CHAPTER 2
LITERATURE REVIEW

2.1 Black glutinous rice

2.1.1 Composition of rice

Rice is the most important cereal on the globe, being the main source of energy and income for the majority of the world's human population. Aside from being the staple food, or a carbohydrate component of a meal, rice is also used in numerous industrial applications. Its use in the diet and in industry depends on its cooking properties. There are two types of starch in the rice grain, amylose and amylopectin. The proportions and structures of the two types of starch are the main factors that affect the cooking quality of rice. Previous studies have shown that amylose has a huge impact in the cooking quality of a rice variety but it cannot be used as a sole predictor. It is also important to determine the effects of the other grain components on the cooking quality (Cuevas and Fitzgerald, 2011).

Amylose is mainly a linear form of starch. The amount of amylose in the grain determines how sticky the rice will be when it is cooked. As amylose content increases, the rice grains become less sticky and more firm. Some varieties do not have amylose in them because of a mutation in a gene called waxy gene. These varieties, called waxy or glutinous rice, are sticky when cooked, and are eaten mainly in South East Asia (Cuevas and Fitzgerald, 2011).

Amylose is considered to be a linear polymer, containing the α-1,4-glycosidic linkages. It contains 300-1000 glucose molecules. Though there is evidence that amylose is not completely linear, its behavior is that of a linear polymer (Vegh, 2012).

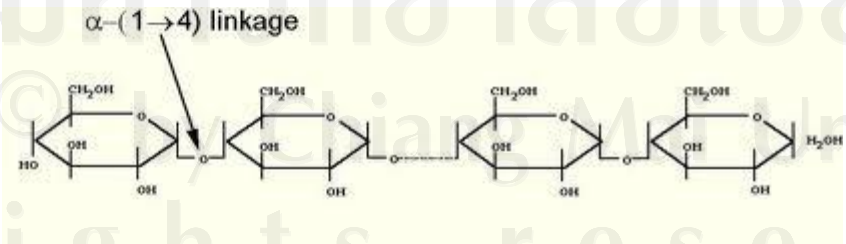

Figure 2.1 Structure of amylose (Cuevas and Fitzgerald, 2011)

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Amylopectin is a highly branched form of starch. Its structure is organized into different levels, with each level contributing to the overall effect of amylopectin on cooking properties (Cuevas and Fitzgerald, 2011). The presence of amylopectin on the qualities of black glutinous rice solution was part of the investigation in this research.

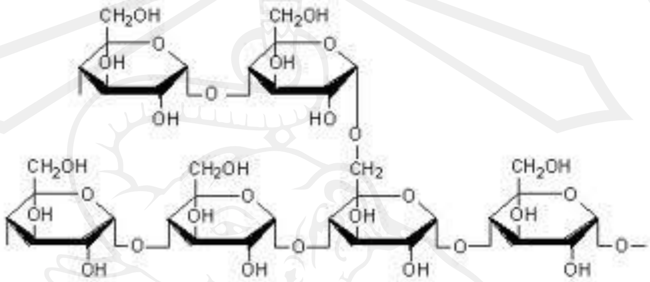

Figure 2.2 Structure of amylopectin (Cuevas and Fitzgerald, 2011)

The physical and chemical properties of amylose and amylopectin are different. Their ratio affects viscosity, shear resistance, gelatinization, textures, solubility, tackiness, gel stability, cold swelling and retrogradation properties of starch. All these properties have high importance in the suitability of the starch of a given crop for various processing and use (Vegh, 2012).

There is a central role of starch in determining cooking and eating quality of rice. Starch structure, the ratio of amylose to amylopectin has a close correlation with rice quality. Starch in waxy rice varieties has an amylose content of 0.8-1.3 percent probably located in the centre of the starch granule. Amylose content of the starch of nonwaxy genotypes is ranging from 8-37 percent. Waxy and nonwaxy rice starch granules have similar gelatinization temperatures, which are in the range from 55-79°C from the beginning of the process to the final gelatinization. Volume expansion and water absorption during cooking are positively, while stickiness and tenderness of cooked rice are negatively correlated with amylose content (Vegh, 2012).

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2.1.2 Antioxidant in plant products

Black rice has a number of nutritional advantages over common rice, such as a higher content of protein, vitamins and minerals, although the latter varies with cultivar and production location. Anthocyanin pigments have been reported to be highly effective in reducing cholesterol levels in the human body. Inhibitory effects of extracts of pigmented rice bran on in vitro allergic reactions have been previously determined. Effects of peonidin, peonidin-3-glucoside and cyanidin-3-glucoside, major anthocyanins extracted from black rice, also exerted an inhibitory effect of cell invasion on various cancer cells (Sompong et al., 2011).

Anthocyanin-pigmented or colored grains hold promise as functional foods (e.g., whole grain products) or functional food colorants (e.g., anthocyanin-rich grain fractions). At present, blue and purple corn grains are used for making blue or pink tortillas. Purple wheat is crushed into large pieces, which are spread over the exterior of multigrain bread (Bezar, 1982). Red rice has been a functional food in China and is commonly used as a food colorant in bread, ice cream, and liquor (Yoshinaga, 1986). Purple corn has been identified as a food colorant since 1977. Anthocyanin pigments are located in certain layers of the kernel, which could be separated into anthocyanin-rich fractions for use as functional colorants or functional food ingredients. In wheat, the blue pigments are located in the aleurone layer, whereas the purple pigments are concentrated in the pericarp layers (Zeven, 1991). The highest concentration of anthocyanin pigments in corn was found in the pericarp, whereas the aleurone layer contained small concentrations (Moreno et al., 2005). Currently, grape skin and red cabbage are the main concentrated sources of anthocyanin colorants.

Although an extensive scientific literature on the composition of anthocyanins in fruits and vegetables exists, little is known about anthocyanin composition in grains. Early studies have shown that cyanidin 3-glucoside and peonidin 3-glucoside are the major anthocyanins in purple wheat and purple rye as detected by paper chromatography using rhubarb and plum extracts as standards. In a recent liquid chromatography study, cyanidin 3-glucoside was the most predominant anthocyanin in purple wheat and the second most common in blue wheat, whereas the first major anthocyanin in blue wheat remained unidentified (Abdel-Aal and Hucl, 2003). In

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corn, cyanidin 3-glucoside, cyanidin 3-(6"-malonylglucoside), and cyanidin 3-(3",6"-dimalonylglucoside) were the major anthocyanins, with cyanidin being the main aglycone or anthocyanidin, accounting for 73-87% of the total. A similar anthocyanin composition was also found in corn flowers. Black rice contained a wide range of total anthocyanin content, with cyanidin 3-glucoside being the most common anthocyanin (0.0-470 mg/100 g) in most of the 10 varieties studied, whereas peonidin 3-glucoside (0.0-40 mg/100 g) was the second dominant anthocyanin. Black sorghum possessed the highest total anthocyanin content among selected black, brown, and red sorghum cultivars with luteolinidin and apigeninidin being the major deoxyanthocyanidins in black sorghum, accounting for 50% of the total anthocyanins. These studies show substantial differences in anthocyanin content and composition between grains and their potential as natural food colorants (Awika et al., 2004).

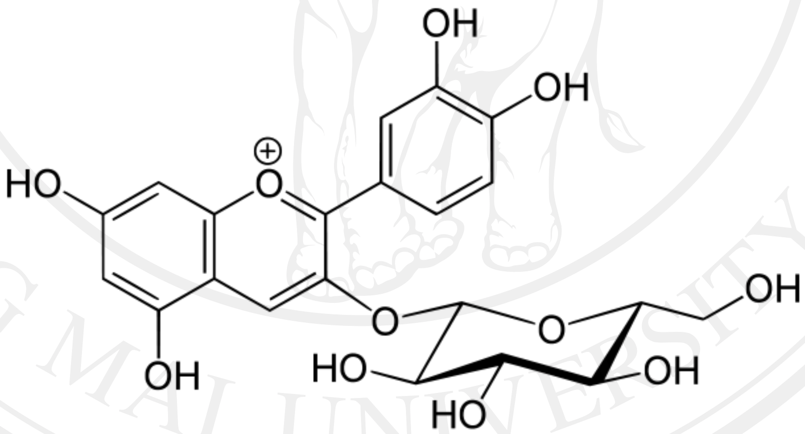

Figure 2.3 Cyanidin 3-glucoside (Abdel-Aal and Hucl, 2006)

2.2 Processing of rice by heating

2.2.1 Soaking

Soaking is an essential step in wet-milling. Water diffuses into the rice kernel and some components leach out during soaking. Both phenomena are functions of time and temperature. The leached out components include soluble protein, sugars, and non-starch bound lipids. The uptake of water resulted in an increase in softness of wheat kernel and reduction in damaged starch. This could also happen in rice kernels.

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Although soaking has been practiced commercially for preparing rice flour, the effect of soaking on the particle size and damaged starch of flour remains unclear (Chiang and Yeh, 2002).

Soaking is an essential step in wet-milling of rice flour. The effects of soaking duration and temperature (at 5 and 25°C) on the properties of rice flour have been investigated. The uptake of water by rice kernels increased with temperature and reached a plateau at about 30-35%. Protein, lipid, and ash leached out during soaking. The moisture content after soaking appeared to be a key factor on loosening the structure of rice kernels, which resulted in the production of small particle flours with little starch damage. The particle size of flours did not alter the gelatinization temperature (T_o and T_p) in differential scaning calorimetric thermograms (Chiang and Yeh, 2002).

2.2.2 Rice Milling

Rice milling is the process that helps in removal of hulls and bran's from paddy grains to produce polished rice. Milling is a crucial step in post-production of rice. The basic objective of a rice milling system is to remove the husk and the bran layers, and produce an edible, white rice kernel that is sufficiently milled and free of impurities. Depending on the customer requirements, the rice should have a minimum of broken kernels (Yadav and Jindal, 2007; Lamberts et al., 2007).

Yafang et al. (2011) studied the total phenolic content, total flavonoid content and total antioxidant capacity of rice grains that were ground to pass through a 100 mesh sieve on a Cyclone Sample Mill. The results showed that rice grains with extremely small size or low 100-grain weight generally had higher phenolic content, flavonoid content and antioxidant capacity than grains with normal or large size. Phenolic content and antioxidant capacity of rice grain are significantly correlated with each other. The phenolic content could be indirectly predicted by grain length and 100-grain weight. Therefore, new rice varieties high in antioxidant levels could be achieved by breeding for extremely small grain rice.

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2.2.3 Heating

Starch is the main constituent of rice that is made up from two major fractions, amylose and amylopectin. Amylose is the key determination of eating and cooking quality of cooked rice. One of the most important processing steps to provide desirable texture in rice grains is cooking. It involves heat and mass (water) transfer. The rice grains are boiled in limited or excess amount of water for cooking. The starch of milled rice grain absorbs moisture and swells during cooking due to its gelatinization (Ghasemi et al., 2009). Rice parboiling is an important process in the rice industry. It consists of three different operations, namely: soaking in water, steaming to complete gelatinization of the starch and drying. The soaking process is essential since water is necessary for an adequate gelatinization (Bello et al., 2004). Some Asian peoples cook their rice in an ample amount of water to obtain desirable texture whereas, in many western cultures, rice is boiled in excess water until the centre of the grain is fully cooked. Texture and physical appearance of cooked rice may vary, depending on the method of cooking. Some research groups have associated cooking conditions with the textural changes. Rice cooking, using isothermal calorimetry at various temperatures (30–120°C), illustrated structural changes induced by water diffusion during starch gelatinization of whole rice kernels (Leelayuthsoontorn and Thipayarat, 2006).

Gelatinization and pasting are transformations when heating starch in aqueous solution, with significance in food production. Starch granules suspended in water considerably swell as they can hold as much moisture as the 30 percent of their dry mass. This process is reversible in room temperature. Heating the suspension results in irreversible changes: with increased extent of hydration the structure of starch granule starts to lose step by step, as soon as the energy of heat is sufficiently high to dissociate the week hydrogen bonds in the granule. During the process hydrated starch molecules diffuse to the solution from the granule. The viscosity of the system increases. Complete solubilization occurs only on high temperatures. Loosing of ordered structure after gelatinization is termed pasting. After the gelatinization and pasting of starch amylose and amylopectin molecules may be considered as dissolved.

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After cooling the system forms a gel. Amylose is considered primarily responsible for gelatinization (Vegh, 2012).

The use of steam under pressure has become very popular in the United States and Europe. The main advantage of steaming is that the time to complete the whole process is relatively short, increasing the plant turnover. However the application of high temperatures above gelatinization temperature increases the cost of parboiling equipment and downgrades the quality of parboiled rice in terms of hydration and cooking characteristics, tenderness and color and yellowness of the grain. As gelatinization of starch in paddy can be achieved even at temperatures lower than 100°C, gelatinization temperature for world rices ranges from 55 to 79°C. Some authors have been developing alternative parboiling techniques involving lower temperature (Bello et al., 2004).

Ohishi et al. (2007) studied the mechanism of the textural changes such as increase in stickiness of rice cooked with acetic acid. The study was focused on the gelatinization and rheological properties of both rice starch and rice flour. The results of swelling power and solubility of rice starch indicated that acetic acid promoted water absorption of amylopectin in rice starch. It was shown by differential scanning calorimeter measurements that rice starch heated with acetic acid was easy to gelatinize compared to that without acetic acid. The pasting properties measured by a rapid visco amylograph and rotational viscometer suggested that the structure of rice starch became more fluid by an addition of acetic acid. Biochemical analysis using α-amylose indicated that the spaces which allowed the enzyme reaction were formed more in the structure of rice starch cooked with acetic acid. It was suggested that these changes in rice starch contributed to the textural properties of rice cooked with acetic acid.

2.3 Yogurt

Yogurts are prepared by fermentation of milk with bacterial cultures consisting of a mixture of *Streptococcus* subsp. *thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*. There are two major types; set and stirred yogurt. The main manufacturing procedures of these two types of yogurts are described in Figure

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2.4. Set yogurt (which includes fruit-on-the bottom) is formed in retail pots as lactic acid bacteria ferment lactose into lactic acid giving a continuous gel structure in the

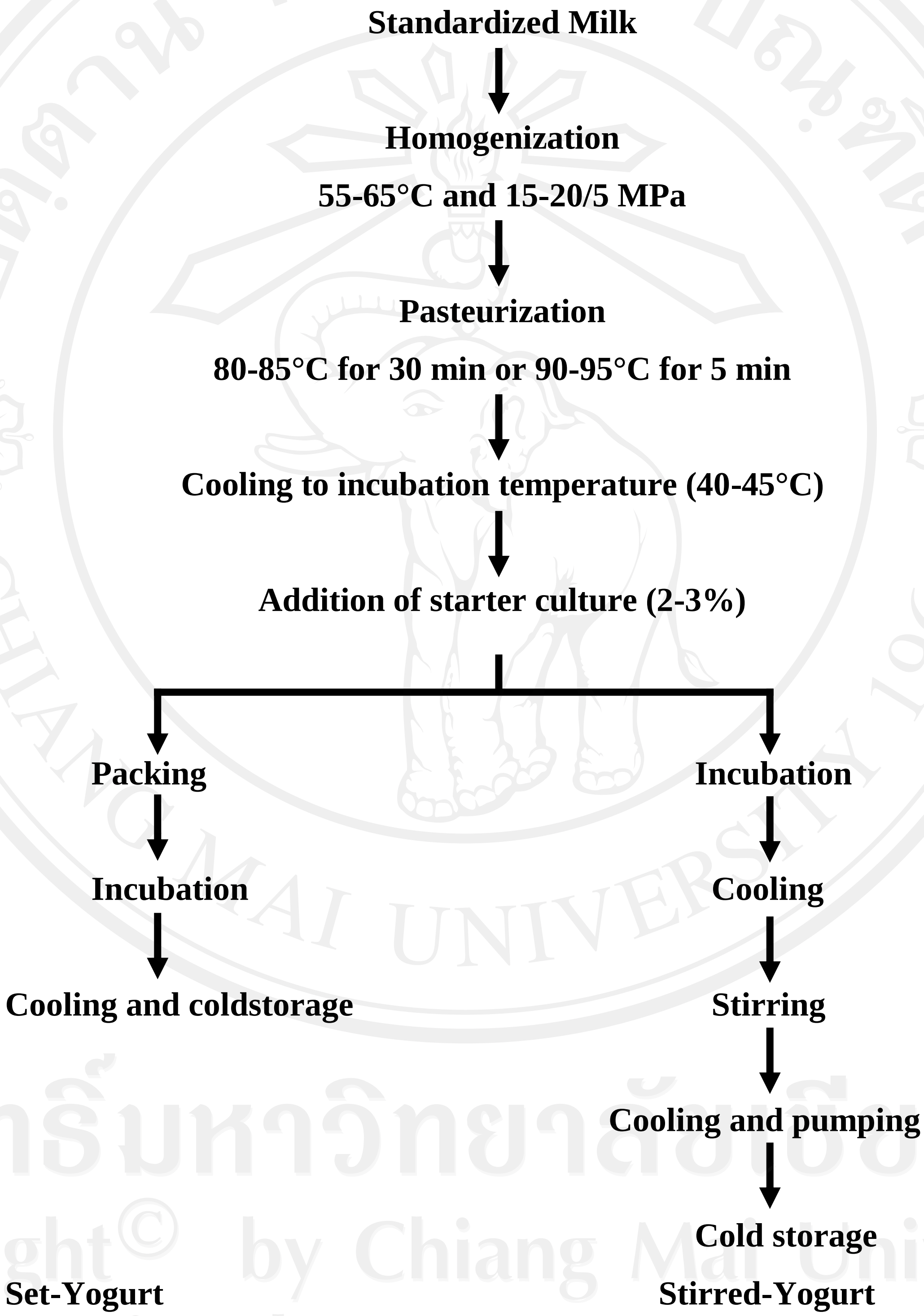

Figure 2.4 Main processing steps in the manufacture of set and stirred yogurt (Lee and Lucey, 2010).

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consumer container. In stirred yogurt, the acid gel formed during incubation in large fermentation tanks is disrupted by agitation (stirring), and the stirred product is usually pumped through a screen which gives the product a smooth and viscous texture (Tamime and Robinson, 1999). The physical attributes of yogurts, including the lack of visual whey separation and perceived viscosity, are crucial aspects of the quality and overall sensory consumer acceptance of yogurts. An understanding of the mechanisms involved in the formation of texture in yogurts and the impact of processing conditions on texture development may help to improve the quality of yogurt (Lee and Lucey, 2010).

Up to the 1980s, there were several published data regarding drinking yogurt. According to Tamime and Robinson (1999), commercial processes for the manufacture of drinking yogurt could be classified into the following types:

- Homogenized stirred yogurt, cool and package. The product has a shelf-life of 2-3 weeks at 5ºC.

- Homogenized stirred yogurt, pasteurized and packaged. The product has a shelf-life of 1-2 months at 5ºC.

- Homogenized stirred yogurt, Ultra High Temperature and aseptically packaged. The product has a shelf-life of several months at ambient temperature.

According to Nongonierma et al. (2006), an alternative approach to classify yogurt drinks based on the physical characteristics of the product could be: (a) viscous products, (b) diluted/beverage and (c) carbonated products. These drinking yogurt products may be fresh (i.e. containing live starter culture bacteria including probiotic bacteria, prebiotic compounds or omega-3 fatty acids) or extended shelf-life products with no live microorganisms. Factors such as the chemical composition of the milk, starter cultures types, additives and process design will also contribute to the final consistency, taste and mouth feel of fermented drinks.

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2.3.1 Factors affecting the physical and sensory properties of yogurts

1. Dry matter fortification

The physical and sensory properties of yogurt gels are greatly influenced by the total solids content of the yogurt milk, especially the protein content. The G′ values of yogurt increases with an increase in the total solids content obtained by the addition of skim milk powder or by ultrafiltration (Biliaderis et al., 1992). Increased yogurt viscosity is observed when the total solids content of milk is increased. The viscosity of yogurt or perceived thickness also increases with an increase in total solids content of milk (Skriver et al., 1999; Sodini et al., 2004). Peng et al. (2009) compared the impact of different types of milk proteins used for fortification on the textural properties of yogurt. The G′ values at pH 4.6 of fortified yogurts increased in the order: skim milk powder = micellar casein < milk protein isolate < sodium caseinate. Addition of whey protein concentrates (WPC) to milk followed by high heat treatment led to increased G′ values and decreased gelation time in yogurt. One issue with the popular use of WPC to fortify yogurt milks is the possible coagulation of whey proteins during the high heat treatment process. The susceptibility to heat coagulation is related to the calcium content of the WPC, with high Ca levels, such as, the levels found in acid whey WPC, making the solutions very unstable. In practice, there is an upper limit (before an increase risk of heat coagulation) of around 4% additional whey protein (from WPC) to give a total milk protein level of about 7%. Improper hydration of powders can result in a number of defects in yogurt including lumpiness, chalkiness, and powdery off-flavors. The increase solids content in yogurt milk as a result of fortification also creates increased buffering that requires additional acid development by the starter cultures to achieve a similar pH target. Most yogurt products are sweetened (not plain). The use of sucrose increases the total solids of the mix and strengthens the gel network. A range of sweeteners are used commercially, especially for low calorie products. Another option is to use β-galactosidase to hydrolyze lactose as the products are glucose and galactose, which are much sweeter than lactose (Lucey et al., 1999).

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2. Incubation temperature

Physical properties and microstructure of yogurt are influenced by incubation temperature. The use of high incubation temperature resulted in a decrease in gelation time and G′ values at pH 4.6, and an increase in LT_{max}, *B*, and whey separation compared with yogurt gels incubated at low temperature. This result indicates that gels formed at high temperature are weak and have a coarse gel network due to extensive rearrangement resulting in the formation of large pores and greater whey separation (Lucey, 2004). During the formation of yogurt gels at a low incubation temperature, slow protein aggregation occurs resulting in the formation of a large number of protein-protein bonds and less rearrangement of the particles/clusters. A highly cross-linked and branched protein network that had small pores was observed in micrographs of yogurt gels incubated at low temperature (Lee and Lucey, 2003; 2004). At lower incubation temperature, there is an increase in the voluminosity of casein particles, which results in an increase in the area of the junctions between aggregated casein particles. Increase contact area between casein particles could contribute to the increase stiffness of gels observed at low temperature (Walstra, 1998). Higher viscosity was observed in stirred yogurts that had been incubated at lower temperatures (e.g. <40°C) compared to gels incubated at high temperature (e.g. >40°C). As incubation temperature increased, there was a decrease in the sensory attributes, such as, mouth coating and smoothness of stirred yogurt. Recently, a novel two-stage incubation temperature method was proposed. Peng et al. (2009) reported that if incubation temperature was changed after gelation, the textural properties of yogurt became similar to those of yogurts made at that new temperature for the entire fermentation process. It may be possible to use high incubation temperature for the initial stage of fermentation to facilitate rapid growth of the starter cultures and then slowly reduce the incubation temperature at some stage to achieve better textural properties. The physical properties of yogurt gels including gel stiffness and permeability, the rearrangement of protein particles in gel network, and the structure breakdown of stirred-type yogurts are important factors influencing the physical and structural properties of yogurts.

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2.3.2 Quality of yogurt

The commercial yogurt is usually made by fermenting milk with a mixed culture of *L. bulgaricus* and *S. thermophilus*. Each of these organisms acidifies milk and produces specific yogurt flavor and aroma. The addition of probiotic bacteria is made because of certain claimed health-promoting effects in the intestinal tract. These beneficial health effects included enhancement of the immune system, reduction of lactose intolerance, control of diarrhea and reduction of low-density lipoprotein cholesterol. Product quality and consumer satisfaction are important for the acceptance of various types of yogurt products. Quality assessment encompasses specifications, sampling, testing procedures and recording or reporting. Yogurt quality is difficult to standardize because of many forms, varieties, manufacturing methods, ingredients and consumer preferences that exist. The quality of the product depends on the production control of lactic acid formed by fermentation. Lactic acid provides the tart flavor and the destabilization of milk protein forms the gel structure. The pH measurement monitors lactic acid production and aids in the quality control of yogurt's ingredients (Lee and Lucey, 2010).

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