CHAPTER II

LITERATURE REVIEW

Rice Flour

Primary processing products from rice or less broken-milled rice cannot directly process for food. Only rice flour form will be used further for food, semi-processed and non food products. Broken rice, special A-one class (more than 74% of broken rice with >5.0 part in length) or A-one class (broken rice with <6.5 part in length and unable to pass through the grating number 7) was cleaned with the cleaning machine. Like paddy cleaning, the machine composed of magnetic separation, stone separation, and white polishing. In some factories, broken-milled rice will re-scrub and remove rice bran powder. Then, broken rice will be grounded into a powdered form, which is classified based on the grid resolution. One of the three milling production processes, dry milling wet milling and mixed methods (wet and dry milling) (Naivikul, 2007) will be used for milling the powder into rice flour.

Generally, there are two types of flour in the market, rice flour and glutinous rice flour. Both flour types are distributed in both domestic and oversea markets, and their market values are usually increased. To promote and increase quality of the flour production industry and examine the buyers and sellers quality, The Product Industry Standard Office, Ministry of Industry establishes the industrial standards for rice flour (TIS 638-2529). The criteria for TIS are determined by flour character, food additives, food hygienic, packaging, mark and label. The test for rice flour, for examples, gridding quality of the flour has to pass through 180 micrometers grid or less than 2.5% (by weight) are left over the grid. Rice flour must be white or ivory, with natural odor (not with stinky, rancid or unwanted smell) and un-contaminated with other stuffs. Under a microscope, rice flour has to be in a polygon shape, with 2-9 micrometers in size (Naivikul, 2007).

Table 1 Proximate composition of rough rice and its milling fractions at 14 percent moisture

Rice fraction	Crude Protein (g)	Crude fat (g)	Crude fiber (g)	Crude ash (g)	Available carbo-hydrates (g)	Neutral detergent fiber (g)	Energy content (kJ)	Energy content (kcal)
Rough rice	5.8-7.7	1.5-2.3	7.2-10.4	2.9-5.2	64-73	16.4-19.2	1580	378
Brown rice	7.1-8.3	1.6-2.8	0.6-1.0	1.0-1.5	73-87	2.9-3.9	1520-1610	363-385
Milled rice	6.3-7.1	0.3-0.5	0.2-0.5	0.3-0.8	77-89	0.7-2.3	1460-1560	349-373
Rice bran	11.3-14.9	15.0-19.7	7.0-11.4	6.6-9.9	34-62	24-29	670-1990	399-476
Rice hull	2.0-2.8	0.3-0.8	34.5-45.9	13.2-21.0	22-34	66-74	1110-1390	265-332

Source: adapted from Juliano, 1985; Juliano, 1993; Eggum, Juliano and Maningat, 1982; Pedersen and Eggum, 1983.

Table 2 Vitamin and mineral content of rough rice and its milling fractions at 14 percent moisture

Rice fraction	Thiamine (mg)	Riboflavin (mg)	Niacin (mg)	α-Tocopherol (mg)	Calcium (mg)	Phosphorus (g)	Phytin P (g)	Iron (mg)	Zinc (mg)
Rough rice	0.26-0.33	0.06-0.11	2.9-5.6	0.90-2.00	10.80	0.17-0.39	0.18-0.21	1.4-6.0	1.7-3.1
Brown rice	0.29-0.61	0.04-0.14	3.5-5.3	0.90-2.50	10-50	0.17-0.43	0.13-0.27	0.2-5.2	0.6-2.8
Milled rice	0.02-0.11	0.02-0.06	1.3-2.4	75-0.30	10-30	0.08-0.15	0.02-0.07	0.2-2.8	0.6-2.3
Rice bran	1.20-2.40	0.18-0.43	26.7-49.9	2.60-13.3	30-120	1.1-2.5	0.9-2.2	8.6-43.0	4.3-25.8
Rice hull	0.09-0.21	0.05-0.07	1.6-4.2	0	60-130	0.03-0.07	0	3.9-9.5	0.9-4.0

Source: adapted from Juliano, 1985; Juliano, 1993; Pedersen and Eggum, 1983

Properties of Rice flour

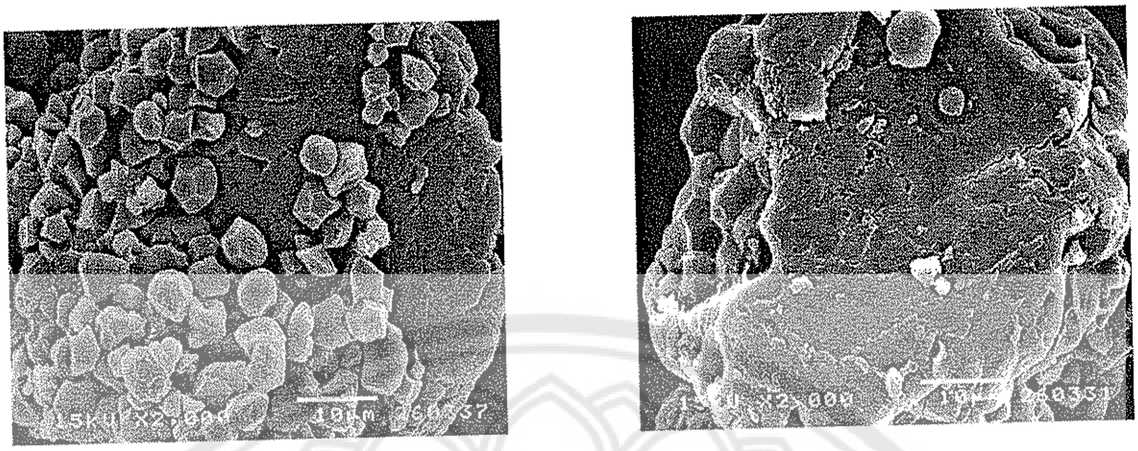
Rice flour is made from broken-rice or broken-milled rice, the properties of rice flour are then based on quality of raw materials. Chemical properties for examples proteins, lipid, starch, amylase/amylopectin ratios in starch and ash content in broken-rice or broken-milled rice will be tested. Physical properties including setting temperature for rice starch gel will be tested by base-heated microscope.

For baking applications, starch granule properties play an important role in dictating the suitability of a rice flour, especially if it presents over 10% messing test amylose content and gelatinization temperature, as measured by birefringence end-point temperature (BEPT). Pasting behavior, as measured in an amylograph, is an important functional property that reflects the combined effects of amylose content, BEPT, particle-size distribution, pretreatment, and physical state of the starch granule after milling to flour. (Luh and Liu, 1991, pp.16-17)

Table 3 Chemical properties of rice flour

Property	Rice flour
Granule size (μm)	6.8
Amylose content (%)	18-27
Degree of polymerization	900-1100
Onset temperature, T_o, °C)	60
Peak temperature, T_p, °C)	77

Source: Sriroth and Piyachomkwan, 2007 adapted from Eliasson and Gudmundsson, 1996; Hizukuri, 1996



Wet milling Flour　　　　　　Dry milling Flour

Figure 1 Flour particles and starch granules of wet milling flour and dry milling

Source: Naivikul, et al., 2006

Effect of milling type on product.

Rice flours can be produced from whole grains or broken pieces of brown or milled rice by dry or wet milling processes, the type of mill and the milling method profoundly affects the function properties of final rice flour quality. (Luh, 1991, p.13; Juliano, 2003, p.303). Wet-milled flour gives a better texture than dry-milled flour (Juliano, 1993, p.112; Suksomboon, et al., 2005) reported that dry- and wet-milled flours caused higher temperature required for gelatinization and provided higher final viscosity. Higher amount of damaged starch and greater degree of starch fragmentation during dry-milling process causes lower RVA peak viscosity and lower enthalpy change during gelatinization than those of wet-milled flours. Enthalpy values, which measure the heat (in joules per gram) necessary to melt the crystalline starch structure, give an indication of relative starch damage occurring to a flour during grinding. Suksomboon and Naivikul, (2006) studied effect of dry- and wet-milling process on chemical, physicochemical properties and starch molecular structures of rice starch. Rice starch from low amylose (Pathumthani1), medium amylose (RD7) and high amylose (Leuang11) varieties prepared from dry- and wet-milling processes were investigated. They found microstructure of starch granules which confirmed that damaged starches occurred from the dry-milling process more than from the wet-milling process. The molecular size distributions indicate that during dry-milling process, starch especially amylopectin, was susceptible to fragment to lower molecular weight fractions more than in the wet-milling process.

Wet milling

Wet milling is a widely used method for production of rice flour. Using this technique, the product is high quality rice flour with high resolution and low contamination. The process begins with cleaning the broken-milled rice using grill rock and wind blow. Then, broken rice will be washed 2-3 times with water to remove contaminating items, at the same time, soften the broken rice. The mill stone will be used in the next step to mill the powder with water, and then separate rice starch using a filter. Normally, the filter plate has been used for this propose but centrifugation can be used as well. The lump of half-dry rice starch will pass the reducing machine, to ease the rice flour size. Followed by incubation under high temperature to reduce flour humidity until less than 14% of humidity is reached, the rice starch will pulp again until consistency of powder size is obtained (Naivikul, 2007). Generally, rice flour is made from wet-milled process. Soaking, adding excess water (three to five time the weight of the rice) during grinding, and removing the excess water are the three steps that differentiate wet milling from dry milling. The wet-milling process consume the large amount of water which in turn creates a lot of waste water (Saksomboon, et al., 2005).

Milling to flours usually occurs when the rice is well hydrated (Luh and Liu, 1991, p.15.; Tungtrakul, et al., 2002). The process begins with washing and soaking whole or broken rice followed with wet milling. Water is decanted to obtain wet flour after which it is dried in hot air before sieving to desired particle size. This process consumes a lot of water and energy but provides low yield due to loss of starchy materials as well as creates the great amount of waste water.

Chiang and Yah (2002) studied the soaking effect to particle size and starch quality using wet milling at 5 °C and 25 °C. Water absorption efficiency in rice grain is increased while amounts of proteins, lipids and rice ash are decreased according to temperature and time. Moisture content in the product is the main factor that causes problem in rice grain structure, and consequently reduces starch particle size.

However, starch particle size does not affect the gel transition temperature (To and Tp) in the DSC thermogram. Small particle size starch with low lipid content will give the highest viscosity peak.

Previous research observed a noticeable improvement in bread texture when wet-milling flour was substituted for dry-milling flour in 100% rice bread (Bean, et al., 1983; Luh and Liu, 1991, pp.15-16).

Mixed milling (wet and dry milling)

Washing and soaking step in mixed milling process is similar with wet milling procedure. Then, immersed broken rice/ milled rice will processed through incubation until 15-17% moisture content is obtained and followed by the dry grinding or dry milling step. The grinder is used to produce flour, with consistency powder size. Mixing-milling process contained steps from both wet and dry milling, is termed as a mixed-milling method (Naivikul, 2007).

Dry milling

Dry milling is the process using broken rice or broken-milled rice as the starch starter. After dry cleaning process, broken rice or broken-milled rice will pass through the millstone, and dry powder will be generated. Quality of the powder is determined by the glider size. However, flour obtained from dry milling method is often low quality flour because the powders are relatively coarse. Moreover, flours are highly contaminated, short storage life with rancid odor, and also easily damage by insects (Naivikul, 2007). Attributes of starch granules are damaged in rice flour as passing through milling by dry milling process.

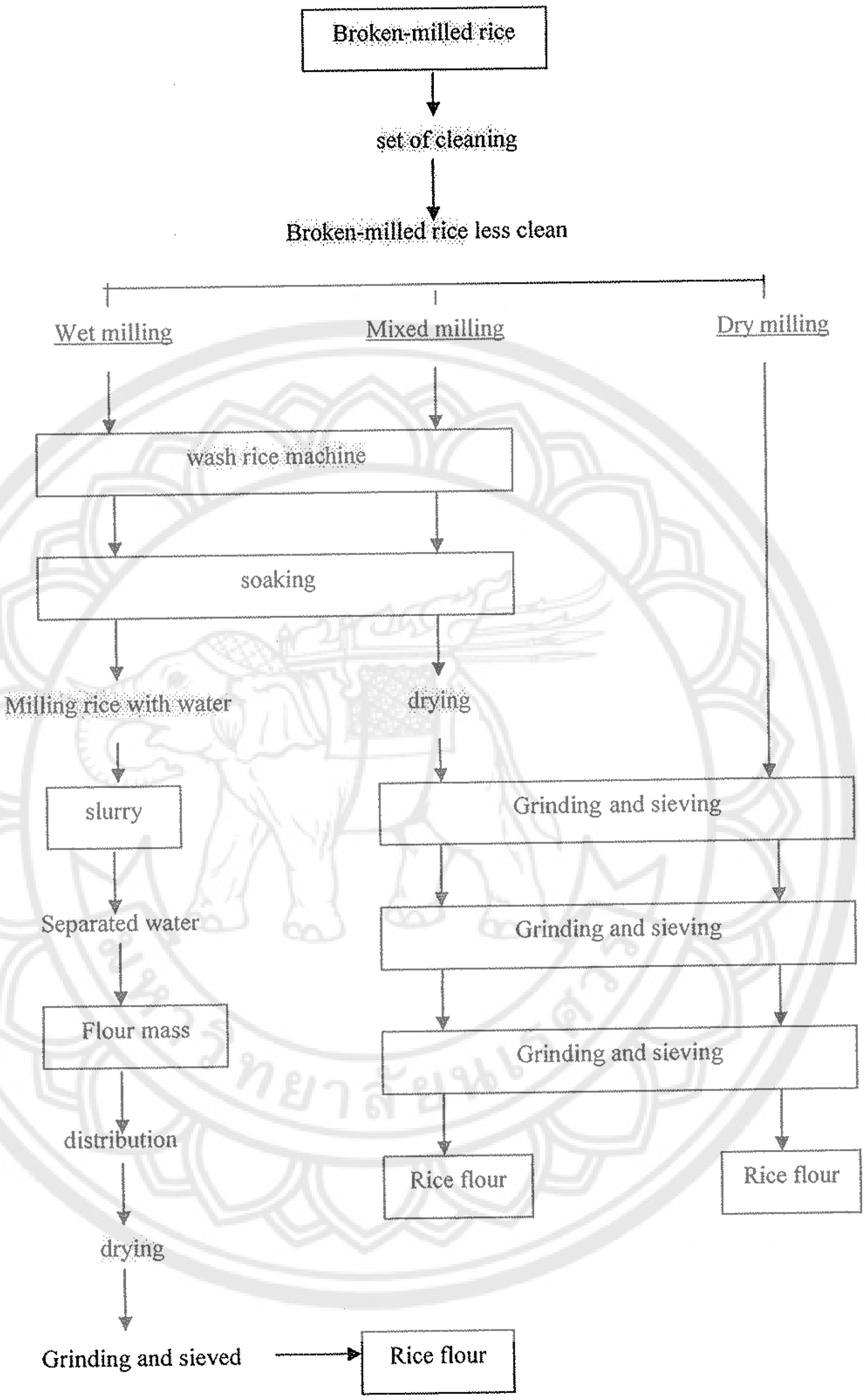


Figure 2 Processing of rice flours from different milling types

Source: Naivikul, 2007 adapted from Kongsaree, 1998

Effect of amylose content on product.

Starch consists of a branched fraction, amylopectin, and a linear fraction amylose. Waxy rice starch has an apparent amylose content of 0.8-1.3%, probably located at the hilum (center) of the granule. Nonwaxy milled rice may have 7-33% amylose, which equivalents to 8-37% amylose in starch. Waxy (glutinous) starch stains red or brown with iodine whereas nonwaxy (nonglutinous) starch stains purple-blue to blue. The amylose content of milled rice may be classified as waxy, 1-2%; low, 7-20%; intermediate, 20-25%; and high, <25% (Juliano, 1979; Juliano, 1985, p.60). There are varietal differences in protein, lipid, starch contents and the amylose and amylopectin ratio in the starch. (Luh, 1991, p.10) which amylose and protein content of rice are considered to be the two most important criterias for eating qualities of rice.

Amylose content is the important inherent factor that must be considered. Luh and Liu, (2010) reported that rice flour from each variety, with the exception of the waxy type, has characteristic viscosity pattern during the heating and cooling cycles of their pastes. Juliano, et al., (1987) reported that rice with higher amylose content and long chain amylopectin tended to have a harder texture, while rice with a lower amylose content and short chain amylose tended to have a softer texture. The changes in viscosity depend largely on the composition of the starch and, to a lesser extent, on the protein and oil components. (Webb, 1985; Moldenhaur, et al., 2004; Kadan, Bryant and Miller, 2008).

For baking applications, the large substitution in wheat flour (usually over 10% substitution) influences the texture of product. Sajilata and Singhal, (2005) reported that the waxy starches usually produce the greatest expansion in snack products. Although all non-waxy rice product breads of equivalent appearance, only low-amylose, low-gelatinization temperature rice give a soft-textured crumb. Intermediate-amylose, intermediate-gelatinization temperature rice give sandy, dry crumb characteristics. However, among them, low-amylose rice gave a lower loaf volume than did intermediate- and high-amylose rice (IRRI, 1976; Juliano, 1993, p. 112).

Effect of particle size on product.

Particle size is a very important concept in flour milling, which is related to water absorption of flour (Mailhot and Patton, 1988, p.75). The resulting flours vary in particle size and differ in chemical and physical properties (Wang and Flores, 2000). Finer average particle size accelerates the rate of flour hydration, thus bringing the plastic dough mass more rapidly to a stage (Mailhot and Patton, 1988, p.75.). Chiang and Yeh, (2002) reported that particle size and damaged starch are two key factors affecting the properties and application of flours. Jomduang and Mohamed, (1994) reported that fine flour yielded better qualities of rice-based snack products than coarse flour. Chiang and Yeh (2002) reported that the turbo mill yielding finer flour, higher flour temperature, and higher percentage of damaged starch than other dry-milled flours, and the flour with high damaged starch generally has high water retention capacity.

Wang and Flores, (2000) reported that particle size is an important factor in flour milling. Coarser flours produced acceptable breads of lower quality. Finer flours, ground on hammer mills or turbo mills, had high levels of starch damage, were heated during milling, and did not function in breads, the dough did not rise during baking (Luh, 1991, p.14).

Crackers

Many pastry products including cracker made from various recipes. Each pastry recipe will give different outcome, from hard dough (similar to bread) to soft dough (similar to cake). However, each recipe contains less amount of water or liquid than bread and cake. Therefore, the pastry characteristic is mainly crispy and crusty. Main ingredients for cracker are wheat flour, water, lipid (for softening cracker), yeast/baking soda (for puffy paste), sugar/salt/milk and flavor ingredients (for cracker taste). Cracker is currently a popular pastry product in the market. Therefore, the alternative ways for cracker production using rice flour instead of wheat flour are in progress for expense reduction from imported wheat flour.

Crackers can generally be subdivided into three basic categories: soda cracker, or saltine (in the United Kingdom, cream crackers), sprayed crackers and savory crackers, which cracker dough differ from bread dough by being much stiffer at both crackers, which cracker dough differ from bread dough by being much stiffer at both the sponge and the dough stage. Leavening can be accomplished either by yeast fermentation or by chemical leavening as occurred by carbon dioxide in chemical leavening is formed by the reaction of sodium bicarbonate with an acidic salt. The individual groups may be distinguished from one another according to the degree to which gluten development occurs, or is desirable, as well as on the basis of the type of equipment used in their production. The key element of the groups are summarized in Table 1 (Cauvian and Young, 2008, p.90).

Table 4 Key characteristics of cracker and cookie dough

Type	Gulten development[a]	Equipment
Crackers	Modest	Sheeter, lamination and cutter
Hard-dough, semi-sweetness	Some to modest	Sheeter and cutter
Soft-dough	Limited	Rotary moulder
Cookies	Limited	Wire-cut

Note: [a] By comparison with bread dough.

Source: Stanley and Young, 2008, p.91

The cracker can be divided in to two groups depending on the nature of dough including hard dough and soft dough. Cracker products from hard dough can group into fermented dough, puff dough and semi-sweetness dough while all products from soft dough is termed as sweetness crackers. Fermented dough is defined by cracker ingredients and fermented procedure. Steps for making fermented dough are similar to bread dough preparation. This dough type is generally used for cream cracker recipes. There are three mixing styles for cream cracker, one-step mixed, two-step mixed and two-step mixed with short flying sponge and dough process.

Cream cracker procedure starts with mixing of all three mixing style dough together. Then, They are rolled into a thin sheet and put together with special flour mixed (flour mixed with salt, lipid and salt or without salt) between each sheet until dough thickness is as required. This dough layers will pass through a cutter machine to generate cracker shape as needed.

Baking cracker causes many interactions in the oven. Firstly, heat will distribute from its origin (gas or electricity) to the crackers (in form of convection, conduction or radiation heat).

Different forms of heat made the following changes to occur.

1. In the first phase of baking, cracker temperature is increasing. Lipid inside is melting while sugar and other chemical substances also start to melt. These effects cause a softening cracker. Gas generates from baking soda reaction, insides cracker and causes structural rearrangement and continue these reactions.

2. In the middle phase of baking, cracker temperature is getting near the water boiling point. This temperature causes protein rearrangement to layer formation. Starch is also affected by this high heat, causing gel formation (only some parts as the mixture contain a few water composition) which finally supports the cracker structure. Remaining water will evaporate into steam, causing high pressure and increasing a cracker volume.

3. In the final phase of baking, heat is increasing consistently. Cracker structure will change to the final stage as starch are completely change their structures. Lipid and sugar content still remains in the liquid state even bake at high temperature, which cause flexibility to cracker structure. Meanwhile, cracker color outside becomes brown from caramelization process while the inside color will not change to brown color as inside temperature is not high enough for caramelization process to occur.

With suitable baking time, crackers will take out of the oven and cool down at appropriate condition. Coagulations of lipid and sugar compositions inside cracker will occur at low temperature condition and moisture remaining within cracker will spread throughout. With inappropriate temperature and relative humidity, low quality cracker will be obtained (delicates and fragile cracker) while under control condition, high quality cracker will achieve instead. (Naivikul, 1996).

Substituted wheat products

The using of rice flour in wheat-based baked product are worldwide. Bean and Nishita, (1985) reported that rice cannot be substituted directly for wheat in a yeast-leavened product without formula modifications. As may be substituted in the part or all of wheat flour in formula. They are blended after milling or during dough preparation at a bakery. The problem associated with rice-bread formulation is due to the absence of gluten in rice flour. The manufacture of rice bread without gluten presents considerable technological difficulties because gluten is the important structure-forming protein (Luh and Liu, 1991, p.27). Bean and Nishita, (1985) also reported that the protein of rice does not develop a film on mixing that is capable on holding fermentation gases, and some of the physicochemical characteristics of rice that influence the eating quality of the parent rice are found in flours and reflected in baked product. Rice flour is an interesting ingredient, for wheat flour replacement. As rice flour compositions are mixtures of glucose polymers including linear polymer (amylose) and branched chain polymer (amylopectin). Amylopectin is the major component involved with structure, function and usage of rice flour, as amylopectin can formed starch granule by itself. As a result, flour from various sources will offered a unique rice flour quality based on its amylose/amylopectin ratios (Sriroth and Piyachomkwan, 2007). Rice flour contains more amount of amylose than glutinous rice, which contain almost amylopectin in its kernel. Therefore, rice flour gel viscosity is also less than gel from glutainous rice flour. (Naivikul, 2007).

Chemical composition of glutinous rice grains are mainly carbohydrate as amylopectin starch is 99-100%. Amylopectin affects the nature of glutinous rice as sticky rice when well cooked. Increase in amylose content in rice starch causes moderation in its texture and reduces its viscosity. Starch with more than 25% of amylose content is classified as high amylose rice. When high amylose rice is cooked, unbroken, solidified rice with puffy character will obtain (Kongseree, 2005; Naivikul, 2007). Glutinous rice flour or waxy flour, almost 100% with amylopectin content, is good wetting. Extraction of proteins and contaminants from Glutinous flour will leave a waxy starch for Latex Emulsion or improve viscosity of Latex (Sriroth and Piyachomkwan, 2007). Waxy flour is also used for thickener agent in food industry due to its ability to resist freezing condition and freeze/thaw repeated cycle to maintain its nature. In addition, waxy flour is useful in some pastry industries, according to its puffy and expansion ability (Wongmaneeted, 2004), a key feature for pastry products from rice flour and wheat flour. The expansion of flour will directly affect puffing and characteristic of the products.

The ratio of amylose and amylopectic in rice flour is an important factor for puffy products and expansion. Amylose has film-forming property while amylopectin is involved with network-framing and products porous structure. Suitable ratios on both amylose and amylopectic result in good expansion and texture quality of product (Wang, 1997). With high amount of amylopectin flour, low density with fragile products will obtain. Appropriate amount of amylose in flour resisted to structure fracture and suitable for bake-type Japanese style snack product (Wongmaneeted,, 2004). A proper proportion of amylopectin in rice flour is 80-100% for bake-type puffed snack (Matz, 1996). Therefore, glutinous rice flour could possibly use with rice flour for butter characteristic of biscuit/cracker products.

Hydrocolloids

Hydrocolloids are high-molecular-weight hydrophilic biopolymer used as functional ingredients in the food industry for the control of microstructure, texture, flavor and shelf-life. There are extracted from plants, seaweeds and microbial source, as well as gum derived from plant exudates, and modified biopolymers made by the chemical or enzymatic treatment of starch or cellulose (Dickinson, 2001).

Additions of hydrocolloid are suggested to help increasing dough properties such as water absorption, gas retention and improving product properties such as texture and retarding starch retrogradation. The one gum, hydroxypropyl methylcellulose, permitted gas retention in a 100% rice flours bread (Nishita, et al., 1976; Bean and Nishita, 1985, p.540). May be due to hydroxypropyl methylcellulose provided the proper dough viscosity and film-forming characteristics so that the rice flour dough would retain fermentation gases during proofing and expand during baking to produce a crumb grain similar to that of typical white pan bread (Bean and Nishita, 1985, p.548). A yeast-leavened bread of 100 percent rice flour has been successfully developed, consisting of 100 parts rice flour, 75 part water, 7.5 parts sugar, 6 parts oil, 3 part fresh compressed yeast, 3 part hydroxypropyl methylcellulose and 2 part salt (Bean and Nishita, 1985; Juliano, 1993, p.112)

Sivaramakrishnan, et al., (2004) examined the two varieties of rice such as long grain and short grain with added hydroxylpropyl methylcellulose (HPMC) three levels at 1.5%, 3.0%, 4.5% added, as gluten substitute were studied using a farinograph and rheometer and compared with wheat dough to find its suitability for rice bread. They found that the farinogram of rice flour supplemented with HPMC reached a consistency of 500 BU at a later time than that of standard wheat dough. The rheological measurements from the oscillation test and creep tests showed that the rice dough with 1.5% and 3.0% HPMC had similar rheological properties to that of wheat flour dough and was suitable for making rice bread. The long grain rice sample produced a rice bread with better crumb texture.

Gomez, et al., (2007) studied the influence of several hydrocolloids that varying in origin and chemical structure on the yellow layer cake quality and its potential use in retarding the staling process during storage. The hydrocolloids selected including sodium alginate, carrageenan, pectin, hydroxypropyl methylcellulose (HPMC), locust bean gum, guar gum and xanthan gum 1% (flour basis) were added. They found that hydrocolloids addition affected all texture parameter of yellow layer cake, leading to harder crumb than those of the control cake and the type of hydrocolloid had a notable influence on texture evolution and retarding shelf-life. Xanthan was able to maintain totally unaltered all texture parameters during storage. The overall acceptability of yellow layer cakes was always improved by hydrocolloids addition except when pectin was used.

Barcenas and Rosell, (2005) examined the effect of HPMC addition on a basis bread formulation, at a level of 0.5% (w/w, flour basis). Bread quality was analysed for physical parameter, crumb grain structure, sensory evaluation and microstructure. The result shows that the use of HPMC in bread making allows improving the bread quality, namely loaf volume, moisture content and crumb texture, and even the sensory quality of the fresh bread was superior to that of the control. Addition HPMC is a good antistaling agent for retarding the crumb hardening rate and also retards the amylopectin retrogradation. The microstructure analysis suggests the existence of multiple interaction between the polymer and the bread constituents, which could explain the ability of this hydrocolloids to retard the bread staling process.

Rosell, Rojas and Benedito, (2001) studied the effect of different hydrocolloids including sodium alginate, κ-carrageenan, xanthan gum and hydroxyproplymethylcellose on the rheological properties of the wheat flour dough and the final quality of bread. Hydrocolloids level at 0.5% was added based on flour weight. The result showed great improvement in dough stability during fermentation, which was achieved by adding xanthan and sodium alginate, that had the most pronounced effect on dough properties yielding strengthened dough. Regarding their effects on bread properties, the hydrocolloids increased the specific volume, with the exception of alginate, as well as water retention and water activity. Addition of κ-carrageenan or hydroxyproplymethylcellose reduced the firmness of bread crumb, and could be improvers in the bread-making performance.

Hydrocolloids have been used as gluten-substitutes in the formulation of gluten-free breads due to their polymeric structure (Rosell, et al., 2001). They can improve food texture, retard starch retrogradation, improve moisture retention and enhance the overall quality of the production during storage (Stauffer, 1990; Gomez, et al., 2007). However, xanthan provoked a great increases of the crumb firmness probably due to the thickening of the crumb walls surrounding the air space; again its strengthening effect was observed in the dough rheology studies (Rosell, Rojas and Benedito, 2001).

Spoilage of biscuits and cracker

Changes in the character of biscuits and crackers in the most common forms of deterioration are due to moisture gain or loss, staling, rancidity and microbiological problems. The rate of deterioration is influenced by intrinsic food-related factors such as moisture content, water activity and level of preservatives, and extrinsic or environmental factor such as temperature, relative humidity and gaseous environmental surrounding the product. The spoilage of biscuits and cracker are divided into three types as described below.

Physical Spoilage

The water activity and moisture content of crackers are low that moisture may migrate from the atmosphere into the product, rather than from product to atmosphere for with bread and cake. A major driving force for the softening of biscuits and pastries is the lack of equilibrium between product and atmospheric relative humidities, accelerated in many case by the presence of undissolved or recrystallised ingredients, especially sugar, which confers so-called humectant properties to the product. In such cases the driving force is force for water to be absorbed by the product in order to achieve equilibrium (Cauvain and Young, 2008).

The checking is the result of moisture migrating within the product after baking. When many biscuits and cracker products leave the oven and begin to cool, the moisture content at the edge of the biscuits is lower than that at the centre. Gradually as the biscuits cools and after wrapping, moisture moves from the moist centre to the drier parts of the product, and stresses are developed within the product, causing the product to break. The critical role that the moisture gradient played in biscuit checking and when the relative humidity (RH) of the atmosphere surrounding the biscuit is low enough (26%) to allow both absorption and desorption to occur that the stresses which are set up can cause the biscuit to crack. If the atmospheric RH is high enough for the biscuit to absorb moisture from the atmosphere, the predicted stresses are insufficient to cause cracking (Saleem, et al., 2005; Cauvain and Young, 2008, p.153). Fear, et al., (1982) studied checking in crackers and concluded that the ingredients and processing made a negligible contribution to the level of checking and confirmed the critical role of role of water removal during baking.

Previous reports found that a lower flour protein increased and finer particle size decreased checking and that substitution of up to 75% of the sucrose with invert sugar syrup decreased the problem. The product is wrapped in a moisture impermeable film to prevent moisture uptake, but this dose not encourage any significant mould growth because the product moisture contents and water activities are so low (Dunn and Bailey, 1928; Cauvain and Young, 2008).

Chemical Spoilage

The complex formulation between starch polymer, lipid and flour proteins are thought to inhibit the aggregation of amylose and amylopectin. Thus, the content of there components can influence the rate of staling. Cookies and biscuits have higher lipid content than bread and tend to stale more slowly. However, these products are more susceptible to lipid oxidation and the development of rancid flavors (Smith and Simpson, 1996). Bakery food with low water activity may be stored without supporting mould growth, but the problem is associated with the autoxidation of the lipids that present in the baked product formulation. This problem usually occurs relatively rapidly in product with water activity of less than 0.3. As the product water activity increases towards 0.5, oxidation decreases but increases again thereafter (Troller, 1989; Cauvain and Young, 2008, p.192).

Lipases (fat-splitting enzymes) if present, can react with the fat component of cookie and biscuits, causing off-flavors such as soapiness. Lipases are most active at higher water activities (a_w), but will continue to react at water activities down to 0.25 and so can be a problem in biscuits, crackers and cookies. However there are destroyed by heat processing before or during production. In some cases the heat processing of baking may be insufficient to ensure that full inactivation occurs and they many contribute to product spoilage (Cauvain and Young, 2008, p.192).

Microbiological Spoilage

Microbiological spoilage is often the major factor limiting the shelf-life of bakery product. Microbiological spoilage is also a major cause of economic loss to the bakery industry. The most important factor influencing the microbial spoilage of bakery products is water activity (a_w). For low-moisture baked product (a_w<0.6), microbiological spoilage is not a problem. In intermediate- moisture productions (a_w 0.6-0.85), atmosphere yeasts and molds are the predominant spoilage microorganisms. In high-moisture products (a_w 0.94-0.99), almost all bacteria, yeast and mold are capable of growth (Smith and Simpson, 1996, p.208).