk drink had been reported to possess therapeutic properties. The king sent for this doctor, who traveled with his sheep from Constantinople to Paris, France. The king, after drinking this fermented elixir, was reported to be healed. However, the sheep were not so fortunate – they all unfortunately died from the long trek and the cold climate. This doctor ultimately returned home without surrendering his “formulation secret” to the king.

The broad popularity of kefir in Russia dates back to the early 1900s, when the All-Russian Physicians Society contacted two brothers who owned a cheese plant for help in obtaining some kefir starter culture. The society was looking to popularize this product for its reputed health and aging benefits. The royal Caucasus family closely guarded the culture used to produce kefir. According to legend, two brothers hired a beautiful young lady to help obtain the prized culture (Mariani, 1999). She failed in her attempt to gain the culture, but did win the prince’s love. He proposed to the lovely lady, but she declined his hand in marriage, and left for home. The prince became so angered with her refusal, that he had her kidnapped, but she was ultimately rescued. The lady and the Physicians Society sued the prince in the Czar’s courts and won a legal settlement. The prince offered her gold and other valuables, but she finally agreed upon gaining possession of some of the valuable kefir culture and thus, the case was finally settled. In September 1908, this successful legal litigant took some of the kefir culture to Moscow, where it was used for many years as the kefir culture strain, and was incorporated into many different medicines. Thus, this beautiful lady was ultimately responsible for both the spread and the popularity of kefir across Russia, and eventually to many parts of the rest of the world.

Yogurt gained global attention in the early 1900s when the Russian bacteriologist, Ilya Metchnikov conducted research on the extended life spans of certain Bulgarians. He noticed that these people had longer life spans than those of the surrounding countries. His studies emphasized that Bulgarian people consumed large amounts of yogurt and related cultured milk products. His papers were widely published and valued; he received a Nobel Prize and the popularity of yogurt significantly increased.

As early as 1784, Turkish immigrants are credited with bringing yogurt to the U.S. However, yogurt popularity commenced in the late 1930s and 1940s when Columbo and Danone (later renamed Dannon in the U.S.) began yogurt businesses on the east coast in the U.S. (General Mills, 2007; Dannon, 2007). In 1947, Dannon started adding strawberry preserves to the bottom of the cup, and thus made the first “sundae” style yogurt.

8.2 Yogurt Defined

The CFR 131.200 definition of Yogurt is "Yogurt is the food produced by culturing one or more optional dairy ingredients with a characterizing bacterial culture that contains the lactic acid-producing bacteria, *Lactobacillus bulgaricus* and *Streptococcus thermophilus* (Olsen, 2002; CFR, 2008a). One or more other optional ingredients may be added, but must be added prior to culturing. Yogurt, before the addition of bulky flavors, contains not less than 3.25 percent milkfat and not less than 8.25% milk solids not fat, and a titratable acidity of not less than 0.9%, expressed as lactic acid. The food (base) may be homogenized and shall be pasteurized or ultra-pasteurized prior to the addition of the bacterial culture. Flavoring ingredients may be added after pasteurization or ultra-pasteurization. To extend the shelf life of the food, yogurt may be heat treated after culturing is completed, to destroy viable microorganisms".

Optional dairy ingredients are described as cream, milk, partially skimmed milk, or skim milk, used alone or in combination. Other optional ingredients include concentrated skim milk, nonfat dry milk, buttermilk, whey, lactose, lactalbumins, lactoglobulins, and/or whey modified by partial or complete removal of lactose and/or minerals, to increase the nonfat milk solids content of the food, provided that the ratio of protein to total nonfat solids of the food and the protein efficiency ratio (PER) of all proteins present shall not be decreased as a result of adding such ingredients.

Nutritive carbohydrate sweeteners such as sugar (sucrose), beet, or cane; invert sugar (in paste or syrup form); brown sugar; refiner's syrup; molasses (other than blackstrap); high-fructose corn syrup; fructose; fructose syrup; maltose; maltose syrup, dried maltose syrup; malt extract, dried malt extract; malt syrup, dried malt syrup; honey; and/or maple sugar may be used (U.S. Food and Drug Administration 2007).

8.2.1 Lowfat Yogurt Defined

The CFR 131.203 definition of lowfat yogurt includes "Lowfat yogurt is the food produced by culturing one or more of the optional dairy ingredients with a characterizing bacterial culture that contains the lactic acid-producing bacteria, *Lactobacillus bulgaricus* and *Streptococcus thermophilus* (CFR, 2008b). One or more optional ingredients may also be added, but must be done so prior to culturing".

Lowfat yogurt, before the addition of bulky flavors, contains not less than 0.5% nor more than 2% milkfat and not less than 8.25% milk solids not fat, and has a titratable acidity of not less than 0.9%, expressed as lactic acid. The food may be homogenized and shall be pasteurized or ultra-pasteurized prior to the addition of the bacterial culture. Flavoring ingredients may be added after pasteurization or ultra-pasteurization. To extend the shelf life of the food, lowfat yogurt may be heat treated after culturing is completed, to destroy viable microorganisms.

Optional dairy ingredients include cream, milk, partially skimmed milk, or skim milk, used alone or in combination with concentrated skim milk, nonfat dry milk, buttermilk, whey, lactose, lactalbumins, lactoglobulins, or whey modified by partial or complete removal of lactose and/or minerals, to increase the nonfat solids content of the food provided that (1) the ratio of protein to total nonfat solids of the food and the protein efficiency ratio (P.E.F.) of all proteins present shall not be decreased as a result of adding such ingredients; (2) nutritive carbohydrate sweeteners such as sugar (sucrose), beet, or cane; invert sugar (in paste or syrup form); brown sugar; refiner's syrup; molasses (other than blackstrap); high-fructose corn syrup; fructose; fructose syrup; maltose, maltose syrup, dried maltose syrup; malt extract, dried malt extract; malt syrup, dried malt syrup; honey; and maple sugar may be also used (U.S. Food and Drug Administration, 2007).

8.2.2 Nonfat Yogurt Defined

The CFR description of nonfat yogurt states that it is the food produced by culturing one or more of the optional dairy ingredients with a characterizing bacterial culture that contains the lactic acid-producing bacteria, *Lactobacillus bulgaricus* and *Streptococcus thermophilus* (CFR, 2008c). One or more other optional ingredients may also be added. When one or more of the ingredients are used, they shall be included in the culturing process. All ingredients used are safe and suitable. Nonfat yogurt, before the addition of bulky flavors, contains less than 0.5% milkfat and not less than 8.25% milk solids not fat, and has a titratable acidity of not less than 0.9%, expressed as lactic acid. The food may be homogenized and shall be pasteurized or ultra-pasteurized prior to the addition of the bacterial culture. Flavoring ingredients may be added after pasteurization or ultra-pasteurization. To extend the shelf life of the food, nonfat yogurt may be heat treated after culturing is completed, to destroy viable microorganisms.

Optional dairy ingredients that may be used are; cream, milk, partially skimmed milk, or skim milk, used alone or in combination. Other optional ingredients are concentrated skim milk, nonfat dry milk, buttermilk, whey, lactose, lactalbumins, lactoglobulins, or whey modified by partial or complete removal of lactose and/or minerals, to increase the nonfat solids content of the food provided that the ratio of protein to total nonfat solids of the food and the protein efficiency ratio of all proteins present shall not be decreased as a result of adding such ingredients.

Nutritive carbohydrate sweeteners such as sugar (sucrose), beet, or cane; invert sugar (in paste or syrup form); brown sugar; refiner's syrup; molasses (other than blackstrap); high-fructose corn syrup; fructose; fructose syrup; maltose; maltose syrup, dried maltose syrup; malt extract, dried malt extract; malt syrup, dried malt syrup; honey; and maple sugar may be used. Color additives, fruit, flavors, and stabilizers are also allowed (U.S. Food and Drug Administration, 2007).

8.3 Yogurt Cultures (Microflora)

The special properties of cultured milk products begin with the unique properties of the microorganisms used in their production. Perhaps more than any other type of cultured dairy products, yogurt has enhanced the shelf life, appeal, and digestibility of fresh milk for the North American consumer. Yogurt is a fermented dairy product resulting from the symbiotic growth of *Streptococcus thermophilus* and *Lactobacillus bulgaricus* to produce a smooth viscous gel with a desirable cultured flavor. Various styles of yogurt are now targeted for a variety of different consumer groups from children to geriatrics, and the variety of products depends on the properties and microbiology of starter cultures used in their production. Many companies use *S. thermophilus* and *L. bulgaricus* strains for production of yogurts with distinctive nutritional or physical characteristics. In addition, *Lactobacillus acidophilus, Bifidobacteria* species, and other strains not required by the standard of identity are added for their purported health benefits. In the current yogurt market, culture strains are selected based on their rate of acid production, flavor profile, exopolysaccharide production, and bacteriophage resistance to produce yogurts with specific textural properties, reduced post-fermentation acidification, and milder flavor than products of the past.

8.3.1 Essential Microflora for Yogurt Production

1. *Streptococcus salivarius* subsp. *thermophilus* (*S. thermophilus*) are Gram-positive cocci in pairs to long chains, with optimum growth temperature of 40–45°C (104–113°F), a maximum growth temperature of 50°C (122°F), and are able to survive lower temperature pasteurization (University of Guelph Dairy Science and Technology, 2007). This organism is extremely sensitive to antibiotics (readily inhibited by 0.01 IU/ml of penicillin, with slight inhibition apparent in as little as 0.001 IU/ml of penicillin). This sensitivity to antibiotics as well as chemical cleaners underscores the need for high-quality milk supplies and sensitive antibiotic testing procedures. While bacteriophage also can be a problem for certain commercially popular strains, sensitive testing procedures and good plant sanitation can minimize the chances of production failures. *S. thermophilus* is weakly proteolytic and requires free amino acids generated by *L. bulgaricus* (below), attained from either severe milk heat treatment or exogenous sources. *S. thermophilus* produces formic acid and is responsible for reduction of oxygen levels in associative growth with *L. bulgaricus.*
2. *Lactobacillus delbrueckii* subsp. *bulgaricus* (*L. bulgaricus*) are Gram-positive rods that occur singly or in pairs in young cultures (University of Guelph Dairy Science and Technology, 2007). In older cultures, Gram-variable rods occur either in pairs or chains, with or without granules. *L. bulgaricus* is less sensitive to antibiotics than *S. thermophilus,* with 0.30 IU/ml penicillin required for significant inhibition. A strict nutritive requirement for formic

acid is satisfied by severe heating of milk (e.g., 88°C (190°F)) for 30 min or by associative growth with *S. thermophilus*. *L. bulgaricus* can be highly proteolytic, affecting yogurt flavor and shelf life if it dominates the cocci organism. Up to 2–3% of lactic acid is produced in pure cultures, as well as high levels of acetaldehyde. *L. bulgaricus* can be attacked by bacteriophage, though not as readily as *S. thermophilus*. Optimum growth temperatures are 40–43°C (104–110°F), with maximums of 53–60°C (127–140°F) for certain strains.

8.3.2 Optional Microflora for Yogurt

1. *Lactobacillus acidophilus* (*L. acidophilus*) is a Gram-positive rod very similar in morphology to *L. bulgaricus*, but it is not a major contributor to acid, flavor, or texture when used as an adjunct microorganism in most yogurts. *L. acidophilus* is able to survive in the small intestine because of its bile and phenol resistance, which *S. thermophilus* and *L. bulgaricus* do not possess (Gibson, 2001; Rahrs, VE 2005). However, propagation and survival of *L. acidophilus* in yogurt is difficult, due to peroxides generated by *L. bulgaricus* when oxygen is present. The NCFM strain of *L. acidophilus,* which was developed at North Carolina State University, is believed to implant in the small intestine and produce anti-microbial substances against undesirable intestinal anaerobes (Gibson, 2001). It may also be beneficial in re-establishing intestinal flora in patients who have undergone antibiotic therapy. Optimum growth temperatures for *L. acidolphilus* propagation are 35–38°C (95–100°F), with maximums of 45–48°C (113–118°F).
2. *Bifidobacteria infantis* and longum (*B. infantis and B. longum*) and *B. longum* are small Gram-positive irregular rods that occur singly or in pairs in milk cultures. Clinical research indicates that these strains may be the predominant organisms in the large intestine of infants and some adults. As with *L. acidophilus*, this organism is considered preferable to the normal anaerobic organisms that inhabit the intestinal tract. *B. infantis* is most common in infants and *B. longum* appears more commonly in adults. The suggested health effects of *Bifidobacteria* species include the ability to inhibit gut invasion by streptococci, inhibition of colonization by *E. coli*, serum cholesterol reduction, and the ability to elevate immuno-competence, as measured by impact on mean corpuscular volume of red blood cells and macrophages (Gibson, 2001).
3. Several types of capsule formers, microorganisms that can be used to produce unique polysaccharides, increase the viscosity of yogurt. Certain strains of *S. thermophilus* and *L. bulgaricus* in regular cultures display little polysaccharide-capsule-forming ability. However, certain cultures produce polysaccharide levels that exhibit improved viscosity. Wise discrimination in the selection and use of capsule formers may relieve excessive reliance on stabilizers and a richer, creamier texture can be achieved even in lowfat or nonfat products. Use of specialized heavy-body strains can also improve consistency and control after acidification. Polysaccharide formers are most often strains of *S. thermophilus*.

8.4 Yogurt Starter Handling and Fermentation

Commercial cultures are available as direct-set cultures or as bulk starter. Proper handling and propagation of yogurt starters is critical for maintaining optimal strain balance, flavor development, and shelf life. The choice between preparing a fresh, milk-based starter culture versus using a frozen or freeze-dried direct-set entails a trade-off between consistency and set times. Direct-set cultures take a little longer than bulk starter and tend to be used in Swiss style yogurt more than cup-set. With the vast range of freeze-dried and frozen direct-set and bulk starter cultures, processing plants can now select strains and propagation techniques that are most amenable to different yogurt styles and production processes.

1. *Starters*. Most plants in the U.S. now use frozen and freeze-dried direct-set types of cultures that perform the basic functions of acid and flavor development. Freeze-dried direct-set cultures are more stable than frozen cultures at storage temperatures of up to 0°C, and tend to involve less risk in shipping, storage, and handling. Fermentation times for freeze-dried cultures last from 5 to 7 h at 41–42°C (106–108°F) until vat set, whereas frozen cultures take 5–6 h, depending on the freshness of the culture. Propagation of bulk starter cultures is still used at some plants that desire a faster product set time of 3–4 h. Good consistency with bulk starter depends on keeping bacteriophage out of the milk-based starter, testing starter milk for low-level antibiotics, and ripening to a consistent end-point pH. The optimum ratio of either a bulk starter or direct-set culture depends on the type of product – a traditional yogurt should be in the ratio range of 1:1 to 4:1 cocci:rods; however, for mild-flavored yogurt the cocci:rods ratio may be as high as 15:1.
2. *Fermentation*. A properly conducted product fermentation will promote balanced growth of the essential yogurt microflora. Normally, *L. bulgaricus* stimulates early growth of the cocci by enzymatically liberating essential amino acids from the milk protein. This is one reason why sufficient inoculum levels are critical for rapid fermentations. As a result of this early stimulation, the streptococci typically outnumber the lactobacilli by three or four to one within the first hour to two hours. The rods begin to develop rapidly once the pH drops below the 4.8–5.0 range, and it is only at or below a pH of 4.5–4.6 that the characteristic "nutty" yogurt flavor begins to be expressed. Most yogurts are considered "ripe" somewhere in the pH range of 4.0–4.5, depending on how strong or mild a product is preferred. A lower pH than 4.0 is undesirable, since *L. bulgaricus* tends to produce excessive lactic acid, acetaldehyde, and proteolytic by-products in this pH range. This culture can help maintain a product pH of 4.1–4.3 throughout shelf life, thereby maintaining a mild flavor and a pleasant product appearance. Such cultures can also eliminate the graininess that commonly develops during breaking and cooling of vat-set yogurts. Reducing yogurt temperature to 21–24°C (70–75°F) is usually sufficient to stop culture activity and allow

packaging without setting up the stabilizer portion of the product. When product fermentation is stopped at too high a pH (above pH 4.7) the yogurt will often have a weak body and/or stringy texture, hence the use of a pH meter for determining the break point is essential.

8.5 Yogurt Manufacturing

Yogurt process and formulation variations are as numerous as the number of manufacturers. The finished yogurt will vary in regard to body and texture, depending upon the type of ingredients, processing, starter cultures, flavor, and packaging that is used.

The processing of yogurts can be broken down into the following steps: blending, pasteurization, homogenization, culturing and cooling, packaging and storage. Each is extremely important in the process, and strict attention to detail must be taken.

Blending. There are a number of different types of blending equipment that are available and used by yogurt manufacturers. Each blender has its own advantages and disadvantages, but all are used to standardize the mix and blend ingredients. At this point, any additional ingredients are added; such as nonfat dry milk, whey or whey protein, sugars, and/or stabilizers.

Regardless of the blender used, the purpose of using the blender is to speed up the time it takes to add the dry ingredients, and to aid in the dispersion of the dry ingredients. It is important to add the dry ingredients to the milk at a point of highest agitation, but at the same time, to avoid air incorporation or foam. Foam tends to hold large amounts of milk solids, and if the foam is left behind in the mixing vat after pasteurization, those solids are not incorporated into the base, and therefore the final product may be low in total solids and have a weak body.

Many of the ingredients added to the yogurt base are very hygroscopic. When these ingredients come into contact with milk, they will absorb liquid quickly and can form lumps, "fish eyes", or in extreme cases can clog a line. Therefore, it is extremely important that the dry ingredients are added at a rate that they become incorporated into the mix without agglomerating. "Fish eyes" are described as a mass of dry material that has a layer of partially hydrated material on the surface, but dry in the center. If the "fish eye" is made up of stabilizer material, this product might not hydrate fully, regardless of the amount of heating and agitation that ensues. These ingredients will not have their full functionality in the yogurt, and thus the body and texture may be lacking. These lumps may be noticed floating on the surface, in in-line filters, or will remain in the tank after emptying.

Many yogurt production plants pre-heat the milk prior to adding the dry ingredients, and generally, this is helpful to completely hydrate the stabilizer and aid in mixing and suspension, but it is not absolutely necessary. The most important aspect of ingredients blending is to incorporate as little air as possible, and to completely and to add the dry ingredients to the base without forming lumps. After the blending process, adequate agitation is important in the holding tank to keep the ingredients suspended. After blending, it is common to hold and agitate the yogurt mix up to 4 h prior to pasteurization, which helps native starch and gelatin to hydrate.

8.5.1 Pasteurization of Yogurt Mixes

Pasteurization of yogurt mixes can be accomplished by several different methods. As with any other dairy product, the purpose for pasteurization is to heat treat milk to eliminate pathogenic bacteria. In addition, it is very important to denature the proteins to attain the highest level of functionality from the milk proteins. Pasteurization also aids in the hydration of the stabilizers and dry ingredients that were added during blending, as well as adding a pleasant cooked flavor. The three main types of pasteurization are (1) vat method (low temperature long time [LTLT], 80°C [175°F] for 30 min), (2) high temperature short time ([HTST], 80–88°C [175–190°F] for 18–50 s depending upon length of holding tube), and (3) ultra-high temperature ([UHT], 138°C [280°F] for 2–4 s). The latter method is not as common, but it is starting to gain application. Some Manufacturers who pasteurize using methods 2 and 3 hold their yogurt mixes in hold tubes for an additional 5–20 min at the pasteurization temperature in order to denature whey proteins and improve product viscosity.

8.5.2 Homogenization of Yogurt Mixes

Yogurt mix homogenization aids in hydration of stabilizers, and the interaction of stabilizers with milk proteins. In the manufacture of yogurt and other dairy products, it is common to homogenize mixes at approximately 63°C (145°F), with a total pressure of between 7 and 10 MPa (1000 and 1500 psi) in the 1st stage and 3 MPa (500 psi) in the 2 nd stage, or alternatively, 7 MPa (1000 psi) 1st stage and 3 MPa (500 psi) 2 nd stage. Different types of homogenizers may be used (such as a microgap type), but the same pressure conditions are applied. Some manufacturers homogenize after the regeneration section of the pasteurizator, and some homogenize after the cooling section.

Composition of the yogurt stabilizer can affect the homogenization pressure and temperature that is used. Some gums and starches that require heat and shear to activate or “bloom”. There are also certain types of starches that will be ineffective if they are homogenized after they have become fully hydrated or bloomed. If this happens, the entire functionality of the starch will most likely be lost, and many body and texture defects in the finished yogurt may be noticed, defects such as weak body, syneresis, or wheying-off. Processing recommendations from stabilizer supplier representatives are advised for material sources and utilization strategies.

8.5.3 Culturing the Yogurt Mix (Stirred Style)

After pasteurization and homogenization, the yogurt mix is cooled to the optimum setting temperature. Depending upon the bacteria used in the yogurt culture, normal set temperatures range between 32 and 46°C (90 and 115°F), with a normal incubation (set) more than 8 h. These incubation conditions are dependant upon the type of cultures used and the type of yogurt produced.

After the yogurt mix has reached its "set" temperature the culture is added. Extreme care should be taken in the inoculation process of the vat. If contamination occurs in the yogurt-making process, this is usually where it occurs. All containers and equipments used in the inoculation process such as pails, buckets, hand agitators and culture packages and cans must be sanitized with an approved sanitizer.

After addition of the culture, the agitator must be left on low speed for a minimum of 15 min to ensure adequate dispersion. Improper agitation may result in pockets in the yogurt vat that have a higher than normal concentration of bacteria, or hot spots, and will develop much faster than the rest of the vat. Also, there may be pockets that have very little bacteria, and therefore will have little to no acid development. When the main body of the vat is ready to be broken and cooled, this portion may affect the finished body, texture, and flavor of the finished product.

Upon adequate agitation of the yogurt, the agitator must be shut off and the culture allowed to grow in the yogurt base and develop acid. During this process, it is extremely important to not disturb the knit or mesh of the product. The agitator must not be turned on for any reason – to do so would cause a weak body and mouthfeel, and/or a lumpy, watery, or wheyed-off final product. In extreme cases where an agitator has been left on during the entire fermentation, the casein will precipitate and there will be no gel and no possibility to save the batch.

After the prescribed set time, the product should be checked for either % acidity by titratable acidity or pH. It is advisable to take samples from several different places around the top of the vat. When using a sanitary straw, the straw should be inserted into the yogurt approximately 46 cm (18 in.). Aliquots obtained from the different locations should be commingled and tested. If possible, it is also advisable to take a sample from the bottom of the vat. Since it is common to have a temperature difference from the top to the bottom of the vat differing acid levels or pH may be seen.

After achieving the proper pH, the agitator may be turned on to the lowest speed and the cooling process initiated. Depending upon the efficiency of the vat, or the method of cooling, this should take anywhere from 2 to 4 h. It is common to cool the yogurt base to between 10 and 20°C (50 and 70°F). When cooling, it is also important to not over-agitate. Setting the agitator at higher than the slowest speed may cause shear of some of the proteins and disturb the "knit process" that has taken place during culture incubation.

Upon reaching the desired cool-down temperature, the agitator(s) should be shut off and the product allowed to remain quiescent until the fruit is added.

As the product is pumped to either the flavor tank or the filler, it is a common and advisable practice to pass the yogurt through an in-line "smoothing" device. This may vary from a simple mesh-screen to a more elaborate bell-valve, or gum-drop-type device. The purpose of any smoothing device is to simply smooth out or break up any remaining yogurt lumps or curds that may have not been broken up during the combined agitation and cooling process. Seek the advice of your stabilizer consultant to ascertain if the selected smoothing device may affect any of the stabilizer components. Some types of smoothing devices need to match up with the process and the temperature that the yogurt is being pumped, blended, and handled.

8.5.4 Culturing the Yogurt (Set-in-the-Cup)

After pasteurization and homogenization, the yogurt mix is cooled and inoculated at a temperature slightly higher than the optimal setting temperature. The inoculated yogurt mix is then is pumped and filled prior to incubation. During the pumping and filling it is common for the mix to cool several degrees. Therefore, it is import that the processor adjust the inoculation temperature so that the product is at the optimal incubation temperature upon reaching the incubation room. Depending upon the bacteria used in the yogurt culture, normal set temperatures range between 32 and 46°C (90 and 115°F), with a normal incubation (set) time of 5–6 h. These incubation conditions are dependant upon the type of cultures used and the type of yogurt produced.

Many manufacturers add the culture "in line" after the mix has exited the regenerator section of the pasteurization unit. If contamination occurs in the yogurt-making process, this is usually at this point, so caution must be taken to avoid any possible contamination. All containers and equipment used in the inoculation process such as pails, buckets, hand agitators and culture packages and cans must be sanitized with an approved sanitizer.

Because the inoculated yogurt mix is placed into a cup prior to culturing, fruit and flavor are also added prior to packaging as well. Addition of the fruit–flavor system is commonly completed in line. Some possible concerns with the fruit are sinking or floating fruits. This can be rectified by adjusting the amount of sugar or total solids in the white mass, and in the fruit–flavor systems. It is recommended that the processor discuss these issues with the approved fruit supplier.

After addition of the culture, the cup-set yogurt is moved to the incubation room where it will be left until the pH reaches pH 4.4–4.6. This usually takes between 5 and 6 hours depending upon regional differences and variations in solids levels, and heat treatments. Product should be checked for pH after 3 h of ripening.

Upon reaching a desired pH, the ripened yogurt should be gently moved to a cooler with a high amount of air movement, and cooled to stop the bacteria growth as quickly as possible. A common practice is to put the pallets of finished yogurt in front of a forced air cooler, open the cardboard boxes to allow adequate air movement. Another common practice is the use of a blast cooler. The cases of yogurt are placed on a conveyer through the blast cooler. If the yogurt is palletized, it is important to place the cases of yogurt in a way that the product will allow for adequate air flow throughout the pallet. This will speed up the cooling process and slow down the acid development. Upon cooling the yogurt, the pallets should be carefully moved to a refrigerated storage facility and not disturbed for 12–24 h. During this time, the product firmness and whey retention is enhanced.

In the process of making cup-set yogurt, variability in culturing, incubating and cooling steps makes it common to have slight differences in product quality and consistency from pallet to pallet.

8.5.5 Fruit Addition

Fruit flavoring may be added in several different ways, either by means of a flavor tank or by the use of a mixing pump. The flavor tank method involves pumping yogurt into a tank and adding the yogurt fruit preparation on top. With this method, an adequate agitator is necessary to properly blend the yogurt and the yogurt fruit. After the product has been thoroughly blended, the yogurt is then pumped to the filler.

With the mixing pump method, fruit flavoring material and yogurt are each pumped separately, and then mixed together as they are both moving toward the filler.

As with any fruit addition, keep in mind that the fruit needs to be completely blended prior to reaching the filler, but over-agitation and excessive shear must be avoided.

8.5.6 Packaging and Cooling

After the product smoothing and filling steps, the filled fruit yogurt cups may be placed into either a corrugated box or a tray, and then over-wrapped with plastic film. These packaged units will then be placed onto a pallet, which will soon be placed into the cooler. Pallets with freshly filled yogurt should be positioned into a designated section of the cooler, or specified pallet space where it will not be moved or disturbed for a minimum of 18–24 hours. After filling, the yogurt begins to re-knit, and forms the unique delicate texture that is important for the final body conformation or tactile properties of the yogurt. If the yogurt is physically disturbed during this knitting process, the end result(s) may be a weak body, syneresis on either the sides and/or surface of the yogurt, and/or a non-homogenous appearance of the yogurt.

8.6 Yogurt Flavors

The preferred or top-selling yogurt flavors have not changed much in the past several decades, especially with fruited, flavored, and yogurt drinks. Most of the yogurt sold in the U.S. is packaged in three sizes: 170 g (6 oz), 230 g (8 oz), and 910 g (32 oz). Some of the larger containers have changed in regard to the top flavors, with strawberry usually at or near the top of the list. In the larger containers sold (1815 g, 64 oz), vanilla or plain are the top sellers, followed by strawberry. Most products are used for home culinary usage and in various food service areas. The top flavors do not seem to change regardless of the sweetener used.

The top 10 flavours for flavored yogurt (ranked from most to least popular; Euromonitor, 2007) are

Vanilla
Strawberry
Mixed berry
Blueberry
Peach
Raspberry
Strawberry/banana
Cherry
Lemon
Key lime

Many additional yogurt flavors have been developed, but are either a version of the top 10 or a combination of one of the above-listed flavors. It has also been a trend to expand with indulgent flavors, such as honey, caramel, chocolate, and additional inclusions such as granola, nuts, and certain unique or heavier flavors to be added to the yogurt. An interesting observation is that the top 5 flavors constitute approximately 80% of all flavored yogurt sales.

8.7 Yogurt Stabilizers

Stabilizer is a term commonly applied to describe an ingredient used to perform a multitude of functions. Stabilizers generally serve to bind water, build viscosity, contribute to creaminess, and protect against temperature abuse.

Ingredients that are normally used as components in yogurt stabilizers are starch, gelatin, guar gum, locust bean gum, carrageenan, pectin, and xanthan gum. The particular makeup of the stabilizer blend will depend on several of the following criteria: desired function, eating characteristics of the finished product, processing parameters, cost, storage conditions and desired shelf life.

Starch. Starch is the major carbohydrate reserve in plant tubers and seed endosperm, where it is found as granules, each typically containing several million amylo-pectin molecules accompanied by a much larger number of smaller amylose molecules. The largest source of starch in the U.S. is corn (maize) with other commonly used sources being wheat, potato, tapioca, and rice. Amylopectin (without amylose) can be isolated from "waxy" varieties of grains. Genetic modification of starch crops has recently led to the development of starches with improved and targeted functionality. Starch is versatile and inexpensive, and has many uses as a thickener, water binder, emulsion stabilizer, and gelling agent.

Gelatin. Gelatin is one of the most versatile ingredients to be used as a yogurt stabilizers. It is a protein that is derived from the partial hydrolysis of skin, bones, and connective tissue from cattle, pigs, and selective fish. The unique attribute of gelatin is its ability to form a clear thermo-reversible gel with a melting point close to the human body temperature. For this reason, it works very well in pre-stirred yogurt. Gelatin will contribute to water-holding capacity in pre-stirred yogurt. If it used excessively, products will develop a short texture and have the potential for syneresis. It is extremely important to heat the product to 60°C (140°F) for complete hydration. Gelatin will start to solidify and become a solid mass at a temperature of ~29°C (85°F).

Guar gum (from Cyamopsis tetragonolobus). Guar gum is a complex carbohydrate obtained from a legume. The guar plant is grown in the geographic regions of India and Pakistan. The seedpod is harvested, and the seed coat isremoved and the endosperm are removed. The usable product component is then milled and sifted. The gum is readily dispersible in cold solutions, has excellent water-holding capacity, and provides good mouthfeel. Guar gum is relatively inexpensive. Excessive amounts of guar can cause a slimy texture and a mouthfeel that is slick-like. Additionally, a distinctive "beany" flavor may be attributed to high usage levels. Guar gum that has not been thoroughly cleaned in preparation stages can add undesirable dark-colored specks to finished products.

Locust bean gum (Ceratonia siliqua). Locust bean gum (also called Carob bean gum), is extracted from the seeds of the Carob tree (*Ceratonia siliqua*), is a galactomannan. These trees are grown around the Mediterranean region, having a history that predates Christ. It was used by the early Egyptians in the mummification process, and was also used as a standard weight measurement for gold and precious gems. The term "carat" is derived from the Latin name Ceratonia. Locust bean gum is an excellent stabilizer ingredient and, used at low levels, will impart a clean flavor and creamy mouthfeel. Fluctuating prices and high demand are issues when considering this ingredient. Locust bean gum must be heated to 79°C (175°F) to properly hydrate the gum prior to its use.

Pectin. Pectin is a structural element in plant tissues. It is most commonly obtained from the peels of citrus fruits such as lemon, lime, grapefruit, and orange. Pectin can also be extracted from apple pomace and pressed sugar beat pulp. Pectin is derived from the original source by initially being ground, then exposed to water and acid extraction processes, followed by an alcohol-precipitation process. The pectin is then dried, milled, and standardized. Pectin is considered by many as an all natural (though no standard of identity for "natural" exists as of the publication date of this book) and is a popular ingredient in yogurt stabilizer. The use of pectin as an ingredient in yogurt typically provides nice pudding-type consistency. The price is dependant upon the particular weather patterns in the citrus-growing regions of the world, especially in hurricane regions.

Xanthan gum. Xanthan gum is a high-molecular weight polysaccharide gum, produced by a pure culture fermentation of a carbohydrate, by a bacterium called *Xanthomonas campestris*. After fermentation, a sterilization step follows and the sought-after component is precipitated with iso-propylalcohol, followed by centrifugation, drying and milling. Xanthan gum is soluble in cold water and is both thixotrophic and thermo-reversible. It is relatively shear and acid resistant, as well as being freeze/thaw stable. It is used sparingly as an ingredient in yogurt stabilizers, since it has a tendency to cause graininess. It has a synergistic affect with other gums such as guar and locust bean gums (Rahrs, VE 2005).

Carrageenan. Carrageenan is a natural product obtained from the pressing and extraction of red or brown seaweed. The three main types of carrageenan are kappa, iota, and lambda. During the extraction process, the seaweed is washed, filtered, concentrated, precipitated with either potassium chloride or alcohol, then dried, ground, and blended. Each of the three types of carrageenan produces different structures. Kappa produces a rigid high-strength gel that is thermal reversible. Kappa has the highest degree of milk reactivity. Iota carrageenans produce an elastic gel that is also thermal reversible, have a high salt tolerance, and are thixotrophic. Iota carrageenan in the presence of calcium tends to gel and has low milk reactivity. Lambda carrageenans are non-gelling, enhance viscosity, and have little to no milk reactivity.

8.8 Yogurt Sensory Defects

8.8.1 Body and Texture

Body and texture defects in yogurt are caused by many different factors, but quite often, they may be prevented and/or minimized by following proper and recommended yogurt manufacturing processes. Many of the defects are the result of improper protocols and mis-handling of ingredients and finished product. When looking to correct any given defect, it is important to first identify the cause of the defect, and then apply the corrective action(s).

Following is a list of the most commonly found body and texture defects in yogurt, their causes, and possible corrective actions steps to eliminate or reduce the problem. Some of the corrective actions are most obvious, while some may be more difficult and complex. Many shortcomings may be corrected before they cause problems in the yogurt. It is always important to screen all ingredients prior to processing that are used in the yogurt. Tasting and smelling all the milk and cream ingredients used is obviously the first critical step. Secondly, all dry ingredients such as whey, nonfat dry milk, stabilizers, and sugar should periodically be smelled, and tasted by making a 1:9 solution in either milk or water. Potentially serious flavor defects may be detected if regularly scheduled tasting sessions occur. The sugar storage tanks should be inspected for yeast and mold growth on a regular basis. This is always a potential source of contamination to the finished yogurt and/or potential off-flavors.

Free whey. This is most noticeable by the translucent, greenish-yellow liquid on the surface and around the sides of the cup of yogurt. It has many different causes, such as (1) excessive agitation, especially above pH 4.7, (2) too low a pH because of fast acid development, (3) disruption of the in-vat coagulum before the yogurt was set, (4) heat shock of the yogurt, (5) subjecting the yogurt to extreme temperature conditions, as well as (6) freezing/thawing of the yogurt. Other possible causes for wheying-off are improper pasteurization, homogenization, inadequate stabilization (either too little or excessive), and rough handling of yogurt cups (Bodyfelt et al. 1988; Lyck S. 2004).

In determining a corrective action, it is a good idea to check all processing procedures to ensure correct make methods, times, and temperatures. Checking homogenization efficiency is quick and accurate. Ascertain whether the homogenizer is working properly and whether maintenance is necessary. Confirm thermometer accuracy, and check pasteurization records to confirm that the yogurt base was treated to the proper temperature to denature proteins. It is also advisable to check temperatures in cooling areas as well as refrigerated transit trucks and trailers to confirm proper temperatures are achieved and maintained. Finally, a critical point must be emphasized to not disturb the curd while it is knitting together after the containers have been filled.

Gel like/too firm. This attribute has the appearance of formed gelatin in the cup (or on the plate), and a very firm set. It can also be noticed by pushing the yogurt to the roof of one's mouth and observing the extent of resistance. Yogurt with the more ideal body characteristics (Fig. 8.1) should have little or moderate resistance, and should melt-away very smoothly. Gel like or too firm (Fig. 8.2) can be caused by too high stabilizer usage, or the wrong choice of stabilizer. It can also be caused by an excessively high amount of milk or whey solids in the product base. To correct, simply reduce the use of a specific stabilizer, the amount of total solids, or alternatively contact the stabilizer technical

Fig. 8.1 Ideal yogurt body

representative to confirm proper usage and incorporation of the best or correct stabilizer for the given yogurt mix formulation (Lyck S. 2004).

Weak. This characteristic is observed within a finished product that appears “runny” or too liquid-like, or has little or no residence time on the tongue. When a spoonful of yogurt is placed into the mouth, it should, for a short time, cling to or reside on the tongue. If it does not, and the flavor dissipates rather rapidly, it is considered to be a weak-bodied product. This defect is quite common with “no-fat and/or no-sugar added” yogurts in which a non-nutritive sweetener has been used. It is simply caused by a rather low amount of total solids in the formulation, but it can also be caused by excessive heat treatment or types of agitation that breaks down the gel structure that was created by the stabilizer, culture and proteins, or combinations thereof (Bodyfelt et al. 1988).

Fig. 8.2 Gel-like or too firm yogurt appearance

Correcting this obvious defect requires adding more milk solids, which can add to ingredient costs, or the manufacturer may need to consider an alternative stabilizer (Lyck S. 2004).

Shrunken. This defect is characterized by the yogurt itself pulling away from the side of the cup and leaving a gap, which usually fills in with free whey (Fig. 8.3). The causes of shrunken defect are many, but fortunately, the corrective action is relatively easy. Defect causes can include heat shock (temperature abuse), too high acid production, too high stabilizer usage or incorrect stabilizer used, or disruption of the yogurt mass – after container filling and while the yogurt is knitting together.

To correct this defect, first try to identify and confirm what is causing the issue, then implement heightened control to prevent this from happening. Make sure that after the product is cup-filled and placed into the cooler, it is not moved until the yogurt has a chance to knit together. Check thermometers to determine proper calibration, and review batch sheets to confirm that proper formulation occurred (Lyck S. 2004).

Grainy. This defect is associated with detection of small particles on the tongue surface. It is an objectionable texture shortcoming that is quite noticeable and un-appealing. The defect causes are harder to determine, because the occurrence of this defect is typically an inconsistent event. Some of defect causes are heating the base milk at too high a temperature, or increasing the temperature at a too rapid rate, such that the protein precipitates out. Another cause is from too high and too rapid acid development due to high fermentation temperature, agitation during acid development, or improper mixing of the starter culture. Graininess may be reduced by routing the yogurt through a screening device prior to cup filling, since this eliminates the small lumps of the coagulum (Lyck S. 2004).

Ropy. Ropy yogurt texture is detected by placing a spoon into a yogurt mass, lifting the spoon. If the observer readily views a trailing stream (or stringiness)

Fig. 8.3 Shrunken yogurt exhibiting free whey

of yogurt between the spoon edge and the product container, it is Ropy. This defect can be confirmed by placing the bottom of the spoon on top of the yogurt mass and slowly raising the spoon vertically for 5–13 cm (2–5 in.). If there is a tail or string of more than 2 in., the product is considered “ropy”. Ropy yogurt normally has a “slick” mouthfeel. Such yogurt body is also often defined as slimy. Ropy-like body in yogurt is usually the result of five different causes: (1) improper stabilizer or gums, (2) microbial contamination, (3) use of yogurt cultures that contain polysaccharide-producing bacteria, (4) improper setting temperatures, and (5) too high sugar content in the product base (mix). If the “long texture” is being caused by contamination, there is sometimes an associated offensive odor with the off-body incident.

To correct the negative attributes associated with ropy body/texture, one should first check the calibration of the thermometers on the setting vat. Next confirm the product formulation to ensure that proper amounts of each ingredient have been added. Also check that any in-line filters or shearing devices designed to smooth the texture are present and working properly. If these parameters seem acceptable, then contact the stabilizer technical representative and the culture supplier to determine future options or corrective actions. Also check the CIP-cleaning charts to determine that vats, lines, and all equipments are being cleaned and sanitized properly (Lyck S. 2004).

8.8.2 Color and Appearance Defects

Atypical color. Atypical color (Figs. 8.4 and 8.5) is when the color of the yogurt does not represent the flavor of the named or labeled yogurt. For instance, a strawberry-flavored yogurt should be a creamy-light red to pleasant pink color. If this color is either too dark, or too light, or possibly the given yogurt has a different color all together, the observed color is considered “atypical” for that flavor of yogurt. Atypical color is usually observed in those products that are

Fig. 8.4 Strawberry yogurt exhibiting atypical color (*light*) (*See* Color Plates)

Fig. 8.5 Atypical color (*dark*) (*See* Color Plates)

labeled "all-natural", or use lower quality fruits or flavorings, or colorants that are not stable under low-acid conditions. It has also been observed that yogurts and yogurt fruit flavorings that have been stored at improper temperatures may lose some of their sensitive pigments. This is typically caused by an oxidation reaction of the fruit.

Problem corrections involve the utilization of only high-quality fruits and fruits-based materials that have acid-stable color, plus storage of yogurt and fruit flavorings under proper temperature conditions.

Color leaching. This defect reflects a difference in color between the yogurt mass and the added fruit. Color leaching (Fig. 8.6) commonly shows up as a ring or a halo effect around pieces of fruit or berry, which is caused by a difference in

Fig. 8.6 Color leaching (*See* Color Plates)

osmotic pressure between the fruit piece and the yogurt mass. This pressure difference may be the result of different sweeteners used: (1) in the fruit and (2) in the yogurt mass. Color leaching can also be caused by using yogurt fruit that has an added color that is not acid-stable, fruit that has had excessive color added, or by using a fruit source that has not been properly stabilized.

Correction, or better control of the color-leaching issue, may be realized by communication with fruit suppliers, confirming the final use of various fruit-based products, and confirmation that these flavor sources are properly stabilized for the purpose of using them in cultured yogurt. Another option would be to substitute some of the fructose used in the yogurt. This could possibly reduce osmotic pressure differentials between the yogurt and the added fruit pieces.

Lacks fruit. This visual defect (Fig. 8.7) is either the result of an insufficient amount of fruit added or usage of a poor-quality fruit that when a minimal amount of agitation is applied to blend the fruit and yogurt mass together, the fruit simply breaks apart and seems to disappear and leads to the impression of being insufficient.

To best prevent or control the frequency of this defect, one needs to confirm that the proper amount of fruit has been added. Use of higher quality fruit that can withstand minimum or typical amounts of agitation and avoidance of excessive pumping and agitation can go a long way to minimize the "lacks fruit" defect in yogurt.

Excess fruit. This yogurt appearance defect is usually provoked by excessive quantities of fruit being added and mixed into the yogurt mass, presumably via improper calibration of metering devices. This costly situation and less than optimal yogurt ingredient balance can usually be rectified by checking and re-checking product-to-product formulation and calibration of pumps and metering devices.

Lumpy. This unpleasant appearance defect causes the yogurt mass to appear rough, uneven, and non-homogenous. It somewhat resembles the surface of cauliflower. Lumpy yogurt (Fig. 8.8) is unattractive although it may not affect

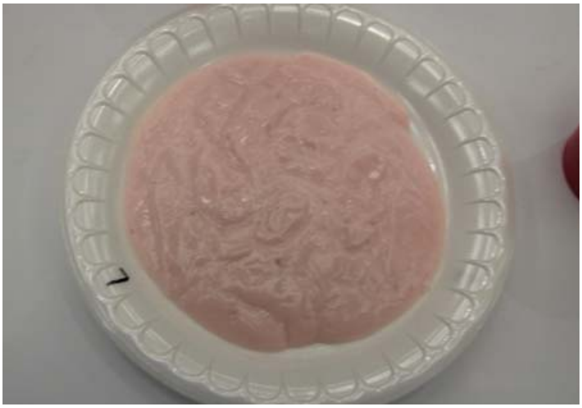

Fig. 8.7 Lacks fruit

Fig. 8.8 Lumpy

the eating quality of the yogurt. It is noticed after it has set-up and knit together as a smooth and uniform coagulum or custard-like light pudding. The subsequent development of the lumpiness may be caused by (1) improper stabilization, (2) the use of too much gelatin as a stabilizer, (3) inadequate agitation at the time the product is broken, (4) not passing the product through a smoothing-device prior to adding the fruit flavoring, (5) filling the yogurt at too high of a temperature (therefore the culture continues to grow) or (6) filling the cups of yogurt at an improper pH value or at too high pH (incomplete, weak fermentation attained).

To minimize and eliminate the lumpy defect, determine that the proper amount of stabilizer has been added to each yogurt mix. Consultation with stabilizer technical representatives may be advisable if yogurt lumpiness prevails. Cooling all yogurt batches to 21°C (70°F) prior to packaging, allowing the finished yogurt adequate time to agitate prior to filling, and the use of a smoothing-device helps eliminate this issue.

8.8.3 Flavor Defects

High acetaldehyde. Acetaldehyde is the chemical compound responsible for the traditional green-apple flavor produced by yogurt bacteria. This flavor note is common in practically all yogurts. It is noticed at the end or near the end of the tasting sequence, and typically lingers for some time. This flavor note is quite similar to a green-apple hard candy. As mentioned, it is a natural, always present flavor common to yogurts. A problem exists if a given yogurt exhibits too high an amount of the acetaldehyde note for many consumers or "would-be" consumers of yogurt. If the green-apple flavor is clearly distinguished in combination with other acidic flavours, it is presumed to be at too high a level.

There are quite a number of reasons for high levels of acetaldehyde in yogurt, particularly in plain (non-flavored) yogurts. Some of these reasons are (1) improper culture, (2) incorrect set temperature, (3) insufficiently low storage temperature, and (4) the yogurt was broken at too high a pH (Tribby, D. 2001).

Bitter. This yogurt defect is characterized by an offensive aftertaste that is sensed at the back of the throat and at the end of the tasting sequence (i.e., delayed detection). This defect is caused by the use of poor quality or old milk that has been contaminated with psychrotrophic or spoilage bacteria or with certain starter cultures with proteolytic activity. Bitterness can also be caused by poor-quality yogurt ingredients, such as NFDM powder, dry whey, as well as fruit flavorings, or by using starter culture that is either old or contaminated. Another potential reason for bitter flavor development is finished products being stored at too high a temperature (Bodyfelt et al. 1988).

Using fresh, high-quality yogurt ingredients and milk suffices to eliminate many potential points of contamination. A prime safeguard is to screen all incoming ingredients and fruit, use a regular rotation of starter cultures, and to assure that proper techniques are used when transferring cultures from the bulk tank, or transferring from the culture freezer to the culture tank.

Cooked. A slight to moderate intensity of cooked flavor is considered a desirable attribute by many yogurt producers, depending upon the relative intensity or severity. Cooked is typically perceived nearer the end of the tasting cycle at the top and the back of the throat. Cooked may have an aroma like that of caramelized sugar, or butterscotch; others are reminded of an eggy-like flavor sensation. Cooked notes are usually caused by higher than optimum pasteurization temperatures and/or holding times. Other dairy ingredients that have undergone severe heat treatments, such as nonfat dry milk, condensed milk, or whey, may also be a cause of this type of flavor note in yogurt. If large amounts of high-fructose corn syrup have been used as a product sweetener, this may also provoke this defect. Fruit preparations that have a jammy consistency and flavor, and are added at high levels, can also give the product a cooked flavor. If the cooked flavor is at a level that is particularly noticeable or overpowers the given yogurt flavor, then it is considered a defect.

Close monitoring of the pasteurization system can suffice to minimize or eliminate the cooked defect; and careful screening of all incoming raw materials against severely "heated" off-flavors is also most helpful.

Atypical (foreign). An atypical flavor defect in most dairy products is usually caused by the presence of an out-of-place aroma and/or an off-taste, reminiscent of residual cleaner, sanitizer, lubricant, or some other out-of-place material within the processing system. Also, the use of excessive amounts of potassium sorbate as a mold inhibitor causes a foreign off-flavor. Many such atypical and objectionable flavor off-notes are generally detected on the middle-backside of the tongue recognized as either an off-taste or as an off-aroma. Or, in the case of potassium sorbate, a burn on the middle of the tongue.

The serious aspect of the Atypical (Foreign) off-flavor is that QA and production staff must prevent it from happening in the first place. All plant personnel have to be absolutely sure that all tanks and lines have been properly rinsed and drained prior to use.

Potassium sorbate is used to control yeast and mold in yogurt thereby extending shelf life. Ways to eliminate this particular defect include (1) adding sorbate to yogurt base directly, (2) requesting that the fruit supplier add potassium sorbate to the fruit, (3) reducing or eliminating potassium sorbate, (4) switching to a different mold inhibitor, or (5) using hepa-filtered fillers to eliminate spore contamination.

High acid. A certain amount of acid needs to be present in yogurt in order to coagulate the proteins and form the coagulum typical of this product. If the acid level becomes too high, the acid taste becomes too sharp, harsh, and/or offensive to a majority of consumers. In addition, the intense acid taste masks the other flavor notes of the yogurt. If the acid flavor is too low, the product will become flat tasting and will seem too sweet and candy-like. It is important to have the correct balance between sweet and sour. The defect of high acid is caused by many factors, such as (1) improper set temperature, (2) too low a break pH, and (3) insufficient or slow cooling after the yogurt has been broken. It is noticed as a severe acid intensity on the front and sides of the tongue, ranging from the beginning to the middle of the tasting cycle. Certain yogurt cultures are also more acid tolerant and capable of acid production during the first weeks of storage of the finished product.

In order to best control against development of the high acid defect, it is important to first check the calibration of the involved thermometers. Second, it is important to monitor the cooling process and determine if the product is being cooled properly. Other control strategies for limiting the high acid off-flavor of yogurt are as follows: (1) make certain that the yogurt is being broken at the proper pH, (2) make certain that the correct yogurt cultures are being used or changed to milder cultures, (3) check the formulation to confirm that the correct acid/sweetness balance is achieved through the formulation, and (4) assure that the proper amount of sugar is added either in the base or through the added fruit (Tribby, D. 2001).

Low flavoring. This is not necessarily a product defect, but may cause the given yogurt to be perceived as not being of the highest quality. In some instances, the low flavoring defect is the result of poor quality flavorings, or an improper amount of flavor being added to the fruit or yogurt base. Checking to insure that the specified amounts of flavoring are being added and blended or changing the flavoring system should solve the problem.

Lacks fine flavor. This comment is used to describe yogurt that is generally a good yogurt but is missing a key attribute that makes it a very good yogurt. It could be product that may be to the end of the shelf life or product that may have had some older fruit used to flavor the yogurt. When "lacks fine flavoring" is used, it usually is given to yogurt that may have some other defects that are not advanced enough to impart a negative flavor, but contribute slightly to bring down the overall quality of the yogurt.

Lacks freshness. This unfavorable flavor defect of yogurt is usually noticed at or near the end of the tasting sequence, perhaps even after swallowing the product. “Lacks freshness” has either a stale off-flavor, a storage off-flavor, or happens to be a product that is at or near the end of its shelf life. Lacks freshness of yogurt may also be the result of using old fruit, or some ingredient that has not been stored under proper temperatures or conditions. Ingredients such as NFDM, whey, or stabilizers can and will contribute to this off-flavor, if they have been subjected to high storage temperatures and/or offensive smelling storage or transportation conditions.

It is important to screen all incoming ingredients for potential off-flavors prior to their use in product formulation. The implementation of an aggressive ingredient stock rotation program (with documentation) and adherence to ingredient shelf life recommendations is an important prerequisite for consistently high-quality yogurt.

Low sweetness. This yogurt attribute (or defect) is generally associated with improper formulation and the result greatly impacts the eating quality of the yogurt. It may also be caused by overheating the mix prior to inoculation or by use of an improper blend of sweeteners. Several of the non-nutritive sweeteners are not as heat-stable as sucrose or high-fructose corn sweetener and therefore they may have had some of their sweetening potency reduced during pasteurization. Also contributing to sweetness is the balance with the pH (or acidity level) of the final product. If the acidity level of the finished product is too high, it will detract from or take away the perception of sweetness in the finished yogurt.

Low acid. Inasmuch as yogurt is considered to be a cultured dairy product, and hence should exhibit an acid taste, it is quite noticeable to the taster or consumer when it lacks an “acid” profile. In yogurt manufacture, there are a number of causes for a finished product to not have a sufficient amount of acid. Typically, low acid is attributed to either too low a setting temperature, a poor quality or inactive culture, or breaking the fermentation prematurely. Yogurt culture “inactivity” can be caused by the presence of inhibitor substances such as (1) residual cleaning compound or sanitizers, (2) an antibiotic in the milk supply, or (3) it may be the result of bacteriophage attack on the starter culture. All of the aforementioned “inhibition incidents” adversely affect the growth of the yogurt bacteria and prevent them from developing the proper pH of the finished product.

For yogurt manufacturing plants, appropriate culture handling programs include (1) comprehensive sanitation programs, (2) personnel training to maintain proper GMPs, (3) a rotation program for the culture strains (established to neutralize bacteriophage lysis of cultures), and (4) routine calibration check of thermometers (to assure that the proper culture incubation protocols are achieved). If slow vat sets occur frequently, it is important to monitor culture freezer temperatures to ensure that cultures are maintained at proper temperatures in order to assure culture activity.

Metallic. The metallic defect has decreased in the last several decades due to the elimination of metals other than stainless steel in dairy plant piping and equipment. The earlier generation of softer and copper-bearing dairy metals triggered serious and objectionable metallic off-flavors very frequently. With the universal use of stainless steel, metallic-type off-flavors are nearly a "defect of the past".

Elimination or good control against the development of any metallic off-flavors in yogurt milk and/or finished yogurt products requires the use of all stainless steel equipment and utensils within all milk handling and transport, throughout the plant. Water supplies are another place to be on constant guard against the presence of even moderate concentrations of divalent cations (Cu, Fe, and Mn). Depending upon the given region of the country, many areas have hard water, which increases the likelihood of having some unwanted minerals in the water. The presence of these minerals can be controlled or eliminated by the use of either water treatment and/or sanitary filters. Mineral additions to yogurt for nutrition reasons can be a source of metallic flavors. Sensory screening of mineral fortifiers and dairy ingredients should suffice to identify any possible metallic off-flavors. In hard water areas, regular scheduled checks of scale build-up on boiler pipes is an appropriate precaution against metal ions being incorporated into the finished products through steam.

Old ingredient. This defect may be one of the most offensive in yogurt or any dairy product. It is described as a "dirty sock" or "dish rag" flavor, and usually is noticed at the end of the tasting sequence. The flavor hangs around quite long after the product is expectorated or swallowed, and does not clean up very well. Either old or out-dated product or contamination from dirty equipment or ingredients frequently causes this off-flavor. Processing milk that is older than 48 h (uncommon today) can cause the old ingredient flavor defect. Using a yogurt starter culture that produces only rather low amounts of acidity may also be a cause.

To prevent the old ingredient defect from occurring, all incoming ingredients need to be flavor-screened prior to acceptance. Also, an ingredient rotation system should prevent product from becoming old and out-of-code. Periodic inspections of the CIP system to confirm that it is working properly is most helpful, as well as conduct of examinations of equipment for cleanliness and sanitation.

Oxidized (light-activated). Oxidized yogurt is recognized by a distinctive "card boardy" or "burnt hair/burn feathers" odor and off-flavor that is caused by the products or ingredients being exposed to either ultraviolet light or direct sunlight. Severe cases make the product unsaleable. This objectionable off-flavor usually is noticed at the middle of the tasting cycle. Added vitamins, particularly Vitamin C, can cause a cardboard-like off-flavor when they oxidize in the product due to light oxidation.

Rancid. This defect, if observed, may lead to the decision that the given yogurt is unsaleable. It is noticed either by the characteristic aroma of hydrolytic rancidity or by its unique off-taste, with bitter taste at the end of the tasting cycle in the back of the throat. It also has an off-smell that resembles feta cheese. The mixing of pasteurized and un-pasteurized milk and cream causes hydrolytic rancidity. It may also be caused by excessive mechanical agitation or freezing of raw milk. Holding raw bases after ingredient blending operations for extended periods of time prior to pasteurization (and inactivation of native milk lipase) will also cause this defect.

To prevent rancidity from occurring, it is extremely important to pasteurize all milk and cream to inactivate the lipase enzyme, and prevent all mixing of unpasteurized milk and cream with product that has been homogenized. Eliminate as much mechanical mixing of the product prior to pasteurization as possible.

High flavoring. This defect is easy to detect and to remedy. It is the overwhelming flavor that is caused by the addition of too much of the individual fruit flavor base, or adding too much flavor itself. It usually is picked up in the middle of the tasting experience and remains on the tongue for an extended time after the yogurt has either been swallowed or expectorated.

This defect can easily be remedied by either reducing the amount of fruit flavor that is added or by asking the fruit supplier to reduce the amount of flavor that is in the fruit. It is also a good idea to check and calibrate the pumps that are used to add the fruit to the base to determine that they are in proper calibration.

High sweetness. This defect is usually the result of an unbalanced formulation that contains either higher than normal amount of sweetener or a wrong acid sweetness profile. It is noticed at the first start of the tasting process in the middle of the tongue, and lasts until the tasting sequence is over.

The first remedy is to review the formulation to determine if the recipe was followed properly. Second, if a blend of sugars is used, either high fructose or sucrose, review should be done to make sure the proper ratio has been followed. Finally, if there is not sufficient acid produced by the cultures, or by the fruit, the acid/sweetness balance will not be proportional and the product will taste sweeter than normal. A simple pH measurement will determine if the product pH meets the specifications.

Unnatural flavor. An unnatural flavor defect refers to any detected flavor that is not the listed flavor on the packaging label. An example would be if a product was labeled "strawberry-flavored yogurt" and when the product was tasted, it instead had a flavor more typical of raspberry, than of strawberry. This defect may also be caused by the excessive use of flavor concentrates, poor-quality flavor concentrates, or the use of poor-quality fruit that has been fortified with other flavors either natural or artificial that are not typical of the named flavor. Sometimes if the acid/sweetness profile is not balanced, the product may have a different flavor profile than the yogurt processor intended. Even human error may be involved in the cause for this flavor defect. It is a common practice to push out the proceeding flavor on a production line with the next flavor to be packaged. An example would be if the processor is filling strawberry-flavored yogurt and the next flavor is raspberry. There will be some mixing of products in the line, and it is up to the operators to ensure that this mixed product is not packaged. If a miscalculation is made, there may be some product that was filled under a different flavor.

Unclean. This defect is characterized by a “dirty sock” flavor and the mouth simply does not “clean-up” (the lingering unpleasant aftertaste remains). It is noticed at the end of the tasting cycle and lingers in the mouth for an extended time. The defect cause is usually the result of microbial contamination of the raw materials, the yogurt cultures, or processing equipment. It is generally presumed that the causative microbial agents are psychrotrophic bacteria (low temperature growing, Gram negative, spoilage bacteria).

The unclean defect may be an important indication that processing equipment is not being cleaned and/or sanitized properly. Thorough inspection of the yogurt making and filling equipment should be conducted. Proper screening of all incoming ingredients should be conducted to determine if the problem may be caused by product that is being added such as milk, cream, nonfat dry milk, whey, fruit, etc. An inspection of how the starter culture is added to the yogurt vat should be conducted to determine if any contamination occurs at this point due to poor aseptic inoculation technique.

8.9 Procedures for Sensory Evaluation

The preparation for evaluating yogurt samples may be as critical as evaluating the samples themselves. Selecting the proper facility or location has an important effect in the way the samples are viewed. Make sure that proper attention is given to this objective.

It is important to select a room or area that has adequate natural lighting. The enhancement of product colors and the range of color and appearance defects, when using natural lighting without any shadows is invaluable. It is also important to select a location that is free of off-odors. Odors such as lab extraction smells, petrochemicals, ammonia, cleaning compounds such as chlorine, or sewer gas will effect the evaluation.

Ongoing product review in yogurt plants occurs on a regular basis and should be scheduled at a consistent time and location. Samples may be evaluated daily to review the prior days production, and possibly end of shelf life or accelerated storage products.

When determining who should attend the product review, it is suggested that anyone who has direct contact with the process or product essentially resides in a “pool” of potential participants, who have some level of interest and concern. The processors who do the blending, processing, yogurt batch break, adding fruit and filling all should or need to be involved, as well as QA, R&D, and plant management. In addition, sales and marketing representatives may want to be involved if they reside in the general area. By reviewing the products, these people have a direct responsibility and ownership in the product's success. They will be able to see both the good job that they are doing, as well as areas or opportunities for improvement.

When setting up an evaluation process, it is important to decide if the purpose is to evaluate the previous days' production in order to determine whether the product meets the requirements. Alternatively, the objective may be to review retained product for the purpose of observing how the product holds up during shelf life studies. Regardless, samples need to be selected and placed in a safe location that is representative of the conditions of the cooler or distribution process. Many processing plants have a section of the cooler that is dedicated to samples only. This potentially eliminates any issues with product being removed. Throughout the processing day, samples need to be pulled routinely and labeled for time and date. These samples then may be pulled in a series of different dates to review shelf life. It is common that for each day of product review, samples from the previous day are reviewed as well. Products in the middle of shelf life and at the end of shelf life should also be reviewed. This process provides a good indication of how the product holds up during a normal shelf life, and will warn of possible issues that are noticed. Issues such as flavor, color, or the beginning of a yeast or mold problem may be addressed before the problem progresses to an "advanced stage".

It is important to look at the product that has been retained in the cooler, and the product that has been through the distribution/marketing process. These samples may be obtained by simply purchasing them at a local grocery store. These samples are more representative of what the consumer will be purchasing, because they have been subjected to temperature changes and handling issues. Many times there are defects that show up when the product is shipped to a warehouse that are not noticed in the samples kept in the plant cooler.

When setting up the samples for review, examiners look first at the outside of the container. They notice any smudges on the package, and whether the code date is easy to read and in the proper place. The next step is to open the container without disturbing the yogurt and view the top of the cup, particularly noticing any possible mold or yeast growth, discoloration, or whey or watery liquid exudates. The observers also look around the sides of the cup for possible indications that the product may have shrunken. Finally, the cup is tipped upside down on a plate and the cup bottom is punctured. The cup is lifted off and the yogurt "mound" left on the plate. Notice is made of any unusual aromas. A spatula or a knife is used to scrape out the remainder of any yogurt in the cup bottom.

The precise time that the product is placed on the plate is noted. This is important, because yogurt will change in appearance as it warms up. Most visual changes occur after it is been left at room temperature for more than 15 min. After the yogurt has been placed on the plate, observers first notice the yogurt appear on the plate. For most yogurts, it should resemble a thick pudding with little to no running. Next notice if there are color streaksance associated with “color leaching”, and any unusual color. There is a wide range of colors for yogurt, but generally, it is most acceptable to have a color that is “true to the natural fruit”. If a blueberry yogurt is being made, then the color should be similar to the color of a fresh blueberry, if a strawberry, then that of a fresh strawberry. If the yogurt color is very pale or extremely dark, the product is characterized as “atypical color”. Otherwise, the color variable is very wide.

A spoonful of yogurt is placed in the mouth and notice of how the yogurt clings or sticks to the tongue and sides of the mouth is made. Also, how fast the yogurt dissipates off the tongue as it is being moved around the mouth determines if the product is judged to be weak. If the yogurt is low in total solids, the yogurt and flavor will dissipate, thus it is perceived to be weak. After noticing the texture and mouthfeel, the first flavors and sensations perceived and where in the mouth they are observed are recognized. One of the first sensations is the acidity of the yogurt. The sensation is on the sides of the tongue. Sweetness is also one of the first flavors perceived. It is noticed in the front and middle of the tongue. Sensing too high an amount of acid and sweetness can cause these flavor notes to be over-powering. Also noticed at the beginning of the tasting cycle may be strong off-flavors like oxidized, atypical (foreign), old ingredient, unclean, and yeasty.

It is advisable to not swallow the yogurt, but expectorate it (spit it out). Therefore the flavor will not stay in the mouth for a long time afterward. After the acid and sweet sensations, the next flavors that are noticed are cooked, too high flavoring, low flavoring, and some of the stabilizer flavors. Also noticed at this time are the high-intensity sweeteners and different types of sweeteners such as acesulfame potassium, aspartame, and sucralose.

Finally, at the end of the tasting cycle (after expectorating), some flavors that are not associated with being the most pleasant are noticed. These include rancid, bitter, old ingredient, lacks freshness, unnatural flavors, and acetaldehyde. Also noticed at the end are some of the preservatives such as potassium sorbate and sodium benzoate. These are noticed after spitting out the yogurt and a burn is typically perceived in the middle and back of the tongue.

The USDA scorecard system (Fig. 8.9) prescribes different penalties for different attributes and defects. These disparities are not arbitrary. Defects arising from egregious manufacturing errors, such as rancid, old ingredient, foreign, or oxidized, or spoilage issues, such as unclean or yeasty require greater penalties than less serious defects, such as low acid, high acetaldehyde, etc., which are less severely penalized (Table 8.1). The origin and remedies of the defects described in this chapter make it clear how to avoid these problems, and sensory evaluation is an invaluable tool that should be made a part of any quality assurance program.

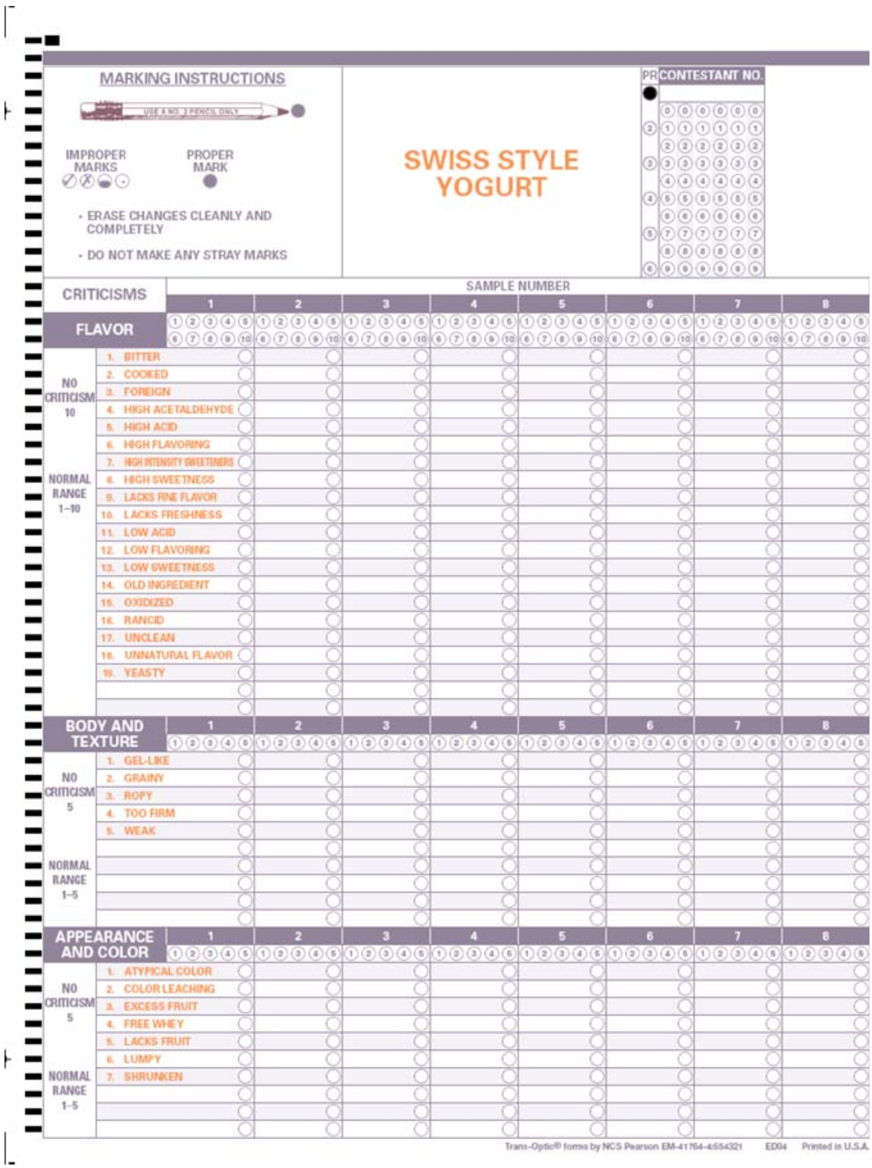

Fig. 8.9 USDA Swiss Style Yogurt scorecard

A scorecard should suggest priorities for improving a product, tracking perceived attributes to likely origins, and indicating processing and product handling improvements. Perfect scores include 10 for flavor, 5 for body and texture and 5 for color and appearance sections.

Table 8.1 Suggested scoring guide (ADSA) for flavor and body and texture and appearance and color of strawberry Swiss style yogurt for designated defect intensities

Swiss style yogurt			
Flavor	Slight	Definite	Pronounced
Bitter	9	7	5
Cooked	9	8	6
Foreign	8	7	6
High acetaldehyde	9	7	5
High acid	9	7	5
High flavoring	9	8	7
High intensity sweetener	9	7	5
High sweetness	9	8	7
Lacks fine flavor	9	8	7
Lacks freshness	8	7	6
Low acid	9	8	6
Low flavoring	9	8	7
Low sweetness	9	8	7
Old ingredient	7	5	3
Oxidized	6	4	1
Rancid	4	2	*
Unclean	6	4	1
Unnatural flavor	8	6	4
Yeasty	6	4	2
Body/texture			
Gel-like	4	3	2
Grainy	4	3	2
Ropy	3	2	1
Too firm	4	3	2
Weak	4	3	2
Appearance/color			
Atypical color	4	3	2
Color leaching	4	3	2
Excess fruit	4	3	2
Free whey	4	3	2
Lacks fruit	4	3	2
Lumpy	4	3	2
Shrunken	4	3	2

8.10 Conclusion

The ability to analyze dairy products is an invaluable tool that can have lasting benefits to the dairy industry. To correct negative attributes in yogurt, the first step is to identify the problem in order to understand the root cause. To look at the appearance, feel the body of the yogurt in the mouth, and be able to identify the flavor attributes, both positive and negative, is the best means to remedying the problem. To become proficient in sensory evaluation can save a business time and money; it is a valuable tool for anyone associated with yogurt manufacturing. With training, patience and practice, it can be mastered.

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