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THESIS

EFFECTS OF JASMINE RICE FLOUR CHARACTERISTICS ON QUALITY OF CAKE MIXED FLOUR

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A Thesis Submitted in Partial Fulfillment of
the Requirements for the Degree of
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The aim of this study was to utilize broken Jasmine rice by substituting it for wheat product. Jasmine rice flours with varying particle sizes (-80,100,120 and 150 mesh) were prepared and used in cake preparation. It was found that particle size may be associated with higher water absorption, set back, pasting temperature, starch damage and storage modulus as particle size becomes finer, whereas it may be associated with lower resistance force (compressibility of flour), peak viscosity, breakdown, gel and cake hardness as particle size becomes finer. The DDA and LRA results from Thai consumer acceptance test data of four Jasmine rice butter cakes indicated that, products were differentiated by appearance attributes. Liking for Flavor and overall liking were identified as the critical attributes influencing acceptability and purchase intent. From the study of Jasmine rice flour storage during 6 months, it was found that the significant change include color, starch damage and gel hardness but not cake hardness for each flour particle size during storage. Cakes prepared from flour with <120 or <150 mesh size were not significantly different and were similarly accepted by consumers. Flour with <120 mesh was then selected as an ingredient in rice butter cake formula, and powdered emulsifier mix was used. The DDA and PCA results from American consumer acceptance test data indicated that liking for texture attributes and overall liking could separate wheat flour butter cake from Jasmine rice flour cake. Taste and overall liking were identified as the critical attributes influencing acceptability and purchase intent. Cake mixed product formulated after storage for 6 months had stable quality and can be used to prepare the rice butter cake with similar acceptability. Replacing butter with 70% rice bran oil by butter weight in cake formula yielded acceptable cake. Cake mixed product consisted of rice bran oil mixed, sugar mixed and Jasmine rice flour mixed. Additional ingredients for household use formula were 1/6 cup evaporated milk and 1 egg yolk and 4 eggs for egg white. The optimum product making process required mixing for 7 min and baking in an oven at 170°C for 35 min. Rice bran oil cake and cake mixed were microbiologically safe. Energy and cholesterol of cake prepared from rice bran oil cake mixed product were 399 kcal/100g and 30 mg/100 g, respectively. Consumers acceptability on cake mixed by the laboratory use test method indicated that consumer moderately liked this product (7.92 of 9 score). All of them (100%) accepted product and 96% would purchase this product at a price similar to the commercial ones. No significant difference in purchase intent was observed, when consumer were asked if they would purchase or if purchase after the influence of family members. In conclusion, this study confirmed the importance of flour particle sizes that affect their properties and end product quality, revealed the storage extension of Jasmine rice flour to supply a year-round utilization, and demonstrated feasibility of completely substituting wheat flour with Jasmine rice flour for production of rice cake products that are acceptable to the consumer.

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Student's signature Thesis Advisor's signature

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EFFECTS OF JASMINE RICE FLOUR CHARACTERISTICS ON QUALITY OF CAKE MIXED FLOUR

INTRODUCTION

Rice is the most economically important crop planted in Thailand. It is not only the staple food for Thai people, but also a major exporting commodity for the country. Thai aromatic rice called "Khao Dawk Mali 105 (KDML 105)" is very popular and widely accepted for consumption in Asia, Europe and USA due to its quality, taste and specific characteristics such as soft texture and unique aroma (Mahatheeranont *et al*., 2001; Suwansri and Meullenet, 2004). These likeable characteristics presently dictate consumer demand both in the domestic and international rice markets, but also resulting in increasing a surplus of broken rice from the milling process. Broken rice is considered as a by-product with the lowest economic value. However, broken rice can be utilized by grinding into flour. In this regard, it may be used as raw materials for some food products, thus increasing its food value.

Rice flour is currently used in many different types of food products including brewed products, cereal products such as snacks, crackers and breakfast cereals, and various health bars. It is also used as base material for desserts and bakery products (Luh and Liu, 1980; Bond, 2004**;** Haruthaithanasan *et al.,* 2002; Toonsakool, 2006; Nukit *et al.,* 2006). Rice flour is free of sodium, cholesterol, and gluten (Shih and Daigle, 2002). As a non-allergic food, rice flour can be used to provide a number of gluten-free baked products, making it the alternative grain incorporated in gluten-free products (Deis, 1997).

Commercial rice flour has a broad range of size distribution which is an important concept in flour milling (Wang and Flores, 2000). In other words, rice flour varies in particle size which affects its properties, and, hence, the end products quality. Particle size distribution is one of the important physical characteristics, which has been reported to be a key factor affecting the properties and application of flour. Particle size also affects food sensory attributes which are important for designing food processing, final product quality and consumer's need. Several researchers have studied the impact of rice flour particle size on processing conditions and final product quality (Nishita and Bean, 1982; Kohlwey *et al*., 1995; Wang and Yung, 1997; Chen *et al*., 1999).

During storage of rice, a number of changes in chemical, physicochemical and biological properties occur that affects rice processing, consumption, nutritional quality and product quality. These properties include cooking, texture, pasting properties, composition, sensory attributes and enzyme activities. Previous studies of rice storage have focused on whole-grain rice rather than the rice flour itself. For example, as rice ages the cooked rice texture becomes harder and less sticky than fresh stored rice (Meullenet *et al*., 1999, 2000). In addition, changes in RVA pasting characteristics occur after storing milled rice for several months (Sowbhagya and Bhattacharya, 2001). During the storage of rice, stale flavor increases with an increase in free fatty acids, significantly causing flavor deterioration (Zhou *et al*., 2002). Other studies have reported that storage also results in changes in swelling, color and dough leavening after rice flour was stored for 10 months (Chrastil, 1990a). The storage stability of flour is primarily important to the manufacturer especially if it is stored before distribution. Whole grain is used in cooked form, whereas rice flour, which is produced from broken rice, is used as a raw material for processed products. Hence, rice flour needs to be stored for extended duration to provide a year-round supply before it is processed for specific end users.

Research reports have revealed that imported wheat flour used as ingredients in bakery products could be replaced by rice flour, which may create a new development for increased exports in the future. Several studies have attempted to improve the quality of baked products such as breads, cakes and cookies which were formulated with rice flour alone or in combination with other flour substitutes or novel ingredients (Bean *et al*., 1983; Gallagher *et al.,* 2003, 2004; Sivaramakrishnan *et al*., 2004; Moore *et al.,* 2004; 2006; Haruthaithanasan *et al.,* 2002; Toonsakool, 2006; Nukit *et al.,* 2006). Some studies have reported the feasibility of incorporating up to 50% rice flour substitutes in cake formulation, which was acceptable to consumers (Bond, 2004; Charoenratanasisuk, 2004; Samutkrut, 2003). Haruthaithanasan *et al*. (2002) successfully developed non-wheat butter cake products prepared from Jasmine rice flour by using 100% rice flour in the formula; however, the limitation of butter cake product was cake texture quality and higher energy and cholesterol. Moreover, there is a lack of information on sensory attributes of Jasmine rice butter cake. Then, in order to enhance the product's success, consumers' acceptance and purchase intent of this product must be evaluated. It is also critical to determine the contribution and influence of each product's attributes on consumer choice, so that quality products may be developed that are not just accepted by the consumer but satisfy consumer need as well (Bogue *et al*., 1999).

Research on the properties of Jasmine rice flour with varying particle sizes, varying storage times, and factors affecting the quality of the end products has seldom been conducted to an in-depth extent. Also, utilization of broken Jasmine rice flour as an ingredient for rice cake formulation and development for ready-to-cook cake mixed product are currently new due to lack of evidence on commercial cake mixed products formulated with Jasmine rice flour on the market. Thus, for in-depth study, Jasmine rice butter will be formulated and developed for cake mixed product for convenience to use and also to produce cake contain with reduced energy and cholesterol.

Thus, in view of the forgoing, this thesis was undertaken to examine and elucidate information on the following:

First, investigated the effects of Jasmine flour particle size on the physicochemical, micro-structural and textural properties, as well as other property changes including previously studied Thai consumer sensory perception of rice butter cake with various flour particle sizes. Next, investigated the effects of particle sizes and storage time on physicochemical properties of Jasmine rice flour and their interaction, including studied Thai consumer acceptability of rice butter cake with various flour particle sizes and storage times. Then, selected the particle size to use as ingredient in cake mixed. Next, developed cake mixed prepared from Jasmine rice flour using a powdered emulsifier mixed, as well as determined and characterized the American consumer sensory perception of rice butter cake made from broken Jasmine rice. Then, determined the effects of storage time of cake mixed properties. Lastly, developed cake mixed (rice bran oil formula) and tested its performance.

OBJECTIVES

1. To investigate the effects of particle sizes on physicochemical properties of flour, batter and cake from Jasmine rice and determine Thai consumer acceptability of Jasmine rice cake.

2. To investigate the effects of storage times on flour physicochemical properties of Jasmine rice and determine Thai consumer acceptability of Jasmine rice cake and determine the effect of storage time on major volatile compound (2AP).

3. To develop and characterize cake using powdered emulsifier mixed formulation and determine American consumer acceptability of Jasmine rice cake

4. To examine the effects of storage times on physicochemical properties of cake mixed and determine American consumer acceptability of Jasmine rice cake prepared from cake mixed during storage

5. To develop cake mixed using rice bran oil formula and develop cake making process, and determine Thai consumer acceptability of cake mixed by testing its performance.

LITERATURE REVIEW

1. Importance of Rice as Food

Rice (*Oryza sativa* L.) is one of the most important cereal grains in the world. It is the staple food in most Asia countries where more than 90% of the world's rice crop is produced and consumed. Milled rice provides 90% starch and 8% protein, so rice provides as much as 80% of the daily caloric intake for the human body. Not only does rice supply more energy than other cereals, it also contains better protein quality (Luh, 1991; Juliano, 1998). Due to increasing demand of rice exporting, industries are facing problem with numerous broken rice, which are low-value from milling process. Currently broken rice are often used as raw material for rice flour manufacturing, and the utilization of rice flour provides a diversity of rice products, depending upon the different rice varieties with specific flour properties (Luh, 1991).

1.1 Variety of Rice

Rice comprises two species related to grass in Graminae family, *Oryza sativa*, which originated in the humid tropics of Asia, and *Oryza glaberrima*, from West Africa. Asian cultivated rice, *Oryza sativa* is well known and widely accepted and has been increasingly replaced the Africa rice. It also can be classified into 3 types according to the cultivated area (Naivikul 2004; Siamvara, 1990).

1.1.1 Indica is grown in the tropical area of the Asian countries such as Thailand, India and the Philippines. This kind of variety is normally tall and puts out several branches. Leaves are wide with light green color. Trunk is quite soft. Grains are long to medium size in length.

1.1.2 Japonica is widely grown in semi-warm area such as Japan, Korea and North of China. This kind of variety is normally short and puts out several branches. Leaves are narrow with dark green color. Strong trunk and grains are short.

1.1.3 Javanica cultivar is widely grown in Indonesia and Burma. This kind of variety is normally tall and puts out little branches. Leaves are wide with light green color. Strong trunk and grains are slightly short in size.

1.2 Classification of Rice

In Thailand, rice can be classified into many categories based on their prominent characteristics: kernel length, shape, variety, amylose content, cooking properties and industrial use.

Rice can also be categorized into two types according to cooked rice characteristics as follows:

1.2.1 Non-glutinous rice contains 70-80% amylose and 10-30% amylopectin and provides firm, dry texture and fluffy when cooked.

1.2.2 Glutinous or waxy rice contains mostly amylopectin in starch molecules and provides very sticky texture when cooked.

1.3 Thai Jasmine Rice

Thai aromatic rice cultivar is commonly referred to as “Jasmine rice” or Hom Mali rice which is the most popular aromatic rice variety grown in Thailand because of its outstanding cooking quality such as stickiness, tenderness and unique aroma. Thai aromatic rice variety includes glutinous type such as RD6, and non-glutinous type such as Khao Dawk Mali 105, Hom Klongluang and Hom Suphanburi. In North and Northeast region of Thailand, glutinous rice is produced and consumed locally with little surplus export. In contrast, the aromatic non-glutinous type is produce for both domestic consumption and exportation.

The well known Thai aromatic rice type in the world market is Khao Dawk Mali 105 variety. In 2006, Thailand exported 1,610,189 metric ton of whole Jasmine rice kernel with value of 30,453.80 million baht whereas 906,947 metric ton of broken Jasmine rice kernel with value of 8,517.03 million baht (Ministry of Commerce, 2007). The important world export market of aromatic rice are Hong Kong, Malaysia, Saudi Arabia, Iran, Iraq, Europe and the United States of America (Mahatheeranont *et al*., 2001; Suwansri and Meullenet, 2004).

1.3.1 Standard of Thai Jasmine Rice (Department of Foreign Trade, 2007)

Partially describing Thai Jasmine rice as standard commodity and standard of Thai Jasmine rice B.E. 2545 (2002) is notified by the Minister of Commerce as follows:

1) Definition

Thai Jasmine rice (THAI HOM MALI RICE or THAI JASMINE RICE or THAI FRAGRANT RICE, or any other names that have the same meaning, whether or not they contain a word that means “Thai”) means Cargo rice or White rice derived from paddy non-glutinous rice of the fragrant rice varieties which are sensitive to photo period and cultivated as a main crop in Thailand, and which are certified by the Department of Agriculture, Ministry of Agriculture and Cooperatives as being Khao Dawk Mali 105 and RD 15 variety with a natural fragrant aroma depending on its age, and when cooked, such rice kernel shall have a tender texture.

2) Characteristic and Grain Size

General characteristic of Thai Jasmine rice is a long grain rice. The average length of grain as a whole kernel without any broken part must not be shorter than 7.0 mm, and the average proportion of grain length to the average width of the whole kernel without any broken part must not be less than 3.0 mm. For chemical properties, Thai Jasmine rice must have amylose content more than 12 percent and not more than 19 percent at 14 percent of moisture content.

1.3.2 Khao Dawk Mali 105 Variety

Khao Dowk Mali 105 (KDML 105) is sensitive to light's wave length. It is approximately 140-150 cm tall. It has flowering stage approximately in October, and is ready to be harvested approximately in November of each year. It has a dormancy period approximately 8 weeks. Brown rice grain is approximately 7.05 mm. long, 2.10 mm wide and 1.08 mm thick. Paddy rice has long grain. The good characteristics of this rice are its fragrance, and soft texture when cooked. For good milling characteristic, white rice grain should be clear, solid and lower in chalky kernels, has worldwide marketing, and gives a good price (Department of Agriculture, 2001).

The characteristic of Khao Dowk Mali 105 (KDML 105) is a long grain upland rice with low amylose content and low gelatinization temperature. The primary aroma compound has been identified as 2-acetyl-1-pyrroline in grain (Buttery *et al*., 1983; Mahatheeranont *et al.,* 2001). The outstanding aromatic of each variety depends on the amount of aromatic substance in its grains. Despite the same variety of aromatic rice, but grown in different environment, different aroma can occur. This substance was found in pandanus leaves. In pandanus leaves, there are 10 times of this substance higher than of in aromatic rice. Levels of rice milling directly affected aroma of rice (Buttery *et al*., 1983).

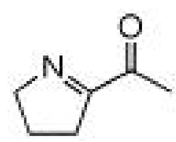


Figure 1 Structure of 2-acetyl-1-pyrroline

2. Rice Flour

Rice demand is increasing both in domestic and international markets, particularly the great demand for a whole rice grain. The milling process can yield as many as 5-10% large broken rice and 10-15% small broken rice depending on the quality of the incoming rice and the milling equipment. Most high quality rice is sold with less than 4% broken rice, and broken rice must be removed in the milling process (IRRI, 2007). Broken rice is considered a byproduct with low value and is less desirable. It is available as the resource of value-added products prepared from rice flour. The flour manufacturing normally uses the broken rice as the raw material.

2.1 Rice Flour Process

Rice flour in Thailand is made from the broken rice, from both glutinous and non-glutinous types. There are three kinds of rice flour process; wet-milled rice, dry milled rice and mixed milled rice.

2.1.1 Wet-Milled Flour; this method is widely used at present. The process begins by cleaning the broken rice, either by using air or water to remove any impurities. Some processors re-mill the broken rice to remove impurities and rancid odor from the rice. Afterwards, the grains are soaked in water for four to five hours before being ground with a stone grinder, filtered off the water to obtain a semi-dry flour cake. The flour mass is then beaten until it becomes smaller, removed and dried to moisture. Then it is once again ground and sieved. There is described on a flowchart below in Figure 2. Wet-milled rice flour is very popular for consumer and it was reported to have better properties than dry-milled rice flour. There are various kinds of products made from wet-milled rice flour; different types of noodles and desserts (Kongseree, 2002).

2.1.2 Dry-Milled Flour; this flour is produced using a hammer mill. Flour after milling process is sieved to obtain the specific particle size of rice flour. This type of milling process is uncomplicated with a lower cost and requires less water than does the wet milling process. The earlier report stated that this type of flour could be used to make bread and cake in substituted for wheat flour, and some products such as Arare and Sembei in biscuit manufacturing process. The process of flour making is described below in Figure 3.

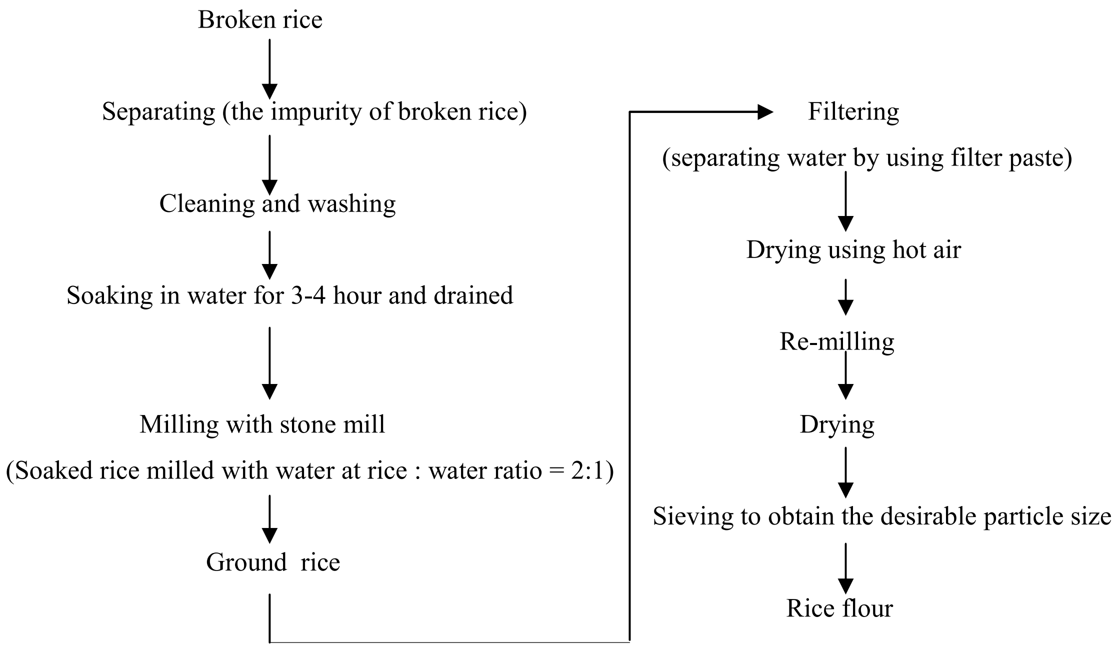


Figure 2 Process of rice flour using wet milling

Source: Kongseree (2002)

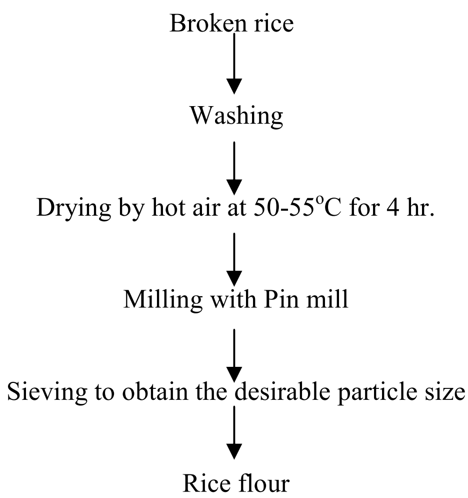


Figure 3 Process of rice flour using dry milling

Source: Nukit (2006)

2.1.3 Mixed-Milled Flour; this flour is produced from broken glutinous rice which has been soaked and steamed until fully cooked. Moisture is reduced after the flour dries up; it is ground into fine powder. This type of flour is finer than normally ground flour. Some products made with this flour type include Khanom Ko.

Many researches were studied on the products from wet and dry milling process. Bean *et al.* (1983) produced rice breads and cake with wet-milled and dry-milled. The results indicated that bread obtained from wet-milled rice flour produced bread with better texture and more desirable qualities than flour from dry-milled. In addition, wet-milled rice flour improved volume of bread compare to dry-milled rice flour. Jomduang and Mohamed (1994) produced Thai puff snack (Khao Kraip Waw) from glutinous rice flour, which obtained from laboratory wet and dry milling process. The results indicated that the product obtained from wet-milled flour had a higher expansion ratio and better product qualities than that from dry-milled flour.

2.2 Rice Flour Particle Size

Flour has composed a range of particle size which is a very important concept in flour milling. Flours varying in particle size differ in chemical and physical properties. The particle size of rice flour plays a key role in flour properties which influence the application of rice flour. Flour milling is an industrial process consisting of a set of grinding and sieving operation. The objective is to break the grain, separate the starchy endosperm from bran, and reduce it into flour (Devaux and Monredon, 1998); the resulting flour varies in the range of particle size and differs in chemical and physical properties (Kohlwey *et al*., 1995). Particle size is an importance parameter in flour milling, affecting the texture quality and taste of products. It also influences functional characteristic of final product quality (Chen *et al*., 1999).

2.2.1 Particle Size Analysis

There are many different techniques available for measuring particle size distribution such as sieving, microscope counting and laser diffraction (Barbosa-Canovas and Yan, 2003; Onwulata, 2005).

1) Sieving is known as one of the most useful, simple, reproducible and inexpensive methods of particle size analysis and belongs to the techniques using the principle on geometry similarity. This method gives a particle size distribution based on the mass of particle in each size range. Sieving analysis consists of stacking the sieves in an ascending order of aperture size, placing the material on the top sieve, vibration by machine for the fixed time, and determining the weight fraction retained on each sieve.

The mesh number system is a measure of how many openings there are per linear inch in a screen. The standard sieve mesh, the ratio of aperture of a given sieve to aperture of the next one in a sieve series is constant. The modern standard are based on square root 2 progression. Two scales that are used to classify particle sizes are the US Sieve Series and Tyler Equivalent, sometimes called Tyler Mesh Size or Tyler Standard Sieve Series. The most common mesh opening sizes for these scales are given in the Table 1 below and provide an indication of particle sizes.

Table 1 The US and Tyler standard sieve series.

US Sieve Size (No)	Tyler Equivalent (Mesh)	Opening	
		mm.	Inch.
20	20	0.841	0.0331
25	24	0.707	0.0278
30	28	0.595	0.0234
35	32	0.500	0.0197
40	35	0.420	0.0165
45	42	0.354	0.0139
50	48	0.297	0.0117
60	60	0.250	0.0098
70	65	0.210	0.0083
80	80	0.177	0.0070
100	100	0.149	0.0059
120	115	0.125	0.0049
140	150	0.105	0.0041
170	170	0.088	0.0035
200	200	0.074	0.0029
230	250	0.063	0.0025
270	270	0.053	0.0021
325	325	0.044	0.0017
400	400	0.037	0.0015

Source: Azom (2007)

2) Microscopy techniques is the most direct method of particle size evaluation, as the particle size is actually counted using an optical microscopy. A sample is prepared by suspending particles in a liquid medium and putting them on a slide for examination. The Scanning Electro Microscope (SEM) is frequently used because the short wavelength of electron beam which makes it possible to determine granule size more accurately than the light microscopy and more detailed perspective on granule surface characteristic and morphology (Lindeboom *et al,* 2004).

3) Laser diffraction is the most widely used technique for flour analysis. It is fast, reproducible, and capable of analyzing over a broad size range, and the samples are not damaged. The results are tabulated into volume, number and surface area percent. The theory on which laser diffraction sizing is based, however, assumes that all particles are spherically-shape. Sample of dry powder can be blown through the beam and the particles are passed through broadened beam of laser light

and scattered the incident light onto a Fourier lens. The lens focus the scattered light onto a detector array and the particle size distribution is inferred from the collected diffracted light data.

2.2.2 Particle Size Properties

Particle size is a small part portion or division of a whole material component which is important to product properties. Particle size distribution measurement is directly related to material behavior and physical properties of products. The flowability, bulk density and compressibility of food powder are highly dependent on particle size and its distribution (Barbosa-Canovas and Yan, 2003; Onwulata, 2005)

Flowability is defined as the relative movement of a bulk of particles among neighboring particles or along the container wall surface (Peleg, 1977). The flow characteristics of powders are of great importance in handling and storage situation, encountered in bulk materials process in agriculture, food, mining, mineral and pharmaceutical industrial because the ease of powder conveying, blending and packaging depends on flowability (Chen, 1994).

Bulk density is one of the properties used as part of the product specifications. Products with bulk density exceeding a specification range will occupy a smaller portion of the intended volume in the package. Although the net weight is correct, the pack will look smaller, as if lack of product. On the other hand, if the bulk density is below the allowed specification, the product volume will be larger than package. As a result, the package volume will be completed with product particles, but it will have a lower net weight of product declared on the label (Barbosa-Cannovas and Yan, 2003; Onwulata, 2005).

Compression test is used widely in many industrial manufacturing applications such as pharmaceutics, ceramic and food powder field. It measures such physical properties as powder compressibility and flowability. For a given powder, a set of compression cell is used (usually a piston in a cylinder). The test powder is poured into a cylinder and compressed with the piston attached to across head of a texture analyzer. The instrument will record a force-distance relationship during a compression test (Barbosa-Canovas and Yan, 2003; Onwulata, 2005).

The various properties of rice flour and other cereals and their final products affected by flour particle size have been reported. Nishita and Bean (1982) reported the rice flour particle sizes affecting its properties and the rice bread product. They found that the fine flour from turbo mills exhibited the highest peak viscosity on pasting characteristic and gave more thickening power than coarse flour. The finest flour had a higher level of starch damage. That, in turn, affected yeast-leavened rice bread baking.

Cauvain and Young (2000) provided a comprehensive study of the effects of changing the particle sizes of cake flour, and showed that the coarse flour yielded cakes that collapsed during baking and had the denser cell structure compared the finer flour. They considered the maximum particle size for cake flour to be 90 µm for cake making.

Wang and Flores (2000) studied effects of particle sizes of wheat flour on tortilla product. The resullts indicated that particle size contributed the major factor affecting the tortilla texture. The finer flour produced tortilla with decreased firmness, stretchability and foldability with undesirable product.

Yoenyongbudhagal and Noomhorm (2002) studied the effects of particle sizes on rice vermicelli. The results indicated flour particle sizes influencing both cooking and textural properties of rice vermicelli. Reducing flour particle sizes improved the cooking and textural properties of product such as decreased cooking loss. Rice flour particle size more than 200 mesh produced the rice vermicelli product with acceptable cooking and textural quality.

Kunathum (2003) studied the effect of particle sizes and starch damage of rice flour on its properties as well as properties of rice noodle. The results indicated that the rice flour gel from the finer flour had higher elasticity but lower viscosity than the coarse flour. The rice noodle prepared from finer flour had higher firmness and elasticity.

Chen *et al*. (2003) studied the relationship between rice grain and flour physicochemical characteristic and flour particle size of 24 Taiwan rice cultivars. They found the resistance time milling, milling temperature, damage starch, moisture content and protein, highly and positively correlated with flour particle sizes distribution. It was concluded that rice grain and flour characteristics was the major factor, followed by chemical composition, affecting the particle size distribution of rice flour.

3. Properties of Rice Flour

Properties of rice flour are important to determine the behaviors of intermediate and end products during processing, cooking, and end product quality. Rice flours from various grain sizes differ in their chemical composition, especially amylose content (Juliano, 1985). For example, short grain and medium grain rice flours are best for soft rice bread and cake products (Bean *et al.,* 1983). Long grain are primary used for rice noodles (Luh, 1991). On this regards, the properties of rice flour are important in obtaining the desired characteristics of final product.

3.1 Chemical Properties

3.1.1 Starch

Starch is a polysaccharide which is one of three major constituents of the rice kernel (the other are proteins and lipids). Starch consists of a branched fraction, amylopectin, and a linear fraction, amylose. Most starch contains 20-30% amylose and 70-80% amylopectin. The amylose-amylopectin ratio is the major factor affecting the functional properties of rice starch (Juliano, 1985, 1998). Amylose content was found in rice flour type and Thai rice variety as shown below in Table 2.

Table 2 Four types of rice flour based on amylose content and their Thai rice variety.

Amylose content(%)	Name	Flour type	Thai rice variety
0-2	Very low amylose	Waxy rice flour	RD6
10-20	Low amylose	Non-waxy rice flour	Kao Dawk Mali 105, RD15, Hom Klong Luang and Hom Supanburi
20-25	Intermediate amylose	Non-waxy rice flour	RD 23, Supanburi 60 and Supanburi 2.
25-30	High amylose	Non-waxy rice flour	Luang Pratew, RD1, RD3, RD13 and Pathumthanee 60

Source: Sarkarung *et al.* (2004); Naivikul (2004)

Native starch granules exhibit three main types of X-ray diffraction patterns. They are A, B and C pattern characteristic of cereal grain starches (French, 1984). Rice starch granules exhibit an A-type X-ray diffraction pattern characteristic of most cereal starches (Zobel, 1964). Waxy and non-waxy rice starches have a similar degree of X-ray crystalinity (Vidal and Juliano, 1967). The branch chain-length of amylopectin was related to the starch crystalline (Hizukuri *et al.,* 1983), gelatinization and pasting properties of starch (Wang *et al*., 1991)

3.1.2 Protein

The protein content in rice varied (6-12% dry basis), depending on variety and cultivated location. Khoa Dok Mali 105 variety contained 7.52-8.10% protein (Piyachomkwan *et al*., 2004; Intae, 2002). Factors affecting difference protein content of rice included the degree of milling. As more surface bran was removed, the protein content of milled rice was minimized.

3.1.3 Lipid

Lipids on the surface of rice caryopsis are composed of fatty acid and unsaponifiable matter. Lipids are associated with protein bodies and starch in the membrane fraction known as lipoprotein and phospholipid. The lipid content in Khoa Dok Mali 105 variety was 3 - 4% in brown rice. After milling process, lipid content was 0.5-1% in rice flour (Intae, 2002).

3.1.4 Ash

Ash content in Khoa Dok Mali 105 variety was 1-2% in brown rice. After milling process, lipid content was 0.2 - 0.5% in rice flour (Intae, 2002).

3.1.5 Vitamin

Vitamin content was higher in brown rice than in milled rice. The contributing factor is concentration of vitamin in the embryo and aleurone layer. Thus, milling results in loss of vitamin more than 50%. Rice flour contains small quantity of vitamin B complex, vitamin B2, vitamin A and vitamin E (Houston, 1972).

3.2 Physical Properties

3.2.1 Gelatinization and Pasting Properties

When aqueous suspensions of granular starches are heated above gelatinization temperature (GT), the granules become hydrated and swell to many times of their original volumes (Smith, 1964). Water absorption and solubility patterns of rice with low and high GT are different (Juliano, 1979). Water absorption and dissolution begin at a lower temperature in the starches with low GT of waxy rice. Non-waxy starch gives lower water absorption values and continues to absorb water above its GT. Starch GT can be determined by detection of birefringence end-point temperature (BEPT) with a polarizing microscope with a hot stage (Schoch and Maywald, 1956) and by amylograph peak viscosity increase (Halick *et al*., 1960; Nishita and Bean, 1979). BEPT is considered to be the temperature at which 90-98% of the granules lose their birefringence under polarized light. Final gelatinization temperature is defined as the range of temperature at which a loss of birefringence and crystallinity occur. According to final GT, GT might be classified as low, < 69.5°C; intermediate, 70-74°C; and high, > 74°C. Low GT has been confined mainly to waxy and low-amylose starch (Juliano, 1979).

The viscosity of starch pastes increases when heated to GT. The initial increase of viscosity is considered as the starting temperature of GT range. Continued heating with shear produces cooked pastes accompanied by significant changes in the viscosity and other rheological properties of the pastes. These pastes contain the mixtures of swollen granules, granule fragments and molecularly-dispersed starch molecules leached from the granules. These changes of viscosity and/or other rheological properties are useful for developing specific applications of the starches.

3.2.2 Starch Damage

Starch damage is the portion of starch granule that is mechanically disrupted during the processes used to extract or refine starch (Thomas and Atwell, 1999). Finney *et al*. (1988) revealed that during milling, starch granules are damaged by pressure, impact or shear force. Damage starch in flour results in aqueous extractability and rapid susceptibility to enzymatic digestion (Mao and Flores, 2001). Damage starch swells in water causing increases in water absorption of flour.

3.2.3 Rheological Properties

Rheology is the branch of science that deals with the flow and deformation of materials. Cake batter is a viscoelastic material, exhibiting both elastic solid and viscous liquid behavior under a wide range of conditions. An elastic solid stores mechanical energy during deformation and reverts its original form upon removal of external forces. The simplest type of viscoelastic behavior is linear viscoelastic, where the measured properties are independent of magnitude. The small amplitude oscillatory shear is the method to study the linear viscoelastic and to determine storage modulus and loss modulus as a function of test frequency in the linear viscoelastic region of test material (Gunasekaran and Ak, 2000).

Oscillatory testing is a small deformation and nondestructive method which is usually used for studying the rheological properties (Steffe, 1996). It also called dynamic testing, is the most common method for studying the viscoelastic behavior of food. Oscillatory testing is referred to as “small amplitude oscillatory testing” because small deformations must be employed to maintain linear viscosity behavior. Dynamic testing instrument can be divided in two general categories. First is controlled rate instrument where the strain is fixed and stress is measured. The other is controlled stress instruments where the stress amplitude is fixed and the strain is measured. Both produce similar results (Steffe, 1996).

Typical oscillatory testing is operated in a strain mode (fixed strain) and this is a predominant testing method used for food. Shear strain may be generated using parallel plate, cone and plate, or concentric cylinder fixtures. In case of parallel plat (Figure 4), there are consider two rectangular plates oriented parallel to each other. The lower plate is fixed and the upper plate is allowed to move back and forth in a horizontal direction, with the sample being tested located between the plates of a controlled rate device. Suppose the strain in the material between the plates is a function of time defined as:

$$\gamma(t) = \gamma_0 \sin(\omega t) \qquad (1.1)$$

Where $\gamma(t)$ = strain at time t

γ_0 = the strain amplitude; equals to L/h

when the motion of the upper plate is $L\sin(\omega t)$

ω = angular frequency(rad/s) equivalent to $\omega/\pi 2$ hertz.

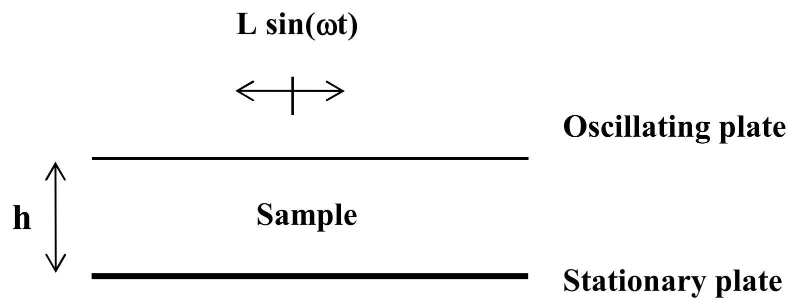


Figure 4 Oscillatory strain between rectangular plates
Source: Steffe (1996)

The applied strain generates two components in the viscoelastic material: an elastic component in line with the strain and a 90°C out of phase viscous component. Differentiation of Equation (1.1) yields Equation (1.2).

$$\gamma'(t) = \gamma_0\ \omega\cos(\omega t) \qquad (1.2)$$

Where $\gamma'(t)$ = strain rate

For the deformation within the linear viscoelastic range, Equation (1.3) expresses the generated stress (σ_0) in terms of a storage modulus and loss modulus.

$$\sigma_0 = G'\gamma_0 \sin(\omega t) + G''\gamma_0 \cos(\omega t) \qquad (1.3)$$

Where σ_0 = stress
G' = storage modulus
G'' = loss modulus

The following expressions that define viscoelastic behavior can be derived from Equation (1.2) and (1.3)

$$G' = (\sigma_0 / \gamma_0) \cos(\delta) \qquad (1.4)$$

$$G'' = (\sigma_0 / \gamma_0) \sin(\delta) \qquad (1.5)$$

The storage modulus (G') expresses the magnitude of the energy that is stored in the material or recoverable per cycle of deformation. Loss modulus (G'') is a measure of the energy that is lost as viscous dissipation per cycle of deformation. Therefore, for perfectly elastic solid so-called “Hookean solid”, all energy is stored and G'' is zero. In contrast, for a liquid with no elastic properties so-called “Newtonian fluid”, all energy is dissipated as heat and G' is zero (Rao, 1999).

Viscoelastic materials are the materials that have both viscous and elastic properties, so storage and loss modulus are not equal to zero. If G' is much greater than G'', the material will behave more like a solid, and the deformations will be essentially elastic or recoverable. However, if G'' is much greater than G', the energy used to deform the material is dissipated viscously and the material’s behavior is liquid-like (Rao, 1999).

4. Rice Flour Utilization

Rice flour granulation ranges from rice meal with coarsest flour to rice starch with the finest flour (Elaine, 1998). Rice flour is utilized as an ingredient in formula and processed food. The basic demands for rice flours are for use in baby foods, breakfast cereals, and snack foods, for separating powder in refrigerated-preformed-unbaked such as biscuits, dusting powders, bread mixed; and for formulations of pancakes and waffles (Luh and Liu, 1980; Bean and Nishita, 1985). Another type of rice flour produced from waxy rice is good for use as a thickening agent for sauces, gravies, puddings and oriental snack foods (Luh, 1991).

Rice flour can be used in many applications to replace wheat flour because it is gluten-free and non allergenic. It is also fat, sodium, and cholesterol free. However, rice flour baking properties are less important commercially in baking industry because its lack of gluten as structure-forming protein that is necessary for gas retention in yeast-raised or chemically-raised baked products. Many researchers improve the formulation to incorporate rice flour alone or combined with other flour substitutes for baked products such as bread, cakes and cookie. Literature reviews on non-wheat rice bakery are available.

Panya (2001) developed bread from wheat-Jasmine rice composite flour using the ratio of wheat : Jasmine rice flour at 100:0, 80:20, 70:30 and 60:40. The results indicated that as Jasmine rice flour replacement increased, the specific volume of bread decreased whereas the hardness of product increased. Up to 30% Jasmine rice flour can be used to replace wheat flour in product that consumer accepted (moderately liked).

Tipkanon *et al*. (2001) developed Mantou (Chinese style bread) from wheat-Jasmine rice composition flour using Jasmine rice flour substitution at 25-35% level. The results revealed that as Jasmine rice flour increased, the degree of elasticity and specific volume decreased with increased hardness of the product. Wheat flour can be replaced with 35% Jasmine rice flour, yielding a moderately liked by consumers.

Haruthaithanasan *et al*. (2002) prepared butter cakes from Jasmine rice flour at 80, 90 and 100% replacement of wheat flour. The results indicated that 100% replacement of wheat flour with Jasmine rice flour was feasible for butter cake preparation, but the texture of cake (firmness and elasticity) were significantly different from the control wheat butter cake. 94% of consumers accepted this product (moderately liked).

Samutkrut (2003) prepared the frozen doughnut, using Jasmine rice flour to substitute 0-100% wheat flour topped with pizza sauce. The results indicated that as the Jasmine rice flour replacement increased, specific volume and springiness decreased whereas the hardness of doughnut increased. Due to the decreased gluten, as Jasmine rice increased, the gas holding capability of the dough decreased. For the optimum formula, 40% wheat flour can be replaced with Jasmine rice flour, and 86% consumers accepted this product (slightly liked).

Charoenratanasisuk (2004) studied on replacing wheat flour with Jasmine rice flour for development of the high protein and fiber bread from wheat-rice composite flour. The results revealed that 37.5% wheat flour can be replaced with Jasmine rice flour. 88.3% consumers accepted this product (slightly liked).

Toonsakool (2006) studied on the fat-sugar reduced Jasmine brown rice muffin using Jasmine brow rice flour. The results indicated that muffin product can be prepared with 100% Jasmine brown rice flour.

Nukit *et al*. (2006) studied on the reduced calories and reduced sugar butter cake from Jasmine brown rice flour. The results indicated that 100% wheat flour can be replaced with Jasmine brown rice flour, and the product had reduced calories and energy up to 52% and 36%, respectively. 99% of specific consumer group accepted the product with moderate liking and 97% of general consumer group accepted this product (slightly liked).

Manothum (2006) developed Kanom Sali from wheat flour and Jasmine rice flour, with an attempt to replace 100% wheat flour with Jasmine rice flour in formula. The results indicated that as the Jasmine rice flour replacement increased, the texture of Kanom Sali (degree of elasticity and hardness) and specific volume were significantly increased. For the optimum formula, only 20% of wheat flour could be replaced with Jasmine rice flour, with 78 % consumers accepted this product (moderately liked).

Yodkansri (2007) developed the reduced cholesterol and reduced sugar chiffon cake from Jasmine rice flour. The results revealed the chiffon cake product can be prepared from 100% Jasmine rice flour but the hardness and chewiness of chiffon made from Jasmine rice flour were higher than that made from wheat flour. To improve the softness of product, 20% water as flour weight was used in the optimum formula. 90% consumers accepted this product (slightly liked).

5. Effects of Storage of Rice and Flour on Their Properties

During storage of rice, a number of changes occur, which is known as aging. Aging rice flour relates to physical and chemical changes that occur in flour during storage. Some researches have shown that the baking performance of flour improves with age to an optimum. The flour will maintain an optimum baking performance for a certain period of time, and then deteriorate as the flour progressively ages. Temperature, moisture content and relative humidity of storage area, the amount and type of light, the microbial activity, and the atmospheric oxygen content will affect the aging process of flour (Wang and Flores, 2000).

Moritaka and Yasumatsu (1972) proposed the mechanism of rice aging involving lipids and proteins. Lipid from free fatty acids (FFA) can complex with amylose and carbonyl compounds and hydroperoxides which can accelerate protein oxidation and consensation plus accumulation of volatile carbonyl compounds. Protein oxidation (formation of disulfide linkages from sulphydryl groups) together with an increase in the strength of micelle binding of starch, inhibits swelling of starch granules and affects cooked rice texture. It is apparent that aging is a complicated process involving physical, chemical and biological change. The release of free phenolic acids alters integrity of the cell wall and at the same time the phenolic acid exerts an effect via their antioxidant activities on the formation of FFA that can further complex with amylose during storage process (Table 3).

Table 3 A schematic model of the aging process in modified rice form.

Substrate	**Storage change**	**Cooking effect**	**Sensory effect**
Starch →	Increased strength of micelle binding →	Inhibit swelling of starch granule →	Texture
		↓	
		Fatty acid-amylose →	Texture
		↑	
	(1) Hydrolysis →	Complex FFA oxidation	
Lipid →		↓	
	(2) Oxidation →	Hydroperoxides carbonyl compound →	Increase of volatile
		↓	carbonyl compound
			↓
Cell wall→	(1) Phenolic acid		Aroma
			↑
	(2) Rigidity →	→	Texture
Protein →	Oxidation →	-SH → S-S →	Decrease of volatile sulphur compound
		Interaction among proteins	→Inhibit swelling of starch granule
			↓
			Texture

Souce: Pomeranz (1991)

Aging is a natural and spontaneous phenomenon involving changes that impact physical, chemical, and biological properties of rice that, in turn modify the cooking processing, eating and nutritional qualities all affect the commercial value of the grain in the market. These changes include cooking, texture and pasting properties, chemical composition, flavor, sensory attributes and enzyme activities on storage condition and storage time (Zhou *et al*., 2002). The property changes in rice and flour during storage process have been reviewed.

5.1 Chemical Properties

The changes in functionality during aging have been focused on the properties of rice components such a starch, protein and lipid and their interactions during storage.

5.1.1 Starch

Some researchers reported no significant effect of storage time on total starch, amylose and amylopectin contents of rice flour (Barber, 1972; Rajendra and Zakiuddin, 1991; Qiu *et al*., 1998; Teo *et al*., 2000) and the finding agrees with that of Noomhorm *et al*. (1997) who reported that total amylose content of waxy rice did not change during 4 months of storage. However, Chrastil (1990a) detected a small but significant increase in amylose content during storage of milled non waxy rice over extended period of 12 months, although total starch content did not change. Amylose content is an importance characteristic that affects rice cooking quality and processing and eating quality. Stored milled rice showed increased water absorption and large volume of cooked rice on which amylose content was directly related (Tsugita *et al*., 1983; Delwiche *et al*., 1996; Hamaker *et al.,* 1993; Perce *et al*., 2001). Some hydrolysis or degradation probably occurs during storage, leading to the significant proportional increase in non reducing sugar and starch. Aging was reported to induced structural changes in the starch molecule of amylose and amylopectin (Chrastil, 1990b).

5.1.2 Protein

Rice has a low protein content. Dhaliwal *et al*. (1991) reported the increased content of free amino acid during storage of milled rice. Some hydrolysis probably occurs during the storage process of rice, which leads to increase or decrease in protein. Chrastil and Zarins (1992) reported that the medium and long grain rice had increased di-sulfide bond during storage. In addition, the free amino nitrogen content in the outer layer was lost during storage, and this loss was related to millard-type nonenzymatic browning as suggested by the parallel losses in free amino nitrogen and whiteness of rice (Barber, 1972). However, Teo *et al*. (2000) reported that the protein content of the non-waxy rice flour stored for 14 weeks remained unchanged.

5.1.3 Lipid

Lipid in rice is usually stable in the intact spherosomes cell. When lipid membrane is destroyed by phospholipase, physical injury or high temperature, lipid hydrolysis is initiated by lipase of the various fractions with the greatest proportional change observed in free fatty acid (Takano, 1989). Dhaliwal *et al*. (1991) observed the change in free fatty acid during rice storage. Lipids are hydrolyzed and oxidized to the free fatty acids or peroxides, thus increasing the level of acidity and significantly deteriorating the taste and flavor.

5.1.4 Enzyme Activity

As storage time increased, enzyme activities from amylase and proteolytic enzyme decreased but protease, lipase and lipoxygenase activities increased. Peroxidase and catalase activities were used as the indices of quality deterioration of rice grain during storage, because these were lost rapidly during storage of rice (Delwiche *et al*., 1996; Zhou *et al*., 2002).

5.2 Pasting Properties

The indices of storage quality of rice are changes in pasting properties of rice paste. Rice exhibits various ranges of cooking quality and rheological properties that are determined by the swelling, gelatinization and retrogradation characteristics of its flour. Many researchers have studied the pasting properties of rice flour during storage duration. The viscosity of rice paste increased dramatically after storage of milled rice. Villareal *et al*. (1976) and Perce *et al*. (2001) reported increase in peak viscosity of rough rice during storage at higher temperature. Teo *et al*. (2000) studied the changes in pasting properties of non-waxy rice flour during storage. The results revealed that peak viscosity of rice paste generally increased with increased storage time. They noted that starch-protein interaction decreased during storage, thereby allowing the predominant starch fraction to more fully exert its effects on the pasting property change associated with aging of rice flour. Some studies revealed that the gelatinization, retrogradation and enthalpy of rice flour were significantly affected by storage temperature, moisture content and storage time. Significant changes of gain hardness, water absorption, volume expand and increased peak viscosity were also observed during rice storage (Tsugita *et al*., 1983; Hamaker *et al*., 1993; Fan and Marks, 1999; Perce *et al*., 2001). Some studies reported higher amylograph viscosities of rice flour after storage (Bean, 1986; Perdon *et al*., 1997; Fan and Marks, 1999).

5.3 Textural Properties

During rice storage, physicochemical changes occur which affect rice functionality and eating quality. Aged rice became fluffier and hardness of cooked rice texture increased during storage (Villareal *et al*., 1976; Indudhara *et al.,* 1978). Meullenet *et al.* (2000) showed decreased stickiness and increased hardness of rice during the first week of storage. Rice stored for a long time is harder and less sticky than fresh rice in the cooked form. Stickiness was greatest when rice was fresh and decreased with aging. Chrastil *et al*. (1990a) investigated physicochemical and functional properties of the American rice grain (short, medium and long grain) stored for 10 months. They noted that swelling, water absorption, bulk density and color intensity of rice flour increased whereas the stickiness of cooked rice decreased.

5.4 Microbiological Properties

During long-term storage with high temperature and high humidity, the appearance of mold, fungi, or toxins may occur, which makes the stored rice unsafe for human consumption (Delwiche *et al*., 1996; Zhou *et al*., 2002).

6. Cakes Classification and Process

Cake is a baked product from batter. It is mainly composed of flour, sugar, eggs, shortening, milk and leavening agent. These ingredients are mixed together to yield specific characteristics of finished cake or bake product such as puffy, light and fine texture. Furthermore, the interaction among them affects product quality. In fact, some processes of cake making, such as whipping of egg white usually determine the final volume, structure and softness of cake product and hence, the various types of cake.

6.1 Cake Classification

Cake can be divided into three categories based on the level and type of leavening (David *et al*., 2002; Favoritebrandrecipes, 2006).

6.1.1 Butter-type cake. There are products leavened mainly by baking powder as the primary leavening agent. There are higher in fat and structure depends on fat, liquid and emulsion created during batter mixing. These cakes contain fat such as butter, shortening, margarine or oil mixed together with sugar until the mixture is smooth, light and fluffy. Examples include pound cake, butter cake, chocolate cake, and fruit cake.

6.1.2 Foam-type cake. The product is less in fat and its structure relies solely on the air incorporation into egg white. Egg white can aerated to a form during mixing, giving a characteristic spongy crumb to products such as angel food cake, sponge cake, and roll cake.

6.1.3 Chiffon-type cake**.** The product is a combination of the 2 types mentioned above. It has a fine structure of foam type cake and it shows a lustrous butter-type cake. Chiffon-type cake is made by vegetable oil instead of butter or margarine as used in butter-type cake. In addition, chiffon cake has different mixing comparing to the other types of cakes.

6.2. Process of Cake

6.2.1 Mixing

The mixing operation is aimed at homogeneity as far as ingredient will allow. The mixing of cake batter is a stage-by-stage process. For the creaming method, traditionally fat and sugar are blended to light, aerated cream to which egg is added as a second stage. This addition may have to be gradual, with time allowed for some of the egg to be incorporated into the cream before the next quantity is added. The final addition is of flour, and at this stage also it is customary to add baking powder and other ingredients.

Cake batter is a complex fat in water emulsion composed of bubbles as the discontinuous phase and the part of egg-sugar-water-fat mixture as the continuous phase in which flour particles are dispersed. Quantity and distribution of air, especially bulk air content, is important, determining the quality of cake. Air bubble affects many aspects of batter and the finish product, including appearance, texture consistency and size per unit weight. The presence of a well-defined volume of gas cell is essential for the characteristic properties of food. The good quality of cake requires incorporation of air into the batter and the retention of these bubbles throughout the baking process, until the starch has swollen and the cake structure is set. Air has been entrained into the shortening phase during the first stage of making cake. This method is not an efficient way to incorporate air as it depends primary upon the ability of the plastic shortening to trap air bubbles during creaming. The shortening contains monoglycerides to subdivide the air bubbles, creating smaller bubbles that are more efficiently retained by the shortening phase and give more uniform nucleation for leavening gases throughout the batter during baking; the final crumb grain, therefore, is closer and overall volume is larger (Townsand, 2002).

6.2.2 Baking

After mixing, cake batter is taken to baking in the oven, the complexity of cake batters enables the mechanism of the heat setting process. Thermal setting of the cake is defined as the temperature at which the batter changes from an emulsion to the porous structure because of starch gelatinization together with protein denaturation. During baking, as temperature increases the vapor of water and the rate of formation of carbondioxide gas increases, which further diffuses into air bubbles, resulting in the expansion of cake batter. Further, the structure set by starch gelling and egg coagulating becomes firm, and color and some moisture loss then follow (Townsand, 2002).

7. Ingredients Use for Cake

Ingredients use in cake are the important raw materials. The proportion of these ingredients could enhance the balance in cake formulation, determine the quality of cakes, and dictate the specific characteristics of finished cake or bake product. According to the compositions used for cake, there are two types: the compositions that forms the cake structure are flour, eggs and milk; the compositions that cause the softness of cake are sugar, shortening, and leavening agent.

7.1 Flour

Flour is the main component, structure, and combining agent for other ingredient mixtures in cake making recipes. Cake flour normally is milled from special selected soft wheat to the finer flour particle sizes. A resulting bleached flour with 7-9% protein produces good quality of cake (Bennion and Bamford, 1997). A fine and color-bleaching flour is suitable for cake making. Flour that has been bleached would absorb more sugar and fat than non bleached flour. The soft flour should be used in order to get the texture and flavor for best quality of cake. Stronger wheat flour would yield products being tough and dry. Rice flour could be use to replace the soft wheat flour in cake due to its low content of protein (6-9%) and its lack of gluten that is necessary for gas retention in yeast-raised or chemically-raised baked products. Then rice flour can be us an ingredient or combined with other flour substitute (Bean *et al.,* 1983; Gallagher *et al.,* 2003, 2004; Sivaramakrishnan *et al*., 2004; Moore *et al.,* 2004, 2006).

7.2 Shortening

Shortening is any fat or oil used in food product, especially baked product, and is used to make a shortness of texture (as in shortbread). It occurs vary widely in nature and can be from vegetable, animal or margarine origin. If liquid at room temperature, it is known as oils but if semi-solid or solid at room temperature, it is known as fat. Shortening used in baked product includes butter from animal fat, margarine, cooking oil and vegetable shortening from vegetable fat and oil (Anonymous, 2007b). Shortening acts as a barrier, and if there is enough of it in the recipe, it will fully coat the flour particles and prevent water from reaching protein. The functional properties of fats used for baking have to be shortening power, batter aeration, emulsification and providing flavor and calories (Cauvain and Young, 2000).

Butter is an animal fat that enhances flavor for bakery products. It contains milk solids (2%), water (16%) and salt. The natural melting point of butter is relatively low (25-28˚C) and it readily turns to oil even under normal bakery conditions. In cakes, the creaming properties of butter are relatively poor and its use may require that the recipe is supplemented with an emulsifier in order to get the best results (Podmore and Rajah, 1997).

Margarines; the composition of margarines is often regulated to be similar to that of butter, but the mixture of oils, and, therefore, the functionality, of different margarines will be different. In addition to milk solids, water and salt, margarines may contain an emulsifier to aid the dispersion and stability of the water phase in a manner similar to that discussed above for high-ratio fats (Cauvain and Young, 2000).

Vegetable Oil and Fat are substances derived from plants. Normally, oils are liquid at room temperature whereas fats are solid. Cooking oil, a purified plant which is almost in actual commercial oil extract from seed oil plant including olive oil, peanut oil, canola oil, sunflower oil, sesame seed oil and rice bran oil. The generic term 'vegetable oil' used to label a cooking oil product refers to a blend of a variety of oil, often palm, corn, soy bean or sunflower oil. Many vegetable oils are consumed directly or used as ingredients in food (Anonymous, 2007a). Vegetable fat, so-called vegetable shortening, is a solid fat made from vegetable oil, such as soy bean and cotton seed, which has been hydrogenated to form a solid. The process creates trans fatty acid which turns polyunsaturated fat into saturated fats. It is virtually flavorless and is used in baked product to enhance lightness and flakiness. The commercial brand of vegetable shortening for example, is Crico®(Anonymous, 2007b).

7.3 Sugar

Sugar is used in baked product as a sweetener. The main sources of sucrose are sugar cane and sugar beet (Jones *et al*., 1997). There are available in a number of different crystalline forms which are widely used in the manufacture of baked products. The different forms of sucrose, granulated, caster, pulverized and icing, are distinguished by their particle size, with the largest being the granulated form. Sugar is combined with protein molecules from ingredients such as egg or milk to give the rich brown color, flavor and aroma characteristic of freshly baked product. These reactions are known as maillard browning. They mainly occur on the surface of the product where the temperature are highest, and the extent of color depends on the amount of sugar in the recipe, its chemical composition, and the temperature in the baking oven. An important role of sucrose is its effect on the water activity of the baked product. Increasing levels of sucrose lowers product water activity and has a significant effect on product spoilage-free shelf-life (Cauvain and Young, 2000).

7.4 Egg

Egg is an important ingredient in many baked products, especially in cake category. Egg is available in many forms: whole, fresh, or preserved ether liquid or powder. The important of egg as an ingredient lies in its contribution to the nutritional value of the baked product and to marked improvement of the appearance and eating quality of the product. Both egg white and egg yolk can be used for bakery products (Cauvain and Young, 2000).

Egg white or egg albumen is used in a number of baked products, where the yellowness conferred by the egg yolk is unacceptable, for example, in white layer cake. Egg white proteins make a contribution to the eating quality of cakes by improving their physical strength (baked product). It consists of the complex structure of proteins, such as ovalbumin and conalbumin. The egg white protein in dry matter is about 85% of the total protein content of egg and contains natural inhibitors, such as lysozyme.

Egg yolk is a dispersion of particle in a continuous phase. The system contain egg liquid, of which 70% are triglycerides. The particles make up 25% of dry matter of yolk, being phosvitin and lipovitellin. The continuous phase contains 75% of the dry matter of the yolk in the form of lipovitellin and globular protein. Cholesterol and lecithin are also present in egg yolk.

7.5 Baking Powder

Baking powder is used for improving quality of bakery product. It comprises a mixture of sodium bicarbonate. The total quantity of carbon dioxide (CO_2) depends on the quantity of sodium bicarbonate that is present in the mixture (Thacker, 1997). Baking powder, by FDA definition, must contain sodium bicarbonate in sufficient quality to release a minimum of 12 % CO_2. The fast-acting baking powder releases most of gas at room temperature. Slow-acting baking powder releases a portion of the available CO_2 during mixing but in the oven generates most of it by reaction. Double acting powder is really a version of the slow-acting type which exhibits somewhat more gas producing potential during mixing (Sammel, 1992). The level of baking powder used in the manufacture of cakes has a significant effect on product volume and quality. Cake products that do not contain baking powder tend to be low in volume and have a dense, close structure. Initially, as the level of baking powder in the recipe increases, cake volume increases and the crumb structure increases. Eventually, a maximum volume is achieved and thereafter as the level of baking powder continues to increase the product collapses, volume falls and the crumb structure becomes coarse and open in nature (Cauvain and Young, 2000).

7.6 Emulsifier

Emulsifiers are natural or synthetic substances that promote the formation and improve the stability of emulsion, e.g., dispersion of fat droplet in aqueous solutions or water droplet in a continuous liquid phase. In some cases, they change the surface tension of water or aqueous solutions. The characteristic of emulsifier molecules is a hydrophilic group (attracted to water) and lipophilic group (attracted to fatty substances). From two group molecules, it is usual to find the one or the other plays a dominant important in the action of the emulsifier (Riken, 2000).

Consumers prefer cakes that are light, tender and moist. Without emulsifiers, cake batter appears greasy and shiny with the fat dispersed in very large, coarse, irregularly shaped particles. Incorporation of certain emulsifiers provides aeration, foam stabilization, emulsification, and crumb softening to cake systems. Commercial emulsifier for use in baked products include monoglycerine and propylene glycol ester.

Propylene glycol monostearate (PGMS); propylene glycol esters of fatty acids are mixtures of propylene glycol mono- and diesters of saturated and unsaturated fatty acids derived from edible oils and fats. The products are produced either by direct esterification of propylene glycol with fatty acids or by transesterification of propylene glycol with oils or fats. Propylene glycol esters of fatty acids have been known to the food industry for 40 years and have been used as the emulsifier shortening for cake mixed and sponge cake (Fleming and Niels, 2004). Painter (1981) reported a comparison of different emulsifiers such as monoglycerides, polyglycerol ester PGMS and lactylated monoglycerides in cake mixed containing hydrogenated animal fat as the shortening. Using a one-stage method, PGMS produces a cake with the largest volume, fine crumb grain, moistness and good eating quality but slightly flat crown. The use of propylene glycol ester requires pre-hydration of the emulsifier, for the cake making. PGMS is applied as a powder-foaming agent for cakes and desserts, liquid shortening, excellent alpha-tending emulsifiers, wide application in toppings, powdered cake improvers, cake mixed, alpha-crystalline stabilizer for sponge cake foaming gel (Riken, 2000).

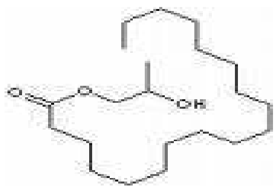


Figure 5 Propylene glycol monostearate

Source: Chemicalland21 (2006)

Diacetyl Tartaric Acid Esters of Monoglycerides (DATEM); an emulsifier in which diacetyl tartaric acid is bound with monoglyceride. It is dispersible in cold and hot water, and soluble in fat and oil. DATEM are ionic oil in water emulsifier. The reactions of mono-diglyceride with diacetylated of the mono and diglycerides are responsible for their hydrophilic properties. At the same time, a huge hydrophilic and polar moiety with free carboxylic group is transferred into the molecule via the esterified diacetylated tartarice acid (Rolf and Wolfgang, 2004). The application of DATEM has an advantage of minimizing loss of water during the baking process; this is due to the starch molecule sticking to each other (Hsu *et al.,* 2000). Due to the action of DATEM in baked product, the use of emulsifier or combination of difference emulsifiers in the baked products offers many advantages during processing and storage. The important advantages are increased air intake into the baking mass during aeration, reduced water loss during baking, increased volume and improvement in constancy of shape and form of the baked product (Robert, 2004).

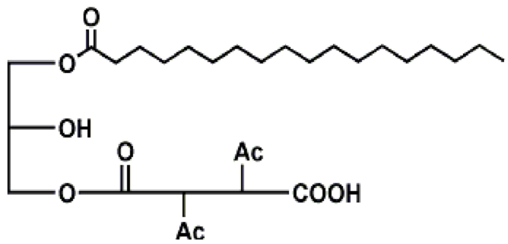


Figure 6 Diacetyl tartaric acid esters of monoglycerides

Source: Danisco (2005)

7.7 Milk

Liquid milk is a mixture of water, fat and protein. It contributes to the hydration of batters and confers color and flavor. Milk is used as the liquid to dissolve sugar and other mixtures, causes baking reaction, and affects cake structure on moistness and softness (Cauvain and Young, 2000).

7.8 Salt

Salt is used for a variety of purposes in the baked products. It makes a major contribution to product flavor. It is important, because of its ionic nature, in the control of product water activity and, therefore, mould-free shelf-life (Cauvain and Young, 2000).

7.9 Flavor

Flavors are the additives for a specific odor and flavor. Selection of most suitable additives should be done for various types of cake. The amount of additives used must not affect already existing odor and flavor of baked cake (Cauvain and Young, 2000).

8. Ingredients for Reduced Fat in Baked Products

Public awareness about the health risk has been increased, and the substitution of high fat by reduced fat ingredient alternatives can significantly reduce the calories derived from fat. For example, American consumers are being alerted by health organizations, American Heart Association that recommended the percentage calories from fat should not exceed 30% of total calories consumed (Bakal, 1991). In England, to make a reduced fat claim on packaging, a 25% reduction in the original formulation is recommended (Dwyer and Gallagher, 2001). Baked products including bread, cookies, muffins, pastries and cakes are considered as a significant source of fat in human diet. For specific health awareness, consumers want fat taken out of food without flavor and texture being adversely affected. Novel ingredients have been investigated for use in the formulation of the reduced fat baked products.

8.1 Fat Replacer

Several commercial ingredients are available that can be use as fat replacers. In general, these can be classified in 4 major categories based on chemical composition, functions of ingredients, and/or both (Roller and Jones, 1996).

8.1.1 Fat Based Ingredients

Emulsifier has been used in the formulations of reduced fat in baked products. The categories include:

Mono-diglycerides are approved by FDA and can be replaced as an emulsifier for all the shortenings in baked products. Some researchers reveal that it can be used to replace 10.4% and 15.4% shortening in a yellow cake and oat meal cookies, respectively (Roller and Jones, 1996).

Polyglycol esters are used to replace part or all of the shortening. These FDA approved ingredients act as the emulsifiers by improving the aeration properties in dough. Other ingredients, including lecithins, are traditionally used as emulsifiers and effective as a fat replacer (Roller and Jones, 1996).

8.1.2 Starch Based Ingredients

Several starch based ingredients have been used as the fat replacers. Several ingredient manufacturers commercialize maltodextrin and rice starch, under various brand names.

Maltodextrin, a plant-derived carbohydrate is often more effective in a reduced fat formula. It is hydrophilic due to large numbers of hydroxyl bond available to bind with water, creating carbohydrate –water network that can mimic the texture of fat. Maltodextrins are nutritive polysaccharide obtained from corn starch and are defined by degree of starch hydrolysis, which is reported as dextrose equivalence (D.E). The FDA classifies this product with a D.E. of less than 20. It provides functional benefits including water binding, humectancy, viscosity and bulking capabilities. It is also combined with other ingredients to provide a pleasing sensory profile of texture and taste in baked products. With a high molecule weight it holds water tightly, binds body in the baked good, and extends shelf life of products. Maltodextrins are used as a fat mimic. In a dry form, maltodextrins replaces fat and adds solid when fat is taken out of a formulation. In case of dry mixed product, it enhances the dispersion of other ingredients. For the dry application, 4 kcal/g of carbohydrate replaces 9 kcal/g of fat, thus partially reducing overall calories from fat (Nonaka, 1997).

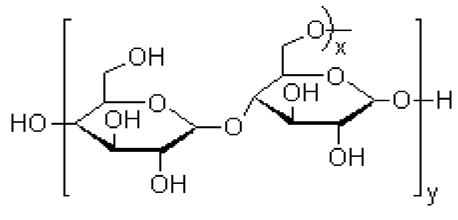


Figure 7 Structure formula of maltodextrin

Source: Chemblink (2007)

Rice starch is another new starch based fat replacer. The granules of rice starch are inherently small, raging from 2-8 μm. It provides a smooth, creamy gel structure. It is also temperature stable and freeze thaw stable. The rich starch is used in many baked products (Roller and Jones, 1996).

8.1.3 Water Solution Based Ingredients

These categories include a variety of materials that can be used to reduce calories. Polydextrose, a condensation polymer of dextrose, is a low calorie ingredient. It was reported as a fat replacer and low-calorie bulking agent in baked product such as cake, cookies, and brownie (Roller and Jones, 1996).

8.1.4 Combination System

Several ingredient manufacturers have formulated a combination of ingredients specifically to reduce fat in baked products. These ingredients are expected to meet the product specification and market need.

8.2 Stabilizer

It is a food additive used to help maintain emulsions in foods. This category includes a variety of material used to reduce calories. A variety of gum such as guar gum, caragenan, cellulose gum, xanthan gum, are commonly used stabilizers.

Guar Gum, also called guaran, is a galactomannan. It is primarily the ground endosperm of guar beans. The guar seeds are dehusked, milled and screened to obtain the guar gum. Guar Gum is the edible polymeric material that is soluble in water and causes a viscous or gelled consistency in food. Important functional properties include water binding, fat rejection, encapsulating and structure forming. Thus it can be used in various multi-phase formulations; as an emulsifier because it helps to prevent oil droplets from coalescing, or as a stabilizer (FAO, 2007).

9. Consumer Acceptance Testing

Consumer test is a market research method that evaluates consumer acceptance toward product usage. Acceptance testing is the evaluation task, referred to as acceptance, preference or consumer testing. In acceptance testing, liking or preference for a product is measured. The test will provide the estimated data of product acceptance based on its sensory properties (Stone and Sidel, 1993). Consumer test is a highly effective tool in designing product or services that will retail in larger quantities or at higher prices (Meilgaard *et al.,* 1999). Typically, the number of participants in a consumer test that is 100-500, divided over three or four cities per location (Meilgaard *et al.,* 1999). The reasons for conducting a consumer test usually fall within one of the following categories: product maintenance, product improvement/optimization, development of new products, assessment of market potential, product category review or support of advertising claims (Meilgaard *et al.,* 1999).

9.1 Laboratory Test

The laboratory is the most frequently used location for sensory acceptance tests because it is accessible, possible to control the test conditions and rapid to collect feedback (Stone and Sidel, 1993). The recommended number of response per product is between 25-50 (Stone and Sidel, 1993) and consumers should not evaluate more than 5 product settings. The advantages of laboratory tests are control of product preparation and presentation, and that employees can be contacted on short notice and the visual aspects can be masked so that subjects can concentrate on other attributes. In addition, the rapid data feedback and the low cost are also advantages (Stone and Sidel, 1993; Meilgaard *et al*., 1999). The disadvantages of laboratory tests are the biases of the location test and lack of normal consumption and usage environment (Meilgaard *et al*., 1999)

9.2 Central Location Test (CLT)

The central location test (CLT) is the quantitative research technique. CLT is the most frequently used of consumer tests. It is usually conducted in a place highly accessible to a large number of potential purchasers, such as shopping mall. Consumer could be pre-recruited or intercepted via mail, telephone or personal interview (Stone and Sidel, 1993). Typically, the quantities of responses that are collected per location are 50-300 (Meilgaard *et al.,* 1999) and 100 responses per product are usual as stated by Stone and Sidel (1993) or more consumers (response per product) are obtained. Product is prepared out of sight and serve on uniform plates labeled with the three digital codes (Meilgaard *et al.,* 1999). Stone and Sidel (1993) offered that the number of samples to be evaluated by the consumers per session at CLT should be 5 or 6, with consideration that fewer samples will minimize test time. The major advantages of using CLT are: the capability of large number of participants and, this obtaining a large number of responses, and that the product evaluation is conducted under controlled conditions and one consumer can evaluate several products during one test session (Stone and Sidel, 1993; Meilgaard *et al*., 1999). The disadvantages of using CLT are that products are tested under semi-artificial conditions compared to normal use in terms of preparation and amount used, and limit information can be obtained due to a limited number of questions that can be asked during the evaluation (Meilgaard *et al*., 1999).

9.3 Home Use Test

Home Use test (HUT) is a method that measures consumer decision. It is a quantitative research technique that can be used at any stage of product development for developed concept (Shaw, 1996). Meilgaard *et al*. (1999) asserted that the home use test (HUT) represents the ultimate in consumer testing. For HUT, the product is tested under actual, normal home-use conditions (Resurreccion, 1998) and other test factors are not controlled. The panel size should be doubled in size (50-100 families) compared to the laboratory test (Stone and Sidel, 1993). More information can be obtained from HUT because responses may be obtained not only from the respondent but also from the other members of the entire household (Resurreccion, 1998). Although HUT has the disadvantages of being expensive, time consuming and lacking environmental control; the product is tested under actual usage conditions, thus it provides the realistic situation among consumer test (Lawless and Heymans, 1998) and all family member's opinions are obtained as well as marketing information (Stone and Sidel 1993).

9.4 Performance Test

Nickols (1997) defines performance as the outcomes of behavior in which the behaving individual's environment is somehow different as a result of his or her behavior. Performance test is defined as a quantified result or a set of obtained results, and also refers to the accomplishment, execution or accomplishment of work (Stolovitch and Keeps, 1992). An objective of progressive evaluation of performance is to monitor the test product in an appropriate controlled use test, in which the product is used by consumer in the normal way and the tested product under control condition (Jenkins and Adams, 1989). The different kinds of products require appropriate types of use and simulated-use test, which must be specifically designed for evaluating the effects of products such as testing human skin irritation for cosmetic product, and test performance of microwave oven and steamer (Jenkins and Adams, 1989; Swain *et al.,* 2007).

Several studies reported the home use test method was used for product test such as flour mixed and bakery mixed in food product (Charoenratanasisuk, 2004 and Chumminkwan, 2006). Meilgaard *et al.* (1999) stated that home use test represented the ultimate in consumer testing as products are tested under normal usage conditions. However, the main disadvantages of this method are that it requires a considerable amount of time to implement and collect participants' responses. In addition, due to the lack of control over condition of testing in home-use test it may result in large variability of response (Resurreccion, 1998). On this regard, performance test may be used instead. It is used to assess behaviors of consumers in relation to specific products. Use of the performance test provides scientifically controlled conditions for testing consumer behaviors.

10. Statistical Technique Analysis

There are numerous different statistical techniques that can be used to analyze the sensory data. Obviously, the objective of analysis is to extract the relevant information contained in the data which can be used to solve a given problem (Sharma, 1996). The collected data are used to statistically test for rejected or non rejected hypothesis, which leads to the solution of the problem. However, when objectives of the study go beyond simple estimation or discrimination, the more sophisticated statistical methods need to be applied. This topic presents the significance of advance statistical techniques, including concepts and reviews and the case study of this application.

10.1 Analysis of Variance (ANOVA)

ANOVA is a powerful statistical tool aimed at statistically quantifying interactions between independent variables through their methodical modifications to determine their impact on the predicted variables (Issa, 2005). Generally, the analysis of variance is suitable for the study of the effects of qualitative factors on a quantitative measurement. The Analysis of Variance (ANOVA) is used for separating the combined variation in an observe data set into component with respective causes for variation. The source of variation in the overall data set is identified and tested for significance. The assumptions behind this statistical technique are normal distribution of the studied variables, variance equality and independence of the errors. Post- hoc comparison test, for which specific hypotheses are tested, is based on the observed differences among the sample means. In the presence of significant differences, it needs to be determined where these differences lie; and for such purpose, Turkey's studentized range test can be performed. This test is defined as "a method of multiple-comparison for pairwise comparisons of k means and for the simultaneous estimation of differences between the means by confidence intervals".

10.2 Multivariate Analysis of Variance (MANOVA) and Descriptive Discriminant Analysis (DDA)

The multivariate analysis of variance (MANOVA) is a procedure used for analyzing multi-component data and it is normally performed after ANOVA. MANOVA is used to determine if there is a significant difference of the measurement values between the classes, i.e., to determine if treatments applied to a product, such as different ingredient quantities used, cause significant differences. Hui (1992) states that this determination is accomplished by calculating a global estimate as to whether there are any significant differences among the different variables or their correlations. This means that if the multivariate F-value is not significant, there is no significant difference among the variables. Conversely, if the F-value is significant, there is statistical significance somewhere. Therefore; for this purpose, the analyst must apply other tests to determine where the significance exists. MANOVA is occasionally used in combination with discriminant analysis for data analysis. When used in conjunction, MANOVA is first used to determine treatment effects, i.e., if differences are present, and the discriminant analysis is then used to determine whether the variables, all combined, are correlated within the classes. Descriptive discriminant analysis (DDA), usually performed after MANOVA, identifies explanatory variables that are the cause of significant differences among samples or units under a study (Huberty 1994). MANOVA can be used to establish if significant differences exist when all sensory attributes are compared simultaneously. DDA can be used to determine, when all attributes compared, which of the attributes are accountable for the principal differences among the products or formulations in terms of consumers' perceptions.

10.3 Logistic Regression Analysis(LRA)

Logistic regression is a predictive analysis which uses binomial probability theory. This analysis involves the prediction of the likelihood of the outcome, a dichotomous dependent variable (yes/no), based on the predictor variables which are quantitative or categorical. Logistic regression is not limited to a single predictor, making it suitable for use in consumer study, in which the acceptability and purchase intent (dependent variables) are predicted by the sensory attributes. Logistic regression calculates the probability of success (event) over the probability of failure (non event); therefore, the results of this analysis are in the form of a likelihood, i.e., the odds ratio, which must be equal to zero or greater. An odds ratio of 1 indicates that event and non event are both equally likely to occur. An odds ratio greater than 1 indicates that the event is more likely to occur and an odds ratio less than 1 indicates that the condition of non event is more likely to occur. In other words, the odds are a non negative number with a value that is greater than 1.0 when a success is more likely to occur than the failure (Agresti, 1996). Logistic regression analysis is employed to predict both product acceptability and purchase intent based on the odds ratio point estimate.

10.4 Principal Component Analysis (PCA)

Principal component analysis is a widely used multivariate statistical technique and is applied to a data set to reduce the set of explanatory variables to a smaller set of underlying variables (factor) based on pattern of correlation among the original variables (Lawless and Heyman, 1998). Principal component analysis (PCA) is a suitable and useful technique for summarizing conventional sensory profile data because it offers underlying independent sensory dimension. The resulting data can be applied to the following: profiling specific product characteristics, comparing and contrasting similar products based on attributes important to consumer and altering product characteristics with the goal of increasing market share of given products.

Examples of the studies that use techniques of MANOVA, DDA, LRA and PCA to characterize the consumer sensory quality are reviewed below.

Bond (2004) studied on a non-wheat butter cake predominately made from rice flour and characterized the US consumer sensory quality by using MANOVA, DDA, LRA and PCA techniques. The results revealed that attributes that separated the wheat flour butter cake product from rice flour butter cake were texture, moistness, taste and overall liking.

Soler (2005) developed non-dairy frozen dessert containing soy protein and coconut milk by using MANOVA, DDA, LRA and PCA techniques to characterize the US consumer sensory attributes. Nine different non-dairy frozen dessert formulations were developed. The results revealed that there were significant differences among the nine formulations, and flavor, texture and overall liking were the attributes responsible for the difference. For LRA technique, flavor and overall liking were the two most important factors determining both consumer acceptance and purchase intent.

Sae-Eaw *et al.* (2007) studied on a non-wheat butter cake prepared from Thai Jasmine rice flour and characterized the US consumer sensory quality of cake products by using MANOVA,DDA, LRA and PCA techniques. Four different formulations were developed. The results revealed that there were significant differences among the four formulations, and from those of techniques, the attributes that separated the wheat flour butter cake product from Jasmine rice flour butter cake were softness, moistness, overall texture, taste and overall liking. For LRA technique, taste and overall liking were the two most important factors in determining both consumer acceptance and purchase intent.

10.5 McNemar Test

The McNemar test is a simple way to test marginal homogeneity for matched binary responses in 2 x 2 tables. Marginal homogeneity implies that row totals are equal to the corresponding column totals. It represents a comparison of dependent proportions for dual response variables. It studies the change in consumer response measured twice as a dichotomous variable, i.e., it compares the same individuals before and after a treatment. The McNemar test is a variation of the Chi-square test for binomial (yes/no) data; therefore it has a Chi-square distribution with two-tailed and one degree of freedom (Agresti, 1996).

10.6 Factor Analysis

Factor analysis is a multivariate technique that reduces a large number of variables to a smaller of new variables (factors) and can be used to explain the variation in the data. Factor analysis creates a smaller number of factors that together can replace the original variables measured in the study (Resurreccion, 1998). Some studies reported the factor analysis technique was used for reducing the complexity of the data variables. Bus and Worsley (2002) surveyed among 345 Australia shoppers to identify their perception of the healthiness of three types of milk, the results revealed major differences in shopper's perception of milk that can be fit to 5 new variables (of 32 variables).

10.7 Partial Least Squares Regression Analysis (PLSR)

Partial least squares regression is a method used for constructing predictive models when there are numerous factors that are highly collinear (Tobias, 1997). PLSR has been used in many food research studies primarily relating instrumental to sensory data. Example of the study that use this technique to interrelate sensory data including those of Pihlsgard *et al.* (1999) on liquid beet sugar. PLSR was also used to determine the effect of panel training and profile reduction on the development of vocabulary for the evaluation of meat quality.

10.8 Preference Mapping

Preference mapping is a type of perceptual mapping method that generates graphical displays from data. In product development, preference mapping can be used to check if the prototype of product is acceptable and that the preference falls within the correct segment of the market (Helgesen *et al.* 1997). In sensory research, preference mapping can be used to integrate between consumer reactions and descriptive sensory analysis. Preference information for each consumer taking part in the study is presented within a multidimensional space, representing the product evaluation (McEwan, 1997).

Depending on the data analyzed, two modes exit. Internal preference mapping models consumer preferences collected for a number of products, i.e., a single data set only. While the external preference mapping deals with two data sets simultaneously, i.e., consumer preference and sensory attribute ratings collected for the same product (Nicolaas *et al.*, 2003). For example, preference mapping was conducted by Cruz *et al.* (2002) for commercial mayonnaise; descriptive analysis of texture, flavor and appearance were related to acceptability data. In another study on ranch salad (Yackinous *et al.*, 1999), the results reveled the average consumer preferred a ranch salad dressing higher in flavor (garlic, pepper, and sourness) whereas lower in viscosity and creamy characteristic.

MATERIALS AND METHODS

Materials

1. Raw materials

1.1 Broken Jasmine Rice

The commercial broken Jasmine rice, Khao Dawk Mali 105 variety, the small broken C1 type (passed through 1.75 mm. mesh screen) was purchased from Chia Meng Rice Mill Co., Ltd., Thailand.

1.2 Ingredients for Cake Making

The ingredients used in the study were food-grade obtained from local markets in Thailand and USA and their corresponding suppliers are listed as follow:

The commercial maltodextrin 10-DE (A.E. Staley Manufacturing Company, Inc., Decatur, IL, USA); baking powder (Best Foods®, Unilever Bestfoods (Thailand) Ltd., Chachoengsao, Thailand); salt (Prung Thip®, Pure Salt Industry Co., Ltd. Nakhonratsima, Thailand); powdered sugar (Dynasty®, Dynasty Pacific Co,. Ltd., Bangkok, Thailand); guar gum (Caltech Co., Ltd., Bangkok, Thailand); butter (Orchid®, Thai Milk Industry Co., Ltd., Ayutthaya, Thailand); rice bran oil (King® Rice Bran Oil, Thai Edible Oil Co., Ltd. Patumthanee, Thailand.) evaporated milk (Carnation®, Nestle(Thai) Ltd., Patumthanee, Thailand); butter essence (Winner ®, Great Hill Ltd., Part., Bangkok, Thailand); fresh eggs number 1 (Animal Science, Kasetsart University, Bangkok, Thailand); emulsifier(EC 25®, America baker Co, Ltd., Bangkok, Thailand)

The commercial maltodextrin 10-DE (Tate & Lyle Ingredients American, Inc., Decatur, IL, USA); baking powder (Clabber Girl, Inc., Terre Haute, IN, USA); iodized salt (Morton International, Inc., Chicago, IL, USA); powdered sugar (Domino Foods, Inc., Yonkers, NY, USA); guar gum (TIC Gum, Inc., Belcamp, Maryland, USA);

margarine (Land O' Lakes, Inc., Arden Hills, MN, USA); evaporated milk (Carnation®, Nestle USA, Inc., Solon, OH, USA); butter essence (Carmi Flavor & Fragrance Co., Inc., Commerce, CA, USA.); Grade A large eggs (Cal-Maine Foods, Inc., Pine Grove, Louisiana, USA), the SaraLee® pound cake (SaraLee, Gosford, New South Wales Central Coast, Australia); propylene glycol ester (GRINDSTED® PGMS USV K-A) and diacetyl tartaric acid ester of monoglyceride (PANODAN® 205 K DATEM) both from Danisco USA, Inc., New Century, KS, USA.

2. Reagent and Test kit

2.1 Reagent for Chemical Analysis

2.1.1 Sulfuric acid
2.1.2 Sodium hydroxide
2.1.3 Hydrochloric
2.1.4 Potassium hydroxide
2.1.5 Petrolium ether

2.2 Reagent for GC Analysis

2.2.1 Internal standard (99.5% 4-methyl-2-pentanone)
2.2.2 2AP standard (2-Acelty-1-Pyroline)

2.3 Reagent for Microbiology Analysis

2.3.1 Standard Plate Count Agar (PCA)
2.3.2 Potato Dextrose Agar (PDA)
2.3.3 Tartaric acid
2.3.4 Phosphate buffer saline

2.4 Test kit

2.4.1 Amylose Assay Test Kit (Megazyme Intl. Ireland Ltd.,Co Wicklow, Ireland)

2.4.2 Starch Damage Assay Test Kit (Megazyme Intl. Ireland Ltd.,Co Wicklow, Ireland)

2.4.3 3M Petrifilm™ Aerobic Count Plate (3M Petrifilm™ , 3M Company, St. Paul, MN, USA)

2.4.4 3M Petrifilm™ Yeast & Mold Count Plate (3M Petrifilm™ , 3M Company, St. Paul, MN, USA)

3. Equipments

3.1 Equipment for Preparing Jasmine Rice Four

3.1.1 Commercial sieve shaking (Kluy Num Tai, Bangkok, Thailand)

3.1.2 Industrial sieve mesh (size -80,100, 120 and 150 mesh) (Kluy Num Tai Co., Ltd., Thailand)

3.1.3 Pin mill (Alpine Mill, Augsburg, Germany)

3.2 Equipment for Cake Preparation

3.2.1 Kenwood mixer-USA work (Kenwood ®, Model KM600, Britain Kenwood Ltd., Havant Hants, England)

3.2.2 KitchenAid mixer-Thailand work (KitchenAid, Model KP2671XWH, St. Loseph, Mich., U.S.A)

3.2.3 Electric oven -Thailand work (Klauy Num Tai Oven, Bangkok, Thailand)

3.2.4 Electric oven -USA work (Turbofan32, Model No. E32, Moffat Ltd., Christchurch, New Zealand)

3.3 Analytical Equipment

3.3.1 Mastersizer-S (Malvern Instrument Ltd., Malvern, England)

3.3.2 Novasina (MSI-Aw, Switzerland)

3.3.3 Spectrophotometer (Minolta, Model CM-3500d, Japan)

3.3.4 KETT-Digital Whiteness meter (KETT, Model C-100-3, KETT Electronic laboratory, Japan)

3.3.5 Tap density tester (Fribilator -Vankel , Varian Inc., USA)

3.3.6 Drying oven (WTB BINDER, Model FD115, Germany)

3.3.7 Hot extractor (Foss, Model 1020, Tecator, Sweden)

3.3.8 Furnance (Stuart, Scientific, England)

3.3.9 Distillation Unit (Buchi, Model B-324, Buchi Labortechnik AG, Switzerland)

3.3.10 Extraction Unit (Soxtoc, Model 2050, Tecator, Sweden)

3.3.11 Benchtop Centrifuge (Sigma, Model 2-16, Germany)

3.3.12 Water Bath (Memmert, Model WB22, Germany)

3.3.13 Rapid-Visco Analyzer (RVA, Model 4D, Newport Scientific Instrument, Australia)

3.3.14 Scanning Electron Microscope (Model Joel JSM 5310, England)

3.3.15 Rheometer (Paar Physica, Model MCR 300, USA)

3.3.16 Microscope (Model Eclipse E400, Japan)

3.3.17 Photomicrographic (Nikon, Model H-III, Japan)

3.3.18 Moisture Analyser (Meltler, Model PM480, Mettler-Toledo International Inc, USA)

3.3.19 Incubator (Yamato® IC 1800, Yamato scientific Co.,Ltd. Japan)

3.3.20 Texture Analyzer- Thailand work (TA XT plus, Stable Micro system, Chapra Techcenter Co. Ltd., Thailand)

3.3.21 Texture Analyzer- USA work (TA XT plus, Stable Micro system, Texture Technologies Crop, NY, USA)

3.3.22 Texture Analyzer- Thailand work (TA plus, Lloyd Instruments Ltd., England)

3.3.23 Digital camera (Cannon, Model 3.2 pix PowderShot A410, Cannon Inc., Japan)

3.3.24 SPME fiber (Bellefunte^{TM}, Supelco Park Belle Fonte, CA, USA)

3.3.25 Gas chromatograph (Varian, Model Varian 2200 a CP-3800, Varian Analytical Instruments.,Walnut Creek, CA USA)

3.3.26 Capillary column (SUPELCOWAX ^{TM} , Supelco Park Belle Fonte, CA, USA).

3.3.27 Novasina (Aw sprint, Model TH-500, Switzerland).

4. Packaging

4.1 High Density Polyethylene (HDPE) Plastic bag

4.2 Polyethylene (PE) bag

4.3 Vacuum Packaging (Food Sarver® Vacloc® vacuum packaging, Jarden Cooperation, Korea)

Methods

Part I : Investigate the Effects of Particle Sizes on Physicochemical Properties of Flour, Batter and Cake from Jasmine Rice and Determine Thai Consumer Acceptability of Jasmine Rice Cake.

1. Effect of Particle Sizes on Physicochemical Properties of Flour, Batter and Cake from Jasmine Rice

1.1 Experimental Design

The design was Completely Randomized Design (CRD) with four Jasmine rice flour particle sizes (<80, <100, <120 and <150 mesh). The design was used to access the effects of flour particle sizes on their physicochemical properties.

1.2 Preparation of Jasmine Rice Flour

Jasmine rice flour was prepared by grinding the commercial broken Jasmine rice using a pin mill (Alpine Mill, Augsburg, Germany). The flour was sieved through 80, 100, 120 and 150 mesh sieve sizes, then collected, packed in plastic (HDPE) bags, stored in card boxes at room temperature (25°C) prior to use.

1.3 Measurements of Flour Properties

All flours (particle sizes of <80, <100, <120 and <150 mesh) were measured for their physicochemical properties.

1.3.1 Measurements of Physical Properties

Particle size distribution and mean diameter measurement of particle size were determined using the laser light scattering type a Mastersizer-S (Malvern Instrument Ltd, Marlvern, England). Mean diameter measurements were reported as the volume-surface mean diameter: d32 =Σnidi3/Σnidi2, where ni is the number of droplets in diameter di.

Water activity of flours was determined using Novasina Water Activity System (MSI-Aw, Switzerland) according to the AOAC (2000) method.

The whiteness of each rice flour was determined using KETT-Digital Whiteness meter(KETT, Model C-100-3, Kett Electronic laboratory, Japan), and Color analysis was carried out on flour samples using the Color Minolta Spectrophotometer (Minolta, Model CM-3500d, Japan) to obtain the color values (CIE -L* a* b* values). Total color difference (ΔE) was calculated using the equation of $(\Delta E) = ((L^*_{std}-L^*)^2+(a^*_{std}-a^*)^2+(b^*_{std}-b^*)^2)^{1/2}$ where L^*_{std} , a^*_{std} and b^*_{std} represented the control flour treatment at <80 mesh.

Packed bulk density of flours was defined as the weight/volume and determined by a trapping method. Packed bulk density was calculated from weight of powder on a mechanical trapping device in a cylinder (Fribilator-Vankel, Varian Inc., USA). Samples were weighed and transferred into 100 ml graduated cylinders and readings were taken before and after flour had been packed (g/cm^3).

Powder flowability was determined using the powder flow analyzer mounted on a Texture Analyzer (TA XT plus, Stable Micro System, Chapra Techcenter Co. Ltd., Thailand), with system setup on 2 conditioning and 3 testing cycles using 140 ml powder through a powder column (70 mm height x 50 mm diameter) at 50 mm/s. The software program (Texture Expo32) was used to evaluate powder flowability on powder compaction and powder cohesion.

Swelling powder (SP) and water soluble index (WSI) of the flour were determined by the modified method of Tsai *et al.* (1997). The weight of the precipitate was used to calculate the swollen powder granule (gram/gram sample). The supernatant was dried at 100^oC to a constant weight, and the weight of the dried solid was used to determine the WSI expressed as a percentage of the original weight sample.

Texture properties of rice flour gel were determined by Texture Analyzer (TA plus, Lloyd Instruments Ltd., England). Gel was prepared by mixing flour with deionized water to make 35% (w/w) slurries. The slurries were precooked first for 10 minutes at 50^oC in a water bath then poured into polyethylene bags seated in a 1.5 cm. diameter container and cooked in boiling bath (100^oC) for 50 minutes, then refrigerated overnight at 4^oC before analysis. Gel samples were cut into 1.5 cm. diameter x 1.5 cm. high and analyzed by Texture Analyzer using a 2.0 cm. cylinder probe. For Texture Profile Analysis (TPA) of gel, samples were compressed to 7.5 mm. (50% deformation) at 20 mm/min. cross-head speed. The software program (Nexygen) was used to calculate hardness. Gel texture was determined by a method according to Tsai *et al*. (1997).

Pasting properties was determined by a Rapid-Visco Analyzer (RVA, Model 4D, Newport Scientific Instruments, Australia) according to the modified method of Becker *et al.* (2001) that extends the heating and cooling program cycle. With the RVA canister containing 3 g of flour and mixed up to 28 g slurry using deionized water, the slurry was heated at 25°C for 6 minutes, then raised to 95^{o}C for 5 minutes at 14^{o}C/minutes, and held at 95^{o}C for another 6.5 minutes before being cooled from 95^{o}C to 25^{o}C over 6 minutes and allowed to stand at 25^{o}C for 9 minutes. The parameters recorded were Peak Viscosity (PV), Hot Viscosity (HV), Final Viscosity (FV), Break Down (BD=PV-HV), Set Back from peak (SB = FV-PV) and Pasting Temperature (PTM).

Flour micro structure was determined using Scanning Electron Microscope (Model Joel JSM 5310, England). Flour samples were dried at 130^{o}C to constant weight, then starch and flour structures were investigated. Samples were mounted on aluminum stubs using double-sided tape, sputter-coated with gold and investigated.

1.3.2 Chemical Properties Measurements

Proximate analysis including moisture, fat, fiber, protein, and ash was determined using the standard AOAC (2000) method. The nitrogen factor used for protein calculation was 5.85. Carbohydrate content was calculated by difference as CHO = 100 - %Fat - %Fiber - %Protein - %Ash. All results were reported on dry weight basis. Moisture content of rice flours was determined by oven drying at 130^{o}C according to the 2000 AACC method.

Amylose content of rice flours was determined using a commercial assay kit of Megazyme (Megazyme Intl. Ireland Ltd., Co. Wicklow, Ireland) described in the Megazyme test procedure. This method uses the specific binding properties of Concanovalin-A to non-reducing end groups of amylopectin and thus precipitates this fraction of the starch.

Starch damage was determined after enzyme digestion by using a commercial assay kit described in Megazyme test procedure (Megazyme Intl. Ireland Ltd., Co Wicklow, Ireland) following the AACC method 76-31 (AACC, 2000). Briefly, a slurry of flour was incubated at 40^{o}C before the addition of the enzyme, amylase. The reaction was then terminated and the slurry incubated further with amyloglucosidase. Glucose was detected using a glucose oxidase/peroxidase reagent.

1.4 Preparation of Batter and Cake

Four Jasmine rice butter cake formulations were prepared from Jasmine rice flour with four different particle sizes at <80, <100, <120 and <150 mesh size. The four Jasmine rice cakes were made according to the formulation as shown in Table 4 and the modified method of Haruthaithanasan *et al.* (2002) and Petchmak *et al.* (2004) as shown in Figure 8.

Table 4 Rice butter cake formulation**.**

Ingredients	**Amount (%)**
1. Jasmine rice flour	17.40
2. Maltodextrin	8.53
3. Baking powder	0.64
4. Salt	0.48
5 Powdered sugar	18.09
6.Guar gum	0.75
7. Butter	15.83
9. Evaporated milk	6.26
10. Emulsifier	3.68
11. Butter essence	0.51
12. Egg white	24.51
13. Egg yolk	3.32

Source: Adapted formula from Haruthaithanasan *et al.* (2002) and Petchmak *et al.* (2004).

Butter and emulsifiers

↓

Whipped for 20 min

Powdered sugar and guar gum → ↓

Whipped for 15 min

↓ ← Egg

Whipped for 2 min

Jasmine rice flour, maltodextrin, baking powder and salt → ↓ ← Evaporated milk and butter essence

Whipped for 5 min

↓

Baked in an oven at 170 °C for 45-50 min

↓

Allowed to cool for 1 hr and then packed in Polyethylene bag

Figure 8 Flow chart depicting the process used to prepare Jasmine rice butter cake
Source: Adapted from Haruthaithanasan *et al.* (2002) and Petchmak *et al.* (2004)

1.5 Measurements of Batter Properties

Color analysis was carried out on batter samples using the Color Minolta Spectrophotometer (Minolta, Model CM-3500d, Japan) to obtain the color values (CIE -L* a* b* values).

Batter specific gravity was determined using the method of Jyuotsna *et al.* (2004).

Oscillatory rheological testing was carried out with a Rheometer (Paar Physica, Model MCR 300, USA). The batter was performed using two separated parallel plates, 50 mm in diameter, and compressed to a gap between bottom plate of 1.0 mm. 2-3 g of batter was placed on the bottom plate. Dynamic frequency sweep test mode was carried out from 0.01 to 100 rad/s. All samples were done in triplicate. Parameters analyzed included complex viscosity, storage modulus (G′), loss modulus (G″) and loss tangent (Tan δ) were all calculated using the software program.

Light microscopy was used to examine batter characterization following the method of Gujral *et al*. (2003). A drop of batter was placed between two cover slips on a microscope glass slide and a third cover slip was placed on the batter sample. This was done to maintain a constant specimen thickness. Bubbles were then observed at a magnification of 10x using the microscope (Model Eclipse E400, Japan) and photographs were taken with photomicrograph camera (Nikon, Model H-III, Japan).

1.6 Measurements of Cake Properties

Color analysis was carried out on cake samples using the Color Minolta Spectrophotometer (Minolta, Model CM-3500d, Japan) to obtain the color values (CIE -L* a* b* values).

Volume and specific volume of cake were determined using the seed displacement method (Park, 1976). The empty pan was filled with sesame seeds and their volume determined by graduated cylinder (V1). The butter cake was placed in a pan and filled with sesame seeds. The volume of sesame seeds was determine by graduated cylinder (V2). The volume of cake was calculated as volume of cake = (V1-V2). The butter cake was weighed after removal from the pan and the specific volume was calculated as specific volume = (V1-V2)/sample weight.

Using a 1.5 x 1.5 cm cake dimension, the cake crumb texture was analyzed according to the method of Tsai *et al.* (1997) with an instrumental texture analyzer (TA plus, Lloyd Instruments Ltd., England) with a 2.0 cm diameter cylinder probe. For Texture Profile Analysis (TPA) of cake samples, thus were compressed by 7.5 mm. (50% deformation), at a speed of 20 mm/min cross-head speed. During a texture profile analysis test the sample was subjected to two successive cycles. The Nexygen software program was used to calculate hardness which is the maximum peak force during the first compression (Sarabjit and Juan, 2003), cohesiveness, springiness (an indication of the recovery of the sample after the two-bite compression cycle) and chewiness.

Cake crumb structure was examined using a digital camera (Cannon, Model 3.2 pix PowderShot A410, Cannon Inc., Japan). A cake was cut into 6 x 8 x 1.5 cm dimension. A photograph was taken within an area of 5 x 6 cm dimension.

2. Thai Consumer Acceptability of Jasmine Rice Cake

2.1 Consumer Acceptance Test

Seven hundred (n = 700) Thai consumers, all older than 17 years old, were recruited from Bangkok area in Thailand. Consumers were prescreened for any reaction to potential food allergies from rice flour and all other ingredients used in the Jasmine rice butter cake formulations. A Central Location Test (CLT) for consumer acceptance of the rice butter cake was conducted from three locations; Kasetsart University, King Mongkut's Institutes of Technology Ladkrabang and Muang Thong Thanee. Following the randomized completed block design of Cochran and Cox (1957), each consumer was presented with four coded butter cake product, sliced into 1.5 x 3.0 x 5.0 cm dimension. Consumers were instructed to visually evaluate each sample, then bite at least three-fourths of the sliced butter cake, and slowly masticate the cake piece before providing acceptability ratings for seven sensory attributes. They provided demographic information and evaluated overall appearance, crumb color, overall odor, butter odor, softness, flavor and overall liking on a 9-point hedonic scale (1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely; Peryam and Pilgrim, 1957). Consumer rated overall acceptance and purchase intent using the binomial (yes/no) scale (Sae-Eaw *et al.,* 2007).

3. Statistical Data Analysis

For physicochemical properties data, Analysis of Variance (ANOVA) was performed to determine the difference in four Jasmine rice flours with different particle sizes. The difference of mean values was performed to compare by the Fisher's Least Significant Difference (LSD). Pearson correlation analysis was performed to determine relation between flour particle sizes and their physicochemical properties. Values were considered at α =0.05 and a statistical program used was SPSS for Windows, version 12.0 (SPSS Inc., Chicago, IL).

For consumer acceptance test data, the percentages of response of the demographic information data were calculated. The Chi-square test was performed to identify if demographic information data significantly influenced the acceptance and purchase intent of Jasmine rice butter cake data collected. Analysis of variance (ANOVA) was performed to determine if overall difference existed among the four butter cake products in terms of acceptability of each sensory attribute and overall liking. Tukey's studentized range test was performed to locate the differences among the four butter cake products. Multivariate Analysis of Variance (MANOVA) was performed to determine if the four butter cake products were different when all sensory attributes were simultaneously considered. The Descriptive Discriminant Analysis (DDA) (Huberty, 1994) was performed to identify sensory attributes underlying the differences among four butter cake products. The Logistic Regression Analysis (LRA) (Allison, 1999) was performed to identify sensory attributes influencing overall acceptance and purchase intent. Values were considered at α =0.05 and a statistical program used was the SAS software version 9.1.3 (SAS Inst., 2003).

Part II : Investigate the Effects of Storage times on Physicochemical Properties of Jasmine Rice Flour and Determine Thai Consumer Acceptability of Jasmine Rice Cake, and Determine the Effect of Storage Time on Major Volatile Compound (2AP)

1. Effect of Storage Time and Flour Particle Size

1.1 Experimental Design

The design was the 4^2 factorial design consisting of 2 variables (flour particle size and storage time), and 4 levels were employed. There were 16 flour treatment combination with 4 flour particle sizes (<80, <100, <120 and <150 mesh) and 4 storage times (0, 2, 4, 6 months). The design was used to access the effects of the particle sizes and storage time, and their relationship with properties of flour and cake.

1.2 Preparation of Jasmine Rice Flour for Storage Study

Rice flour was prepared, sieved, packaged and stored by grinding commercial broken Jasmine rice using a pin mill (Alpine Mill, Augsburg, Germany). The flour was sieved through 80, 100, 120 and 150 -mesh. One kilogram of each flour was individual packed in plastic (HDPE) bags and kept in storage card boxes, then stored at room temperature (25°C) prior to evaluation at 0, 2, 4 and 6 months.

1.3 Measurements of Flour Properties

Samples of each flour were examined over a six-months storage period at 0, 2, 4 and 6 months.

Color analysis was carried out on flour samples using the Color Minolta Spectrophotometer (Minolta, Model CM-3500d, Japan) to obtain the color values (CIE -L* a* b* values). Total color difference (ΔE) was calculated for flour with different particle sizes using the equation of $(\Delta E) = ((L^*_{std}-L^*)^2 + (a^*_{std}-a^*)^2 + (b^*_{std}-b^*)^2)^{1/2}$ where L^*_{std} , a^*_{std} and b^*_{std} represent the control flour treatment at 0 month.

Whiteness of flours, water activity and textural properties of flours in this section of the study were all done according to the aforementioned protocols in Part I, section 1.3.1.

Moisture content of rice flours and starch damage evaluation were done according to the protocols in AOAC (2000).

1.4 Preparation of Jasmine Rice Cake

Sixteen rice butter cake formulations prepared from four flours with different particle sizes (<80, <100, <120 and <150 mesh) at four storage times (0, 2, 4 and 6 months) were evaluated. Each flour sample was prepared into Jasmine rice cake according to the aforementioned protocols in Part I, section 1.4. The resulting cake product was used for physiochemical cake property evaluations and consumer acceptance test.

1.5 Measurements of Cake Properties

Cake hardness was measured using a texture analyzer (Model TA 500, Lloyd Instrument, USA). The method used here was done according to Tsai *et al* (1997). A 2 cm diameter cylindrical probe was used for the compression test at a speed of 20 mm/min, and compression distance at 7.5 mm. The butter cake was sliced into 1.5 x 1.5 x 1.5 cm. The software program was used to calculate the hardness of cake.

1.6 Consumer Acceptance Test

Fifty (n=50) Thai consumers, all above 17 years of age, were recruited from Kasetsart University student and faculty population in Bangkok, Thailand. The test was conducted at Product Development Department's sensory evaluation laboratory at Kasetsart University. 16 cake samples were evaluated for four consecutive days, with four samples per consumer. Each consumer was presented with four randomly coded butter cakes (each slice about 1.5 x 3.0 x 15 cm dimension) and then asked to rate the acceptability of four sensory attributes including aroma, softness, flavor and overall liking using a 9-point hedonic scale. They also rated overall acceptance using the binomial (yes/no) (Sae-Eaw *et al,* 2007).

1.7 Statistical Data Analysis

Analysis of Variance (ANOVA) was performed to determine the difference in flour and cake properties due to four storage times. The difference of mean values was located by the Fisher's Least Significant Difference (LSD). Values were considered at α =0.05 and a statistical program used was SPSS for Windows, version 12.0 (SPSS Inc., Chicago, IL).

The 4^2 factorial design was used for experimental design. Data were analyzed using Response Surface Methodology (RSM). The predictive model were obtained using regression analysis. The response surface was plotted using STATISTICA program.

For consumer acceptance test data. Analysis of Variance (ANOVA) were performed to determined the difference in four storage times on flour and cake properties. The difference of mean values was performed to compare by the Fisher's Least Significant Difference (LSD). Values were considered at α =0.05 and a statistical program used was SPSS for Windows, version 12.0 (SPSS Inc., Chicago, IL).

2. Effect of Jasmine Rice Flour Storage on Major Volatile Compound (2AP)

2.1 Experimental Design

The design was Completely Randomized Design (CRD) with six storage times (7, 8, 9, 10, 11 and 12 months). The design was used to assess the effects of flour storage on major volatile compound (2AP).

2.2 Preparation of Jasmine Rice Flour

The broken Jasmine rice was ground into flour with a pin mill and sieved through 120 mesh (105 µm mesh screen). Jasmine rice flour was kept in polyethylene bag, sealed and stored at room temperature (ca. 25^{o}C). After 6 months, a

100 g of Jasmine rice flour was repacked in Ziploc ® bag, 8.2 cm x 16.5 cm dimension (Ziploc ®, Johnson & Son, Inc. Racine, USA), and stored in an incubator (Model IC 1800, Yamato Sciencetific Co., Ltd, Japan) with temperature setting at 25 ^{o}C prior to analysis.

2.3 Storage Study

The triplicate Jasmine rice flour samples (1 sampling per each bag) were taken from the incubator for each rice flour population at 0, 1, 2, 3, 4, 5 and 6 month of storage time for analysis.

2.4 Volatile Components Analysis

2.4.1 Aqueous Extraction

Volatile extraction was determined according to the modified method of Cramer *et al.* (2005) as shown in Figure 9.

Rice flour(5 g) mixed with
25 ml of 99.5 % 4-methyl-2 pentanone(0.05 ppm) in a 250 ml flask
capped with cork stopper

$\downarrow$

SPME device and introduced by nitrogen gas supply

$\downarrow$

A SPME fiber :100 µm polydimethylsiloxane(PDMS) fiber from Supelco (Bellefunte)^{TM}
exposed to the headspace of the flour slurry

$\downarrow$

Flour slurry was heated in a plate with water bath temperature controlled
at 60^{o}C for 20 min

$\downarrow$

Optimize the extraction for volatile components

Figure 9 Aqueous extraction for volatile components

2.4.2 Volatile Components Identification

The volatile adsorbed in the SPME fiber was thermally desorbed into the injection port of Varian 2200 CP-3800 gas chromatograph (Varian Analytical Instruments.,Walnut Creek, CA USA). The gas chromatography was connected to a FID detector and equipped with a SUPELCOWAX ^{TM}–10 fused silica capillary column (30 m x 0.25 mm i.d. , 0.25 μm film thickness) from Supelco Park Belle Fonte, CA, USA. Helium was used as a carrier gas. The temperature and detector temperature were 150°C. The column temperature was initially maintained at 35 °C held for 5 min before increasing to 150°C at the rate of 4°C/min. The pressure flow rate was at 6.0 psi. The mass spectrometer was directly interfaced with the GC with a segment time of 33.75 minutes. The rice flour volatile components was identified using GC-MS(a 2200 series Iron Trap GC/MS) under the same condition, exception that the column length was 60 m. The rice flour volatile components were identified by comparing their spectra with those in the Wiley-NBS library.

2.4.3 Major volatile component (2AP) quantification

Recovery of 2AP was determined from rice sample and an internal standard (4-methyl-2 pentanone) with the concentrate ratio.

$$\text{Concentrate ratio (sample)} = \frac{\text{Height of 2AP sample peak}}{\text{Height of internal standard peak}}$$

2.4.4 Standard 2AP curve

Recovery of 2AP was determined by adding known quantities of standard and internal standard (4-methyl-2-pentanone) with the concentrate ratio.

$$\text{Concentrate ratio (std)} = \frac{\text{Height of 2AP standard peak}}{\text{Height of internal standard peak}}$$

Then, standard 2AP curve was plotted between concentrate ratio(std.) and the concentrate of 2AP standard. The amounts of 2AP in rice samples were obtained by considering a ratio on the height of 2AP sample peak to the internal standard and plotting them on the standard 2AP curve.

2.5 Statistical Data Analysis

Analysis of Variance (ANOVA) was performed to determine the difference in flour and cake properties due to six storage times. The differences of mean values were compared by the Fisher's Least Significant Difference (LSD). Values were considered at α =0.05 and a statistical program used was SPSS for Windows, version 12.0 (SPSS Inc., Chicago, IL).

Part III : Develop and Characterize Cake using Powdered Emulsifier Mixed Formulation and Determine American Consumer Acceptability of Jasmine Rice Cake

1. Develop of Cake Using Powdered Emulsifier Mixed Formulation and American Consumer Acceptance.

1.1 Preparation of Rice Butter Cakes

Three rice butter cakes were prepared with varying amounts of emulsifier gel (propylene glycol ester:diacetyl tartaric acid ester of monoglyceride, PGMS:DATEM, 8:2) at 0% (product A), 7.5% (product B), and 15% (product C) of the margarine content in the cake formulation (Table 5). The SaraLee pound cake served as the control (product D). All ingredients used for preparing non-wheat rice butter cakes are listed in Table 5. The process of cake making was depicted in Figure 10.

Table 5 Rice butter cake (emulsifier mixed) formulations.

Ingredients	Formulation (%)[1/]		
	A	**B**	**C**
Part I: Emulsifier gel			
PGMS	0.0	0.98	1.93
DATEM	0.0	0.24	0.48
Margarine	0.0	1.62	1.61
Part II: Other ingredients			
Jasmine rice flour	18.11	17.89	17.68
Maltodextrin	8.88	8.77	8.67
Baking powder	0.67	0.66	0.65
Salt	0.50	0.49	0.49
Powdered sugar	18.83	18.60	18.38
Guar gum	0.52	0.51	0.51
Margarine	16.48	14.65	14.48
Evaporated milk	6.52	6.44	6.36
Butter essence	0.53	0.52	0.52
Egg white	25.51	25.20	24.90
Egg yolk	3.46	3.41	3.37

[1/] Formulation A, B, and C, respectively, contained 0, 7.5, and 15% w/w emulsifier gel (propylene glycol ester:diacetyl tartaric acid ester of monoglyceride, PGMS:DATEM, 8:2) based on the margarine content in the total formulation.

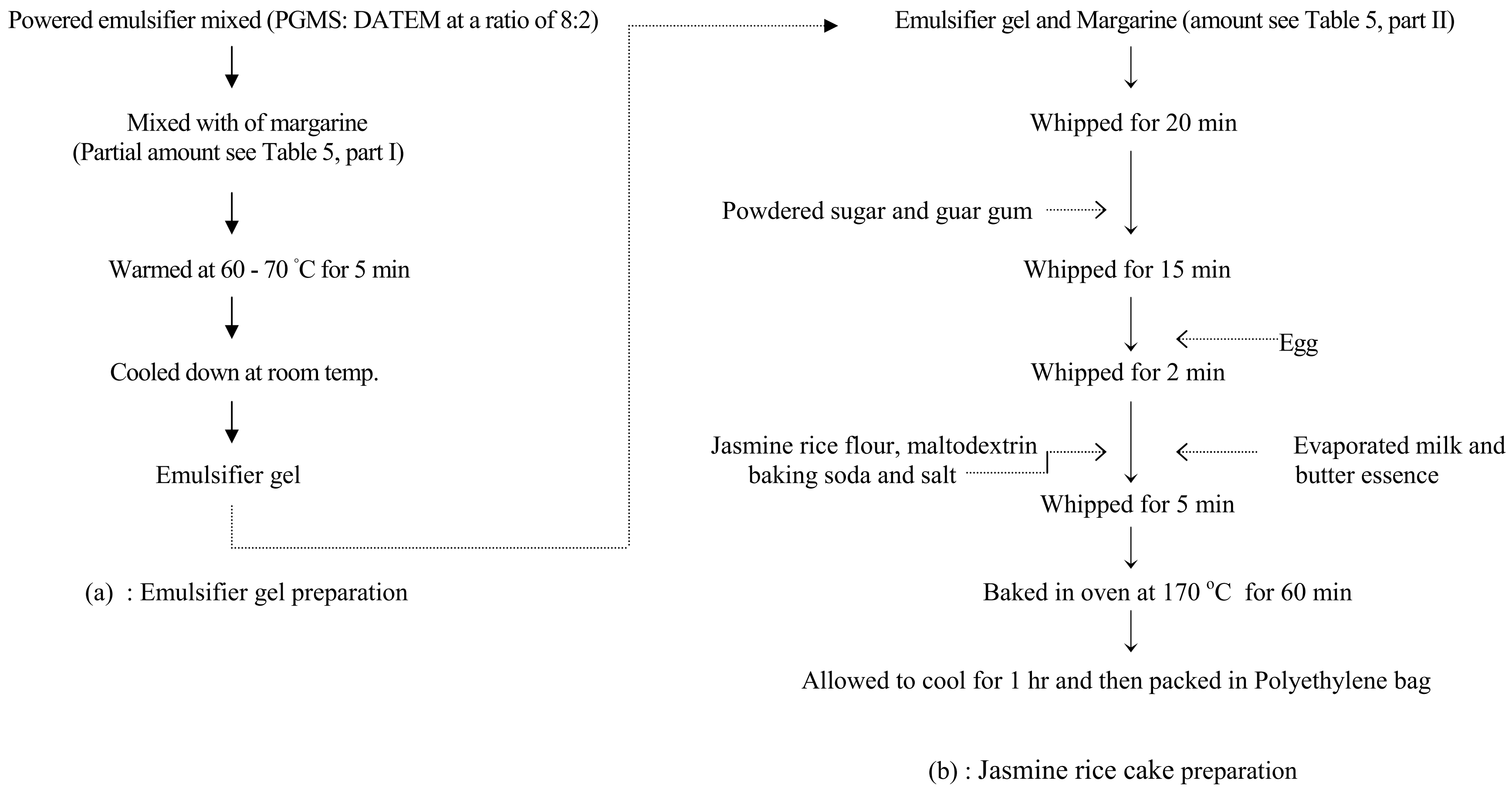


Figure 10 Flow chart depicting the process used to prepare (a) emulsifier gel and (b) Jasmine rice cake.

1.2 Consumer Acceptance Test

The experimental consumer test protocol was approved by the LSU AgCenter Institutional Review Board. Four hundred (n=400) American consumers were recruited from Baton Rouge, Louisiana State., for this study. They were prescreened for potential food allergies to rice flour and all other ingredients used in our nonwheat rice butter cake products. Of the 400 consumers who participated in the study, 42.5% were male and 57.50% were female. They were between 19 and 65 year of age. The central location test (Resurreccion 1998) for consumer acceptance was conducted for 5 days at the dairy store at LSU AgCenter. Prior to the consumer test, all consumers thoroughly read and signed the consent form. Consumers were asked to provide demographic information, including age and gender. They were briefed about the questionnaire, particularly the sensory attributes and their meanings. Following the randomized complete block design (Cochran and Cox 1957), each consumer was presented with 4 coded butter cake products (each slice was 5 × 5 × 1.5 cm). Additional test products were given upon request. Water, unsalted crackers, and expectoration cups were provided for consumers to use during the test to minimize any residual effect between samples. Consumers were instructed to visually evaluate product acceptability For overall appearance, puffiness, and crumb color, and then to sniff each sample prior to evaluating odor acceptability. Afterwards, they were instructed to take 2 bites (about three-fourths) of the butter cake slice. After each bite, they had to slowly masticate the product before providing acceptability ratings for softness, moistness, overall texture, and overall taste (after the 1st bite), and overall liking (after the 2nd bite). The 9-point hedonic scale (1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely) was used for acceptability ratings (Peryam and Pilgrim, 1957). Consumers rated texture softness and moistness using the 3-point Just About Right (JAR) scale, where 1= not enough, 2 = JAR, and 3 = too strong (Stone and Sidel, 1993). Overall acceptance and purchase intent were evaluated using the binomial (yes/no) scale (Sae-Eaw *et al.,* 2007).

1.3 Consumer Acceptability, Product Acceptance and Purchase Intent, and Product Rank Sums among Three Jasmine Rice Butter Cake Products

Among four butter cake products, the sensory data of three Jasmine rice butter cake (Product A, B and C) were selected and used to compare among three Jasmine rice butter cake products in terms of the overall liking score, the positive acceptance, the positive purchase intent and product rank sums. The overall liking scores for consumer acceptability test were converted to the rank orders which were transformed into score where 1=most preferred (or the highest overall liking score) and 3= least preferred (or the lowest overall liking score).

The selected formulation based on consumer acceptability score among four butter cakes as well as consumer acceptability data among the three Jasmine rice butter cake was the best cake formula which was then further subjected to cake mixed storage study.

1.4 Statistical Data Analysis

Among four cake products, Analysis of variance (ANOVA) was performed to determine if differences existed among the four butter cake products in terms of acceptability of each sensory attribute and overall liking. The Tukey's studentized range test was performed to locate the differences among the four butter cake products. The multivariate analysis of variance (MANOVA) was performed to determine if the four butter cake products were different when all 9 sensory attributes were simultaneously considered. The descriptive discriminant analysis (DDA) (Huberty, 1994), in conjunction with principal component analysis (PCA), was performed to identify sensory attributes underlying the differences among the 4 butter cake products. Logistic regression analysis (LRA) (Allison, 1999) was performed to identify sensory attributes influencing overall acceptance and purchase intent. The JAR data were analyzed using the Stuart-Maxwell and the McNemar tests (Fleiss and Everitt, 1971; Stone and Sidel, 1993). Values were considered at α =0.05 and a statistical program used was SAS software version 9.1.3 (SAS Inst., 2003).

The Corhran's Q test was used to determine if differences existed among the four butter cake products in terms of the positive overall acceptance and purchase intent. Values were considered at α =0.05 and a statistical program used was SPSS for Windows, version 12.0 (SPSS Inc., Chicago, IL).

Among three Jasmine rice cake products, Analysis of variance (ANOVA) was performed to determine if differences existed among the three Jasmine butter cake products in terms of acceptability of overall liking. The Tukey's studentized range test was performed to locate the differences among the three Jasmine rice butter cake products. The Corhran's Q test was used to determine if differences existed among the three Jasmine butter cake products in terms of the positive overall acceptance and purchase intent. The Friedman's test was used to determine significant differences among three Jasmine butter cake products rank sum scores. Values were considered at α =0.05 and a statistical program used was SPSS for Windows, version 12.0 (SPSS Inc., Chicago, IL).

Part IV : Examine the Effects of Storage Times on Physicochemical Properties of Cake Mixed and Determine American Consumer Acceptability of Jasmine Rice Cake Prepared from Cake Mixed during Storage.

1. Effects of Storage Times on Physicochemical Properties of Cake Mixed

1.1 Experimental Design

The design was Completely Randomized Design (CRD) with six storage times (0, 1, 2, 3, 4, 5 and 6 months). The design was used to assess effects of storage times on cake mixed properties.

1.2 Packing of Cake Mixed Flour and Storage Study

Ingredients were selected and packed based on results from study in Part III, and an optimum formulation from the rice butter cake products was used for preparing the cake mixed in this study. The quantities of ingredients in their various combinations was converted into the scale unit in gram. Triplicate cake mixed bags were stored in an incubator (Yamato® IC 1800, Yamato scientific Co., Ltd. Japan) at 25 ^{o}C and evaluated at 0, 1, 2, 3, 4, 5 and 6 months.

1.3 Measurements of Cake Mixed

Physiochemical analysis of the three bag mixtures (i.e., rice flour mixed, sugar mixed and powdered emulsifier mixed) was evaluated over a 6 month storage period.

1.3.1 Physiochemical Properties

Color analysis was carried out on cake mixed using the Color Minolta Spectrophotometer (Minolta, Model CM-3500d, Japan) to obtain the color values (CIE -L* a* b* values). Water activity of flours was determined by using Novasina (Aw sprint, Model, TH-500, Switzerland). Moisture content of rice flours was determined by Moisture analyzer (Meltler, Model PM480, Mettler-Toledo International Inc, USA).

1.3.2 Microbiological Properties

1) Microbial Assay

Microbiological assay of the cake mixed flour was done followed the method of the Bacteriological Analytical Manual online (BAM, 2001), using aerobic count plates petrifilm™ and Yeast & Mold count plates petrifilm™ (3M, St. Paul, MN, USA). Three samples were taken form incubator at 0, 1, 2, 3, 4, 5 and 6 months. Serial dilutions (1:10) of each sample were plated in duplicates. The results were expressed as log colony-forming unit per gram (log CFU/g).

2) Sample Preparation

10 g samples were weighed into the sterile bag and 90 ml of Phosphate Buffer Saline (PBS) solution added, then mixed/vortex for 2 min (sample were prepared using 1:10 dilutions). Phosphate Buffer Saline (PBS) solution was a general or multipurpose buffer used for routine washes and dilutions. The buffer solution comprised of sodium phosphate monobasic(Na_2HPO_4-7.2 g), sodium phosphate dibasic (Na_2HPO_4-8.52 g), sodium chloride (NaCl - 25.5g), which were dissolved in 3 L of distilled water, then autoclaved (Vacamatic autoclave, Model 3023 Eagle Series, AMSCO, U.S.A), cooled and stored at room temperature. Five serial dilutions from 10^{-0} - 10^{-4} per sample were made.

3) Total Aerobic Plate Count

The aerobic count petrifilms™ were placed on a leveled surface under a hood (Model - Class II A / B3 Biological Safety Cabinet, Forma Scientific Inc., Marjetta, OH, U.S.A). With top film lifted, 1 ml cake mixed flour dilution was dispensed in the center of the petrifilm™ and the top film gently dropped onto the sample. With the recessed side of the spreader faced down, the sample was evenly distributed under the petrifilm™ by pushing gently downward on the center of the plastic spreader. The spreader was lifted and the petrifilm™ left undisturbed for at least one minute to permit the gel to solidify. The solidified gel plates were incubated in stacks with clear sides up at 37°C (98.6°F - relative humidity) for 48 h. After incubation, petrifilm™ plates were removed from incubator and colonies counted on a standard colony counter with magnified light

4) Yeast & Mold Count

The 3M petrifilm™ Yeast & mold count plates were placed on a leveled surface under a hood (Model - Class II A/B3 Biological Safety Cabinet, Forma Scientific Inc., Marjetta, OH, U.S.A). With top film lifted, 1 ml of rice flour cake dilution was dispensed in the center of the bottom film, and the top film gently dropped on to the sample. Using the recessed side of a spreader faced down, the sample was evenly distributed under the petrifilm™ by pushing gently downward on the center of the plastic spreader. The spreader was lifted and the petrifilm™ left undisturbed for at least one minute to permit the gel to solidify. The solidified gel plates were incubated in stacks with clear sides up at 20-25°C for 72 h. After incubation, petrifilm™ plates were removed from the incubator and colonies counted on a standard colony counter with magnified light source.

5) Colonies Count Determination

The colonies in the dilution plate ranged from 25 - 250 colonies. Total plate count was determined as follows:

$$\text{Log CFU/g} = \log \left(\frac{1 \times \text{colonies counted}}{\text{(Initial dilution x subsequent dilution x volume plate)}} \right)$$

1.4 Preparation of Jasmine Rice Butter Cakes

Cake mixed samples stored for 0 and 6 months were taken to prepare rice butter cake. The additional ingredients (margarine, evaporated milk, butter essence and egg) were focused on formula B as in Table 5 and cake making method followed the method shown in Figure 10.

1.5 Measurements of Cake Properties

Color analysis was carried out on cake crumb using the Color Minolta Spectrophotometer (Minolta, Model CM-3500d, Japan) to obtain the color values (CIE -L* a* b* values).

Texture properties of rice butter cake were determined with Texture Analyzer (TA XT plus, Stable Micro system, Texture Technologies Crop, NY, USA). Cake samples were cut into 1.5x1.5cm dimension and analyzed using a 2 inch platten probe (TA 25). Texture Profile Analysis (TPA) of gel samples was compressed to 7.5

mm (50% deformation) at a 5 mm/s cross-head speed. The software program was used to calculate hardness.

1.6 Consumer Acceptance Test

The cake mixed stored for 6 months was taken for consumer acceptance on rice butter cake. Consumer acceptance test in this study was also done according to the protocols reported in Part III section 1.2. Cake mixed samples stored after 6 months were prepared into cakes for consumer testing. Commercial cake product (Sara Lee pound cake) was used as control in this study and evaluated along with the rice butter cake products. The experimental consumer test protocol was approved by the LSU Agricultural Center Institutional Review Board. Four hundred (n = 400) American consumers, all 18 years of age and older from the university population and the general Baton Rouge area participated in this study. A Central Location Test was conducted for five consecutive days at the LSU Dairy store. Consumers evaluated acceptability ratings of the cake products plus nine other sensory attributes including overall appearance, visual puffiness, crumb color, odor, softness, moistness, overall texture, taste and overall liking using a 9-point hedonic scale; while overall acceptance and purchase intent were evaluated using the binomial (yes/no) scale (Sae-Eaw *et al.,* 2007).

1.7 Statistic Data Analysis

Analysis of Variance (ANOVA) was performed to determine the difference in cake mixed properties during storage. The differences of mean values were compared by the Fisher's Least Significant Difference (LSD). Values were considered at α =0.05 and a statistical program used was SPSS for Windows, version 12.0 (SPSS Inc., Chicago, IL).

Consumer acceptance data on cake mixed stored for 6 month were presented as mean and standard deviation values. The two-samples t-test between Jasmine rice butter cake formula (at 0 and 6 month of cake mixed storage) and wheat butter cake formula was performed to compare the mean values of sensory data. Values were considered at α=0.05 and a statistical program used was SPSS for Windows, version 12.0 (SPSS Inc., Chicago, IL).

Part V : Develop Cake Mixed Using Rice Bran Oil Formula, and Develop Cake Making Process, and Determine Thai Consumer Acceptability of Cake Mixed by Testing its Performance.

1. Development of Cake Mixed Using Rice Bran Oil

1.1 Replacing Butter with Rice Bran Oil in Cake Formula

Four cake formulations were made according to the formula as shown in Table 6. Cake formulations with three levels of rice bran oil content (60%, 70%, and 80%) were used to replace butter in formula wherein 0% rice bran oil was 100% butter by weight. The rest of the ingredients remained the same. All cake formulations were prepared as listed in Table 6 and by the modified method of Haruthaithanasan *et al.* (2002) and Petchmark *et al.* (2004), except for the butter whipping step of three rice bran oil cake formulations, the mixing time was reduced from 20 min to 5 min instead.

1.2 Consumer Acceptance Test

One hundred and sixty six (n=166) Thai consumers aged 22 years and over were recruited from Kasetsart University. The test was conducted at Kasetsart University's Product Development Department sensory evaluation laboratory. Each consumer was presented with four coded butter cake slices (size - 1.5 x 3.0 x 5 cm) and asked to rate the acceptability of five sensory attributes including butter odor, sweetness, softness and overall liking using a 9-point hedonic scale.

The rice bran oil cake formula with highest sensory attribute score was selected and subjected to optimize process study.

Table 6 Formula of Jasmine rice cake containing rice bran oil

Ingredients	Formulation(%)			
	Butter[1/]	Rice bran oil [2/] (%)		
		60	70	80
1. Jasmine rice flour	17.55	18.66	18.35	18.05
2. Maltodextrin	8.55	9.09	8.94	8.79
3. Baking powder	0.63	0.67	0.66	0.65
4. Salt	0.27	0.38	0.38	0.37
5. Powdered sugar	17.37	18.47	18.16	17.86
6. Guar gum	0.63	0.67	0.66	0.65
7. Emulsifier	4.05	4.31	4.23	4.16
8. Butter	15.93	-	-	-
9. Rice bran oil	-	10.16	11.66	13.10
10. Butter essence	0.54	0.96	0.94	0.93
11. Evaporated milk	6.30	6.70	6.59	6.48
12. Egg yolk	24.75	26.31	25.87	25.45
13. Egg white	3.42	3.64	3.58	3.52

[1/] The butter formula modified from Haruthaithanasan *et al,* (2002) and Petchmark *et al,* (2004).

[2/] The rice bran oil formula was adjusted by adding salt and butter essence content in the butter formula, and replaced butter with rice bran oil wherein 0% rice bran oil was 100% butter content.

1.3 Statistical Data Analysis

The consumer acceptance data were analyzed using ANOVA to determine the difference in sensory data among cake formulations. Differences of mean values were performed to compare by the Fisher's Least Significant Difference (LSD). Values were considered at α =0.05 and a statistical program used was SPSS for Windows, version 12.0 (SPSS Inc., Chicago, IL).

2. Process Development of Cake

2.1 Experimental Design

The experimental design was a 3^2 factorial design consisting of 2 variables (mixing time and baking temperature), and 3 levels of processing condition as employed. There were 9 treatments containing rice bran oil, prepared at three mixing times (0, 10, and 20 min) and baked at three different temperatures (150, 170, and 190°C). Treatment 10 was a butter formulation that served as control. Processing conditions also shown in Table 7. Batter and cake preparation flow chart is shown in Figure 11.

Table 7 Cake preparation conditions using 2 variables, 3 levels of mixing time and baking temperature.

Treatments	**Mixing time (min)**	**Baking temperature (°C)**
1	0	150
2	0	170
3	0	190
4	10	150
5	10	170
6	10	190
7	20	150
8	20	170
9	20	190
10 [1/]	20	170

[1/] Formula 10 was a butter formula (as control formula).

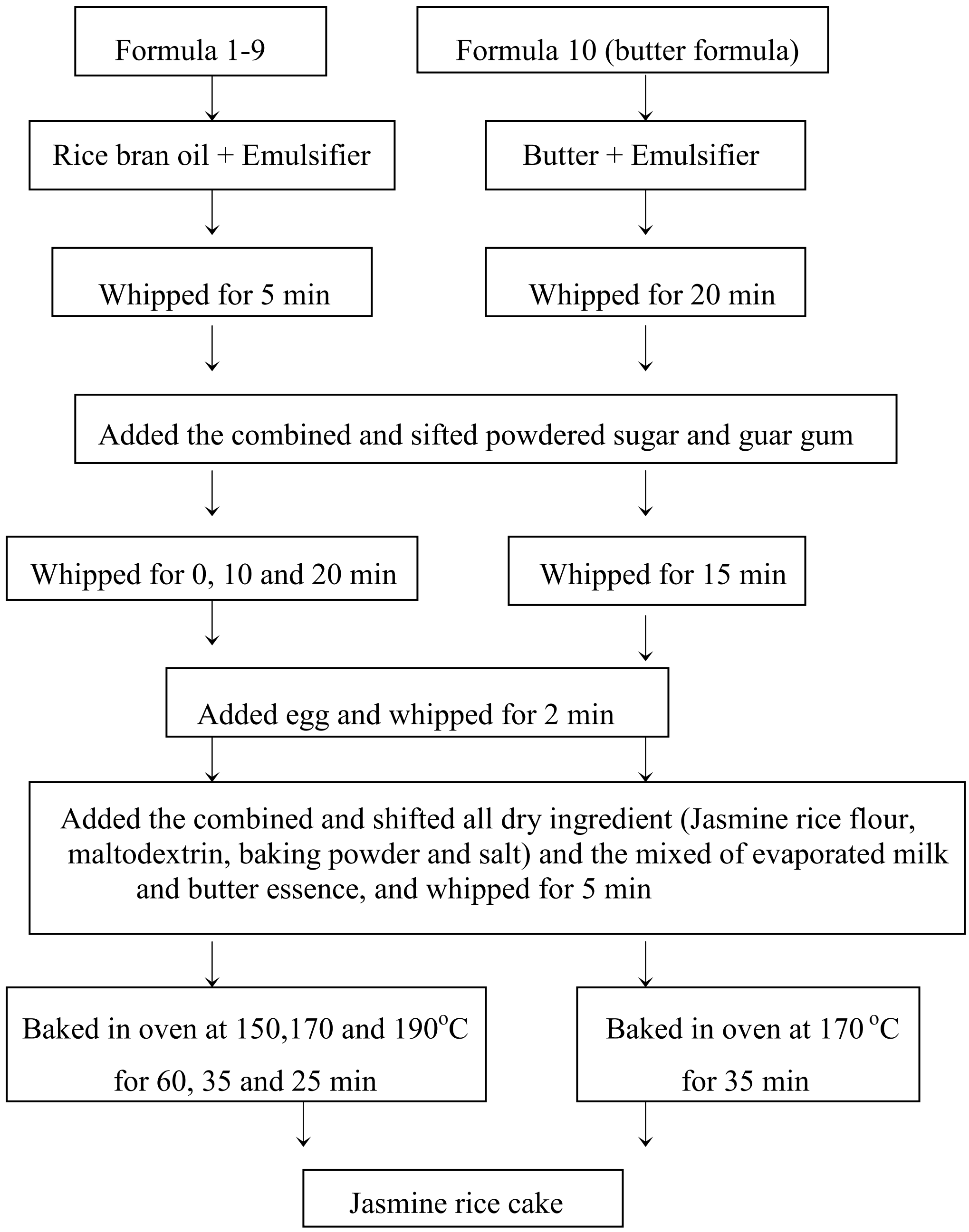


Figure 11 Process flow chart of ten formulations used in preparing Jasmine rice cake

2.2 Batter and Cake Measurement

Color analysis was carried out on batter samples using the Color Minolta Spectrophotometer (Minolta, Model CM-3500d, Japan) to obtain the color values (CIE -L* a* b* values).

Batter specific gravity was determined according to the method of Jyuotsna *et al.* (2004). Batter viscosity was measured with a bostwick consistometer. Approximately, 100 ml of batter was poured on a slanted (rack) trough of the bostwick, and the distance of batter flow within a given period of time (10 second) was then measured.

Batter microscopy was used to determine batter characteristics following the method of Gujral *et al*. (2003). A drop of batter was placed between two cover slips on a microscope glass slide and third cover slip was placed on the batter sample. This was done to maintain a constant specimen thickness. Bubbles were then observed at a 10x magnification under microscope (Model Eclipse E400, Japan) and photographs were taken using a photomicrographic (Nikon, Model H-III, Japan) shot.

Cake volume was determined using a sesame seed displacement method according to Park *et al*. (1976) and cake hardness was measured using texture analyzer (TA plus, Lloyd Instruments Ltd., England) according to Tsai *et al.* (1997).

Optimum process of cake making was selected by considering in cake hardness at different baking temperature and baking time, and the minimum of baking time.

2.3 Statistical Data Analysis

Analysis of Variance (ANOVA) was performed to determine the difference in batter and cake properties among their samples. The differences of mean values were performed to compare by the Fisher's Least Significant Difference

(LSD). Multivariate Analysis of Variance (MANOVA) was performed to determine if the process conditions were different when two cake properties were simultaneously considered. Factorial design analysis was used to analyze the related effect of baking time and baking temperature of cake process. Values were considered at α =0.05 and a statistical program used was SPSS for Windows, version 12.0 (SPSS Inc., Chicago, IL).

3 Cake Mixed Packing Design and Cake Mixed Measurements

3.1 Replacing Laboratory Use Formula with Household Use Formula

3.1.1 Replacing a Gram Unit with Measuring Unit of Ingredient

Two cake formulations were made according to the ingredients as listed in Table 8. The first, an experimental laboratory formulation, was selected from the previous study in section 1 above and all ingredients were converted into a scale unit of gram. The second one, a household formulation, remained the same as the first formulation, except for the three ingredients (egg yolk, egg white and evaporated milk). These three ingredients were converted to a measuring scale unit based on the convenience to prepare for consumers. Each formulation was prepared according to the optimized process study in section 2 above.

3.1.2 Consumer Acceptance Test

Fifty (n=50) Thai consumers aged 17 years and over were recruited from the Kasetsart University Annual Conference in 2007(or KUFair'50) at Kasetsart University, Bangkok, Thailand. The test was conducted at Kasetsart Agricultural and Agro-Industrial Product Improvement Institute's Booth during the KUFair'50. Two cake samples were evaluated; therefore, each consumer was presented with two coded butter cake slices (size - 1.5 x 3.0 x 5 cm) and asked to rate the acceptability of four sensory attributes including aroma, softness, flavor and overall liking using a 9-point hedonic scale. Consumer protocols were followed as described in previous studies.

Table 8 Laboratory and Household Formulations.[1/]

Ingredients	Formulation (g)	
	Laboratory use	**Household use**
1. Jasmine rice flour	97.50	97.50
2. Maltodextrin	47.50	47.50
3. Baking powder	3.50	3.50
4. Salt	3.00	3.00
5. Powdered sugar	96.50	96.50
6. Guar gum	3.50	3.50
7. Emulsifier	22.50	22.50
8. Rice bran oil	61.92	61.92
9. Butter flavoring	5.00	5.00
10. Evaporated milk	35.00	1/6 cup [2/]
11. Egg white	137.50	4 egg of egg white [3/]
12. Egg yolk	19.00	1 egg of egg yolk [3/]

[1/] Substitution's for equivalent household measuring scale of cake ingredients.

[2/] Prepared with evaporated milk of 1/6 measuring cup.

[3/] Egg yolk and egg white prepared by broken the four whole eggs into the bowl. Spoon off the three eggs yolk and then the rest were used as egg ingredient for cake making.

The selected formulation from the preceding study above was further subjected to ingredient packing design study.

3.1.3 Statistical Data Analysis

The two sample t-test from replacing laboratory use formula and household use formula was performed to compare the mean values of sensory data. Values were considered at α =0.05 and a statistical program used was SPSS for Windows, version 12.0 (SPSS Inc., Chicago, IL).

3.2 Packing Design for Cake Mixed Product

Packing size of package was defined according to the results in household use formula of rice bran oil cake based on the suitability for a single time use. The ingredient mixed packing was designed by grouping ingredients base on raw material characteristics (dry form or liquid form), and process of cake making (the study above in the optimum process of cake). The procedure instructions of cake making was labeled based on ingredient mixed packing and process of cake making.

3.3 Quality Measurement of Cake and Cake Mixed Product

The resulting ingredient mixes in each group were separately analyzed for their physiochemical properties and quality based on microbial evaluation. The amount of calories and cholesterol of the resulting cake product made from these mixed were also analyzed.

3.3.1 Cake Mixed Properties

Color analysis was carried out on the individual ingredient cake mixed using an Automatic Reflectance Colorimeter (Tintometer Model RT 100) to obtain the color values (CIE -L* a* b* values) according to the methods of Strait (1997). Water activity (a_w) and moisture content were both measured according to AOAC (2000).

3.3.2 Measurement of Cake Properties

Cake was prepared from cake mixed product, followed the procedure instructions and then used for measurement.

1) Physical and Chemical Properties

Color analysis was carried out on cake samples using an Automatic Reflectance Colorimeter (Tintometer Model RT 100) to obtain the color values (CIE -L* a* b* values) according to the methods of Strait (1997). Specific volume was determined according to described methods in Part I, section 1.6 following Park (1976) methods. Moisture, fat, protein, fiber, ash, and carbohydrate content were also determined according to described methods in Part I, section 1.3.2, following AOAC methods. Residual cholesterol in cake product was determined by the GC method (GC Compendium of methods for food analysis, 2003). Energy value of the cake samples were calculated using caloric factor for fat (9 Kcal/g), protein (4 Kcal/g) and carbohydrate (4 Kcal/g).

2) Microbiological Properties

Product quality was evaluated by microbial aerobic total plate count, yeast and mold and *B. Cereus* count following the Bacteriological Analytical Manual method (BAM, 2001) methods.

3.3.3 Statistical Data Analysis

The properties of cake and cake mixed were presented as numeric, percentage and means (standard deviation) values using SPSS for Windows, version 12.0 (SPSS Inc., Chicago, IL).

3.4 Thai Consumer Acceptability of Cake Mixed by Laboratory Use Test

Cake mixed product was taken for consumer acceptance on product preformance using a laboratory use test method.

3.4.1 Laboratory Use Test Process

The laboratory used test process consisted of three steps as follows:

1) Panel Selection

Panelists 17 years old and over were recruited from among the people that visited the KAPI exhibition's booth at KUFAIR'50, Kasetsart University in January 2007. Panelists were selected solely based on their interest in our study, their availability, experience in preparing bakery products, being accustomed to consuming products from such flour mixed or potential users. All participants who volunteered to participate were also given a date and time for testing the product.

2) Product Sample and Facility Preparation

The cake mixed product was prepared according to the results on previous study in Part V. Product was stored in room temperature and labeled HDPE bag with procedure instructions. All the equipment and testing area were provided at the facility for testing.

3) Testing Procedure

Acceptance of cake mixed product with 50 Thai consumers was conducted at Rice Unit, at the Kasetsart Agricultural and Ago-Industrial Product Improvement Institutes, Kasetsart University during May 18-21, 2007. The tests were conducted in three sessions at the testing area to complete the laboratory use test (Figure 12).

First, orientation was provided in the area. Consumers were welcomed by the project leader, and given a brief overview of the objectives of the study. Each consumer was presented with one package of cake mixed product and given product information, testing procedure in sequence and how to use the equipment for cake making. Following orientation, they moved to the performance testing zone for product testing.

Second, testing was held in the performance testing zone. Each consumer was instructed to read the cake making procedure carefully before testing and conducting the product test on their own using the equipment provided at the facility.

Third, after preparing the product, the panelists moved back to the reception area where they evaluated the product performance by completing the questionnaire. Each consumer received a cake sample (5.0 diameter x 3.0 height dimension) from their own cooking and then they were asked to complete a two section (1 and 2) questionnaire providing demographic information and rates of product performance using a 9-point hedonic scale, where 1 = dislike extremely, 5 = neither like nor dislike, and 9= like extremely (Peryam and Pilgrim, 1957). Consumers were also asked to rate overall acceptance and purchase intent using the binomial (yes/no) scale. A portion of the cake product was set aside to be later evaluated by each panelist's family members on section 3 of the questionnaire which involved additional product evaluation by the panelists to be completed at home. Data from consumer and family evaluation were obtained via telephone call.

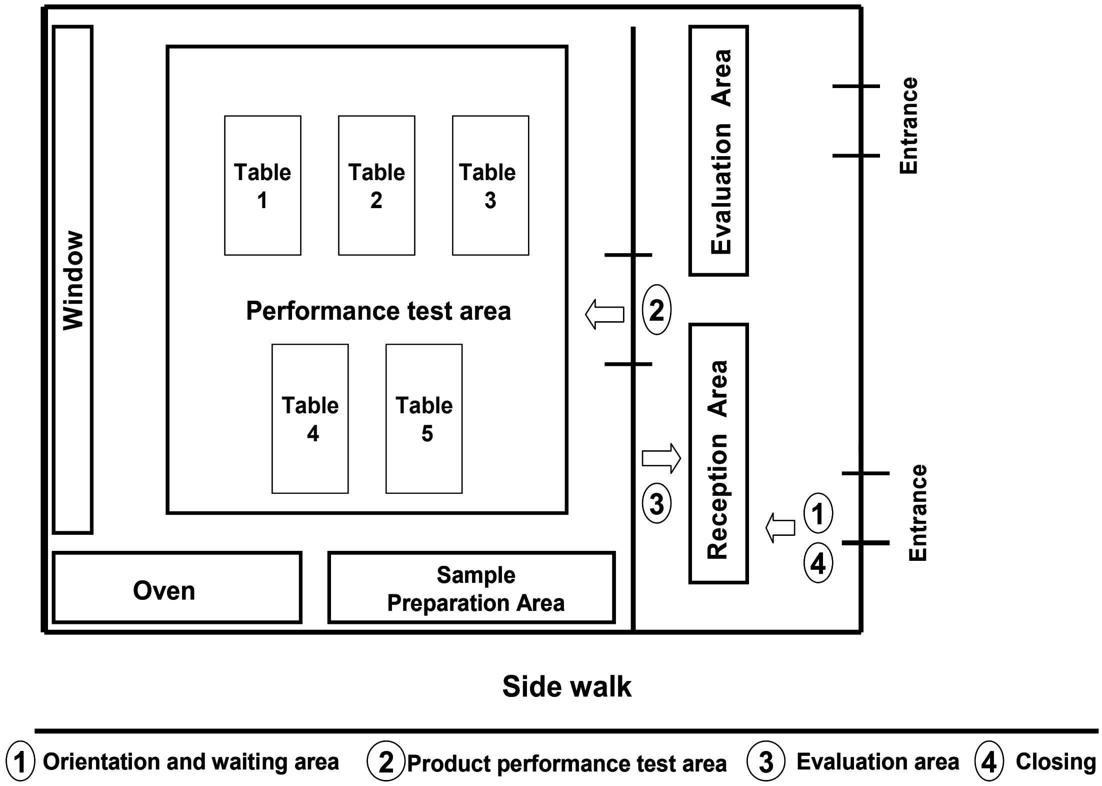


Figure 12 Floor plan for the product laboratory used test area.

3.4.2 Statistical Data Analysis

Demographic consumer data on product laboratory test was presented as numerical, percentage and means (standard deviation) values. Change in consumer's acceptability and purchase decision data were analyzed by McNemar Test (Agresti, 1996). The values were determined using SPSS for Windows, version 12.0 (SPSS Inc., Chicago, IL).

RESULTS AND DISCUSSION

Part I : Effects of Particle Sizes on Physicochemical Properties of Flour, Batter and Cake from Jasmine Rice, and Determine of Thai Consumer Acceptability of Jasmine Rice Cake.

1. Effect of Flour Particle Sizes on the Physicochemical Properties of Flour Batter and Cake

1.1 Flour Properties

1.1.1 Physical Properties

1) Particle Size Distribution and Mean Particle Size

Figure 13 showed the particle size distribution of four flour samples analyzed by using laser light scattering (Mastersizer-S measurement). The coarse flour size (<80 mesh) distribution had a population of large particles and different size range, which was different from that of other flour treatments. The size distribution of two intermediate flour treatments (<100 mesh and <120 mesh) had similar pattern and the finest flour (<150 mesh) had the narrowest range of particle size. The results of mean particle size (Table 9) showed that the finer flour had decreased the mean diameter particle size. The curve of flour with smaller particle size showed the shifting of particle size distribution curve to the left-side; this indicated smaller particle size. The shifting in flour size distribution and the difference in flour particle diameter were caused by reduction in size during sieving. These results show that size reduction resulted in various flour particle size distribution.

Particle size distribution indicated the percentages of flour in different size ranges. Flour particle size significantly affects the performance and functional properties of flour which affects quality of end products. It determines the interaction of particle with other ingredients during processing. Many researchers studied the significance of flour particle size. Halick and Kelly (1959) and Cagampang *et al.* (1973) noted that the particle size greatly influenced the properties of rice flour. Cauvain and Muir (1974) studied of the effect of particle size of cake flour; they showed that the coarse flour particle yielded cake that was collapsed during baking and had a dense cell structure. Bushuk (1998) found that the particle size distribution determined the degree of interaction of flour particle with water during dough formation in bread product.

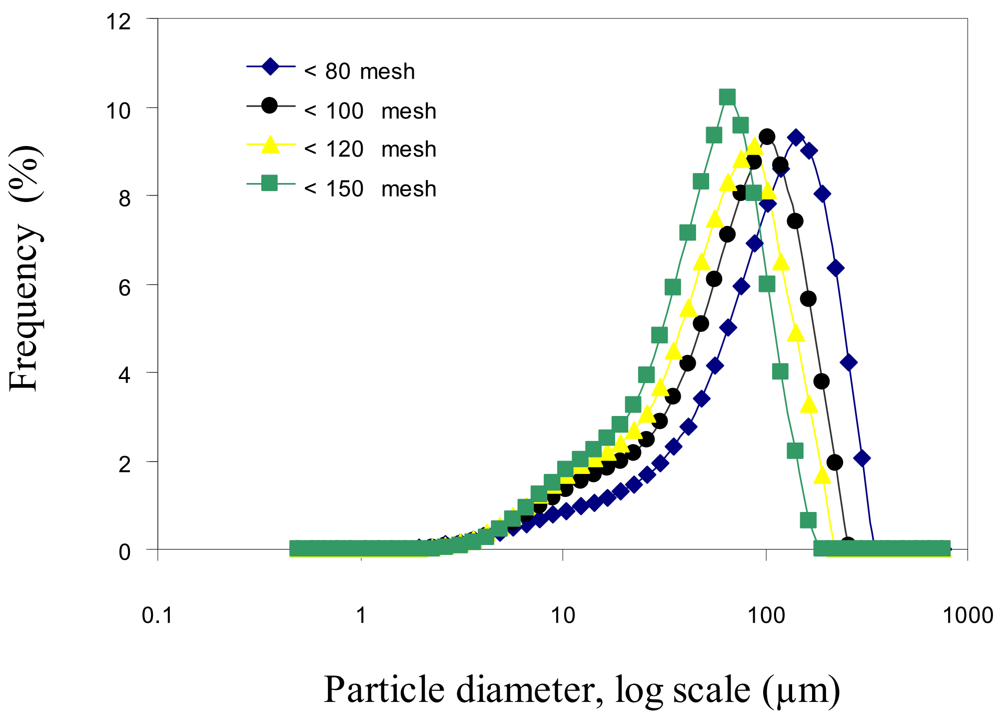


Figure 13 Particle size distribution of Jasmine rice flour with various mesh sieve analyzed by Mastersizer-S measurement.

2) Water Activity, Flour Color and Bulk Density

Physical properties (water activity, flour whiteness and flour color) are shown in Table 9. The water activity of flours ranged from 0.434 to 0.459. The color L* value of the coarse flour (<80 mesh) was significantly ($P<0.05$) lower than that of the finer flour. These indicated that the finer flour was brighter. Flour particle size did not affect the whiteness and the color a* value, whereas the color b* value was significantly ($P<0.05$) lower in the finer flour. These indicated the tendency towards decrease in yellowness as the particle becomes finer. The L*, a*, b* value can also be expressed by a single value of the total color difference (ΔE). This value defines the magnitude of the total color difference. The total color difference (ΔE) of flours was significantly ($P<0.05$) increased with decreased particle size. This indicated overall color differences between the fine flour and the coarse flour size (flour at <80 mesh).

The finest flour (<150 mesh) had the lowest packed bulk density (1.51 g/cm^3), whereas the coarse flour had a higher value (2.02, 1.72 and 1.67 g/cm^3 for <80, <100 and <120 mesh, respectively). The density of flour tended to increase with increased flour particle size (Table 9).

A positive correlation among the color L* value, packed bulk density, and flour particle size was observed. The color L* value was higher with decreased flour sizes and decreased packed bulk density. This was due to the larger flour particle size having less porosity than the smaller particle size, and, hence, affecting the intensity of lightness. The larger flour particle size had more compressive force among particles, hence, higher bulk density.

Bulk density is the weight per unit of volume in the quality of flour particle. It is an important physical property of preprocess cereal flour, powder handling and during product process (Barbosa-Canovas and Yan, 2003).

3) Powder Flow Behavior

Powder flow behavior of four flour particle sizes was shown on Table 9. The powder flow is defined as the relative movement of bulk of particles among neighboring particles or along a container wall surface. The easy conveying, mixing and packing characteristic depend on flow properties (Barbosa- Canovas and Yan, 2003). The results of the finer flour particle (<120 mesh and <150 mesh) showed that the average compact coefficient (blade mixer of powder flow analyzer move through powder sample) and the average cohesion coefficient (blade mixer of powder flow analyzer move up through powder sample) as measured by the force required to move, were lower indicating resistance force as indicated by the best flowing powder. No significant changes were observed for cohesive index. Cohesive index or flow index of all flour samples indicated flour flow behavior in the range of free flowing with more than 10 (Jenlike, 1964). In this regard, particle size did influence flour flowability.

Table 9 Physical properties [1/] of Jasmine rice flour with various mesh sieves.

Flour treatments (mesh)	Mean Diameter[2/] $d_{3,2}$ (µm)	a_w	Whiteness [3/ ns]	Color values				Packed bulk density (g/cm^3)	Powder flow behavior		
				L*	a* [ns]	b*	ΔE [4/]		Average Compact Coefficient (g.mm)	Average Cohesion Coefficient (g.mm)	Cohesion Index [ns]
< 80	59.82 a (0.15)	0.434 b (0.00)	85.65 (0.49)	92.87 c (0.03)	-0.37 (0.00)	6.11 a (0.06)	0.00 d (0.00)	2.02 a (0.04)	6,107.78 a (24.44)	875.03 ab (6.23)	-10.18 (0.00)
<100	40.88 b (0.32)	0.459 a (0.00)	85.95 (0.07)	93.18 b (0.02)	-0.35 (0.00)	5.74 b (0.01)	0.49 c (0.05)	1.72 ab (0.07)	6,203.87 a (151.61)	937.38 a (4.55)	-11.57 (0.06)
< 120	34.99 c (0.41)	0.453 a (0.00)	85.53 (0.00)	93.25ab (0.06)	-0.37 (0.00)	5.57 c (0.05)	0.67 b (0.05)	1.67 ab (0.17)	5,248.40 b (304.10)	798.35 b (60.74)	-10.24 (0.77)
< 150	33.49 d (0.12)	0.453 a (0.00)	85.49 (0.02)	93.34 a (0.03)	-0.36 (0.00)	5.33 d (0.01)	0.92 a (0.04)	1.51 b (0.06)	5,089.09 b (179.64)	849.99 ab (71.01)	-11.33 (0.95)

[1/] Mean values with different letters in each column are significantly different (*P*<0.05) as determined by Fisher's Least Significant Difference (LSD), and numbers in parenthesis represent standard deviation.

[2/] Measurements are reported as the volume-surface mean diameter: d32 =Σnidi3/Σnidi2, where ni is the number of flour particle of diameter di.

[3/] Whiteness was determined by Kett digital whiteness meter.

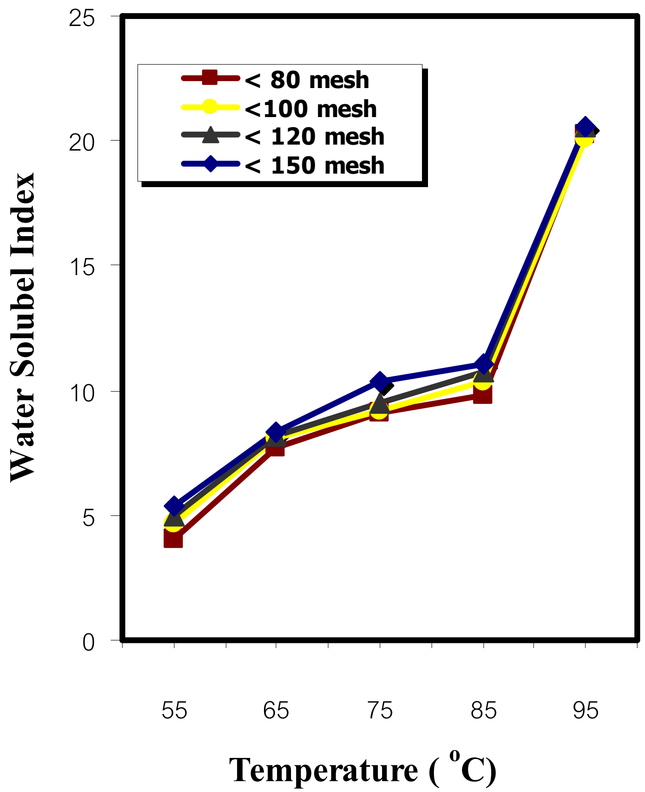
[4/] Total color difference was compared with L^*_{std}, a^*_{std} and b^*_{std} represented the reading of the control flour (flour with 80 mesh)

[ns] mean not significantly different (*P*>0.05).

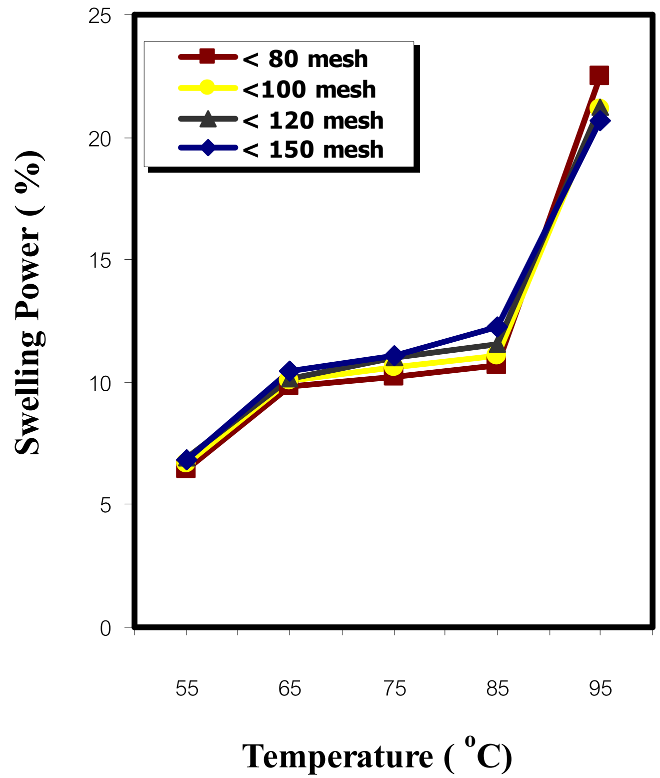
4) Water Soluble Index and Swelling Power

Water soluble index and swelling power, as shown in Figure 14 (A) and (B) indicated that flour with finer particle sizes had higher uptaked water than flour with coarse flour particle sizes (temperature range of 65 to 85^{o}C). This was due to the smaller particle size that increased surface area of flour, increased enzyme hydrolysis and thereby allowing particles to absorb water at a higher rate. The significance of water soluble index and swelling power is related to damaged starch. The observation was confirmed by the finding in our next studies on damaged starch shown in Table 12, and also the results were supported by findings of Oh *et al.* (1985) and Mok and Dick, (1991) who agreed that flour with high damaged starch required more water absorption, and that the swelling power of the coarse rice flour exhibited low swelling power at high temperature than the finer flour (Chen *et al.*, 1999).

The finer flour swelled to the higher extent than the coarse flour at 65^{o}C to 85^{o}C indicating weaker starch granules in the finer flour than the coarse flour. This was caused by the higher starch damage that occurs in finer flour since disruption of the crystalline structure in flour allowed permeation by water into the whole granules (Multon, *et al.*, 1980; Grant, 1998). The results are supported by finding of Grant (1998) which reported the higher water holding capacity of starch with higher starch damage.



(A) : Water Soluble Index



(B) : Swelling Power

Figure 14 Effect of flour particle size on water soluble index (A) and swelling power (B) of Jasmine rice flour with various mesh sieve.

5) Pasting Characteristics

The RVA has been used to determine the viscosity of rice flour. Pasting properties of rice flour were measured by RVA as showed in Table 10. The pasting profile of flour indicated that particle size influenced flour pasting properties. The finest flour showed a significant drop in peak viscosity and breakdown, whereas pasting temperature and setback were higher compared to other flours particle sizes. Peak viscosity refers to maximum viscosity value reached during heating of the starch paste. RVA profile showed decreasing peak viscosity from the coarse flour to the finest flour (from 4487.67 cP to 3993.33 cP). Peak viscosity of the finest flour (<150 mesh) was lower than the coarse flour (<80 mesh), which was caused by a higher starch damage produced during the grinding process and higher water absorption. The higher starch damage in the finer flour contributed significantly to increased water absorption, resulting in lower pasting viscosity of flour.

Pasting temperature (PTM) of the finest flour was higher than the coarse flour, which could be explained by swelling pattern at high temperature (95°C). Swelling power was lower for the finest flour (<150 mesh). Therefore, it required a higher amount of heat to create viscosity up to the level detectable by RVA, resulting in higher pasting temperature for the finest flour size.

The finest flour (<150 mesh) showed the lowest breakdown (Peak viscosity - Hot peak viscosity). From Figure 14(A) and Figure 14(B), the finer flour has higher water absorption (swelling) when smaller granules swell to imbibe the limited free water during gelatinization. When temperature increased and held constant for a time, the peak viscosity was reached and decreased because of the swelling smaller granules broken by continued stirring, and more granules ruptured and fragmented. Thus, they produced lower viscosity.

No significant difference was found in Hot Peak Viscosity (HPV) and Final Peak Viscosity (FPV) among four flour with different particle sizes. Setback represents the rise and fall in the viscosity at the end of the cooling cycle. The set back (Final viscosity-Peak viscosity) in the finest flour showed the highest value in viscosity on the cooling due to slow rate retrogradation (starch granule partially reassociate to form gel network). These results indicated that the finest flour differed in the recrystallization of gelatinization starch during cooling compared to other flours.

Table 10 The pasting properties [1/], [2/] of Jasmine rice flour with various mesh sieve measured by Rapid Visco Analyser.

Flour treatments	PTM	PV	HV [ns]	BD	FV [ns]	SB
< 80 mesh	74.27 b (0.03)	4,487.67 a (2.31)	2,163.33 (5.77)	2,324.33 a (2.89)	4,170.33 (32.33)	-317.33 b (30.02)
< 100 mesh	74.35 b (0.09)	4,332.67 b (34.24)	2,095.00 (49.49)	2,237.67 b (18.58)	4,150.33 (22.23)	-182.33 b (15.95)
< 120 mesh	74.73 b (0.06)	4,317.33 b (95.84)	2,056.67 (105.67)	2,260.67 b (9.24)	4,155.00 (29.44)	-162.34 b (66.39)
< 150 mesh	75.38 a (0.06)	3,993.33 bc (72.95)	2,077.67 (41.79)	1,915.67 c (38.73)	4,123.33 (42.00)	130.00 a (36.37)

[1/] All pasting parameters of the flour slurry, including PTM: Pasting Temperature (^{o}C); PV: Peak viscosity (cP); HV: Hot Peak Viscosity (cP); BD: Break Down (cP); FV: Final Peak Viscosity (cP); SB: Set Back from peak.

[2/] Mean values with different letters in each column are significantly different (P<0.05) as determined by Fisher's Least Significant Difference (LSD), and numbers in parenthesis represent standard deviation. [ns] mean not significantly different (P>0.05).

6) Texture Properties

In Table 11, texture profile analysis of gel from the finest flour (<150 mesh) showed the lowest hardness (P<0.05). The result obtained in this study indicated that flour with high viscosity tended to yield gels with harder texture; and it agrees to the results of powder flow behavior (compact coefficient and cohesieve coefficient from results of Table 9) which could explained the hardness of the coarse flour and its gel hardness. Moreover, it agreed to the results of the effect on water soluble index, swelling power and starch damage of the finest flour (based on the previous results from Figure 14, and Table 12). Coheseiveness, springiness index and gumminess of gel were not affected by flour particle size.

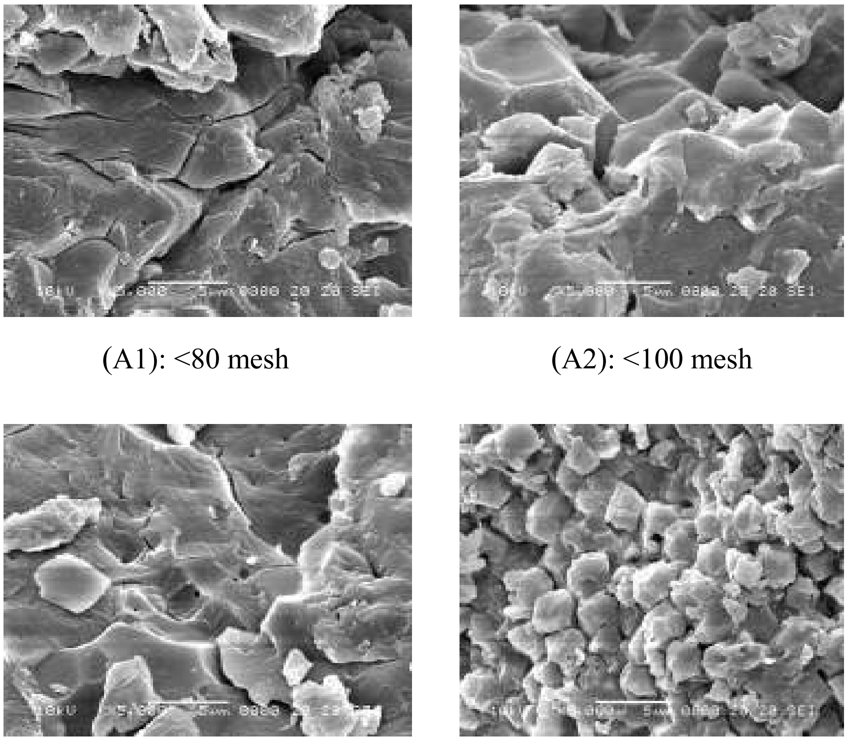
Table 11 Texture Profile analysis of gel.1/ , 2/

Flour treatments (mesh)	**Hardness (N)**	**Cohesiveness ns (-)**	**Springiness Index ns**	**Gumminess ns (N)**
< 80	6.39 a (0.63)	0.36 (0.02)	0.75 (0.06)	0.013 (0.00)
< 100	5.50 b (0.20)	0.35 (0.03)	0.77 (0.14)	0.011 (0.00)
<120	5.41 b (0.39)	0.32 (0.03)	0.79 (0.12)	0.010 (0.00)
<150	4.37 c (0.16)	0.32 (0.03)	0.72 (0.08)	0.008 (0.00)

1/ Mean values with different letters in each column are significantly different (P <0.05) as determined by Fisher's Least Significant Difference (LSD), and numbers in parenthesis represent standard deviation.
2/ Gel from 35 % flour slurry
ns mean not significantly different (P>0.05).

7) Flour Micro Structure

The observed differences in Scanning Electron Micrographs (SEM) micro-structure from different flours with various particle sizes are shown in Figure 15. The surface of the large (coarse) flour particle sizes (Figure 15 A1) showed less erosion than that of small flour particle sizes. The appearance of the coarse flour particle was affected by exo-erosion due to milling process, and can be observed with differences in flour micro-structure with various flour particle size. The smaller the particle size, the looser the pack of starch granule of the finer flour particle which affected size distribution, water absorption capacity and damaged starch. As for the effects of reduced size on surface area of flour granules, the smaller the particle size, the higher the surface area which affected the damage on the surface of granules and thus more water absorption. These are reasons for increased starch damage and swelling of starch as compare to the other flour treatments.



(A1): <80 mesh

(A2): <100 mesh

(A3): <120 mesh

(A4): <150 mesh

Figure 15 Scanning Electron Micrographs of the packed starch granule on flour with; (A1): <80 mesh, (A2): <100 mesh, (A3): <120 mesh, and (A4): <150 mesh with magnification of 5000x

1.1.2 Chemical Properties

1) Chemical Compositions

Chemical compositions varied significantly among different flour sizes as shown in Table 12. The moisture content of flour of different flour sizes ranged from 11.71% to 12.16%; fat content ranged from 0.40% to 0.61%; fiber content ranged from 0.32% to 0.34%, flour sizes did not affect fiber content; ash content ranged from 0.38% to 0.50%; protein content ranged from 6.78% to 7.31%; carbohydrate content ranged from 91.43% to 91.85%. Flour sizes did not affect amylose content. Amylose contents were from 11.70% to 12.66%, which was not significantly different among flour particle sizes.

2) Starch Damage Content

The results of starch damage are showed in Table 12. Starch damage was higher in finer flour. This result agrees with that of Nishita and Bean (1982), who studied grinding impact on rice flour properties and found that the finer rice flour had a higher level of starch damage. Hatcher *et al.* (2002) and Wang and Flores (2000) studied the effect of different wheat flour particle sizes on starch damage and found that the damaged starch increased with decreased in flour particle size. Damaged starch was the portion of starch granules that was mechanically disrupted during the process of extracting or refining flour. The increase in damaged starch in the small particles sizes was due to the small size flour which was more damaged. The extruded amylopectin increased surface area of starch which affected water absorption and enzyme hydrolysis (Ranhotra *et al.,* 1993). Starch damage is important for flour properties. It contributes significantly to water absorption into flour. The higher the damaged starch, the more susceptible to degradation of the starch by enzyme activities. The results obtained from this study could be concluded that starch damage content was higher in the finer flour and was directly related to water soluble index and swelling power.

Table 12 Chemical compositions [1/] of Jasmine rice flour with various mesh sieves.

Flour treatments (mesh)	**Moisture (%)**	**Fat (%)**	**Fiber [ns] (%)**	**Protein (%)**	**Ash (%)**	**CHO [2/] (%)**	**Amylose content [3/] [ns] (%)**	**Starch damage [3/] (%)**
< 80	11.71 c (0.01)	0.61 a (0.00)	0.34 (0.01)	6.78 b (0.01)	0.42 ab (0.04)	91.85 a (0.00)	11.85 (0.62)	10.58 d (0.15)
< 100	11.73 b (0.05)	0.61 a (0.06)	0.33 (0.02)	7.10 a (0.01)	0.38 b (0.01)	91.57 b (0.06)	12.66 (1.48)	12.16 c (0.01)
< 120	11.91 a (0.14)	0.40 b (0.09)	0.32 (0.01)	7.29 a (0.01)	0.43 ab (0.02)	91.57 b (0.06)	11.98 (0.19)	13.05 b (0.00)
< 150	12.16 a (0.10)	0.40b (0.00)	0.33 (0.01)	7.31a (0.02)	0.50 a (0.00)	91.43 b (0.01)	11.70 (0.32)	14.24 a (0.02)

[1/] Means values with different letters in each column are significantly different (P <0.05) as determined by Fisher's Least Significant Difference (LSD), and numbers in parenthesis represent standard deviation

[2/] CHO = Carbohydrate calculated by difference of 100-Fat-Fiber- Protein-Ash

[3/]Amylose content and Starch damage as %db of Megazyme test kit

[ns] mean not significantly different (P>0.05).

1.2. Batter Properties

1.2.1 Physical Properties

The results of cake batter color are shown in Table 13. The color L*, a* and b* values varied (L* value from 86.31 to 88.73, a* values from 0.64 to 0.83 and b* value from 13.34 to 15.13). The color L* as well as the color b* values were higher in cake batter from the finer flour. The batter specific gravity ranged from 1.22 to 1.39 cm^3/g. Specific gravity of cake batter from finer flour particle size (<120 and <150 mesh) was lower than that from the coarse flour.

Table 13 Physical properties [1/] of cake batter from Jasmine rice flour at various particle sizes.

Flour Treatments (mesh)	**Color values**			**Specific gravity (cm^3/g)**
	L*	**a ***	**b***	
<80	86.66 bc (0.30)	0.67 ab (0.10)	13.34 b (0.29)	1.39 a (0.01)
<100	86.31 c (0.34)	0.77 ab (0.06)	13.36 b (0.30)	1.39 a (0.00)
<120	86.88 b (0.59)	0.83 a (0.04)	14.86 a (0.15)	1.23 b (0.00)
<150	88.73 a (0.54)	0.64 c (0.24)	15.13 a (0.43)	1.22 b (0.01)

[1/] Mean values with different letters in each column are significantly different (*P*<0.05) as determined by Fisher's Least Significant Difference (LSD), and numbers in parenthesis represent standard deviation.

1.2.2 Rheology Properties

The strain sweep ranged from 0.01 to 100% is the first step in dynamic mechanical test performed prior to specify the strain level for frequency sweeps. A test at constant strain amplitude at 0.1% was carried out to determine the limit of linear viscoelasticity which provided the linear viscoelastic region of each sample (see Appendix A) at a low shear rate. After that, cake batter samples were then subjected to a frequency sweep test ranging from 0.01 to 100 rad/s at the specified strain level (at 0.1%). Flow curve behavior of cake batter from various flour sizes are shown in Figure 16 - 19. Storage modulus, loss modulus, and complex viscosity were higher in cake batter of flour with finer particle size.

Frequency sweep test was performed by inputting the strain with different frequency into cake batter to determine the response behavior of batter when it received higher force. The results can be used to determine the structure and strength of cake batter. Storage modulus(G′) shows the elasticity of portion of batter with viscous-like structure. Figure 16 showed the storage modulus of cake batter at a wide range of frequency from 0.1-100 rad/s. The storage modulus of cake batter with coarse particle size (<80 mesh) was lower than other treatments. These results indicated that structure of elasticity of portion of batter from coarse flour is less than the finer flour.

Figure 17 showed the changes in loss modulus (G′′) of cake batter with various particle sizes. The G′′ value of coarse flour (< 80 mesh) was lower than the other treatments. The modulus(G′′) value has a tendency toward more fluid-like structure. This results indicated that part behavior fluid in structure of cake batter in coarse flour is less than the finer flour.

Tan δ, the ratio of loss modulus (G′′) to storage modulus (G′) were presented in Figure 18. Tan δ values of cake batter of all flour particles were lower than 1. These results indicated that the part of the elasticity of portion of cake batter with viscous-like structure was more effective than behavior fluid-like structure.

With regard to the effect of particle size on batter rheology, both G′and G′′ moduli of small particle size were significantly higher than the coarse flour. The effect may be explained by the higher water uptake of the finer flour. According to water holding capacity in the prior results, water acted as a plasticizer in finer flour, causing higher both G′and G′′ values. In addition, the finer flour had increased complex viscosity. The batter became less fluid as the flour particle size became finer. This is consistent with the results for aqueous phase. Initially the batter was a viscoelastic fluid, where the viscous moduli was greater in magnitude. There is the effect of flour particle size on batter, so that the G′ value become predominated on the G′′ value.

Figure 19 showed the changes in complex viscosity of rice flour cake batter at different flour particle sizes. The finest flour particle (<150 mesh) had the highest complex viscosity. This was due to its higher water soluble index and swelling power that allowed the flour to absorb more water than the coarse flour. As a result, there was less free water available to facilitate the flow of particle in batter system.

The data in Table 14 showed storage modulus, loss modulus, Tan δ and complex viscosity as constant strain level (0.1%) at frequency sweep determined at 0.1, 1, 10 and 100 rad/s. With increased angular frequency, the storage modulus and loss modulus were significantly (P<0.05) increased whereas complex viscosity were significantly (P<0.05) decreased. The storage modulus was found to be greater than loss modulus and so the Tan δ (G′′/G′) was closed to the elastic character determined over viscous character. Complex viscosity increased when the finer flour particle increased.

The finest flour particle sizes (<150 mesh) showed the highest complex viscosity. The viscosity in cake batter is significantly important for baked cake quality. The higher viscosity also keeps the air bubbles away from forces to coalescent in the batter in which large bubbles would have sufficient buoyancy to rise the surface and be lost. A cake batter is very complex mix with interacting ingredients in an aqueous system. It has a number of dispersed phases such as fat, air and starch. If the viscosity of the batter is too low, these phases separate easily, leading cake to tough, rubbery layer at the bottom pan and light open-cell at the top of baked cake. (Hoseney, 1998).

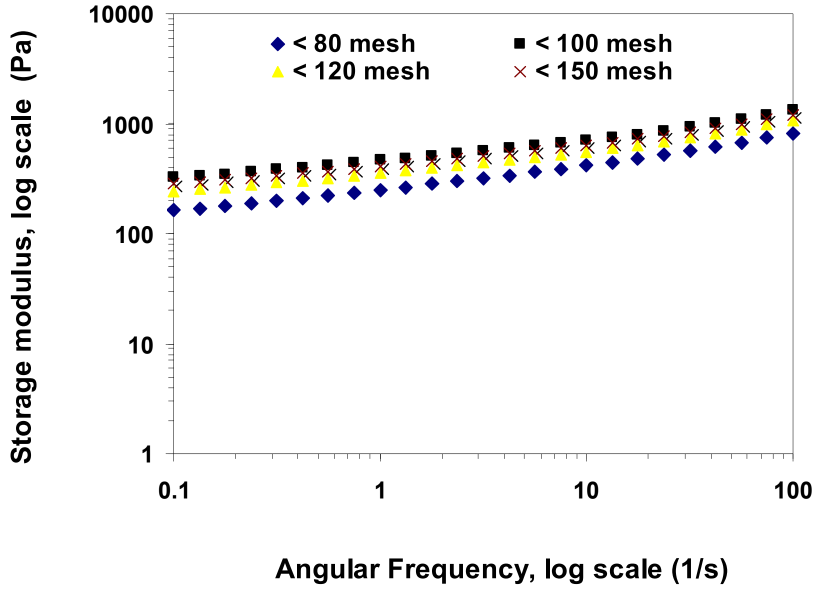


Figure 16 Change in storage modulus of batter with the frequency sweep test at various flour size.

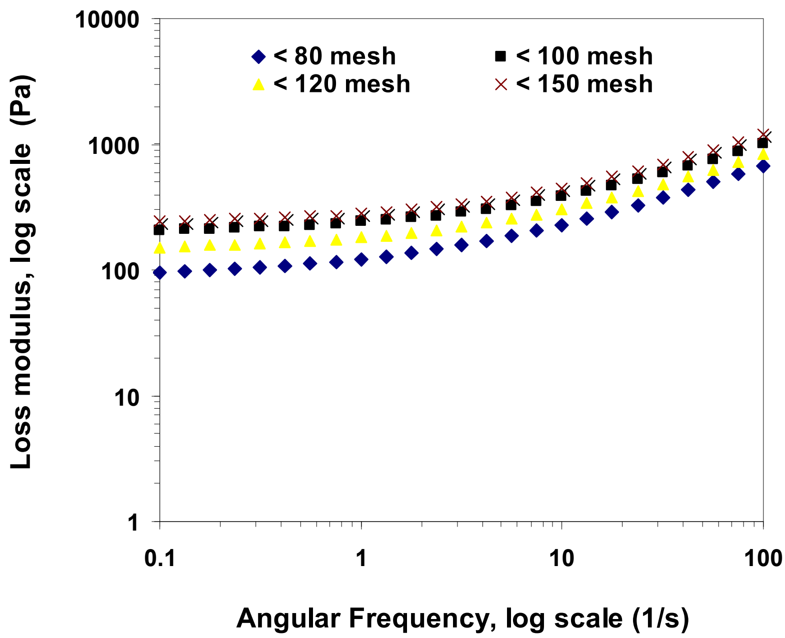


Figure 17 Change in loss modulus of batter with the frequency sweep test at various flour size.

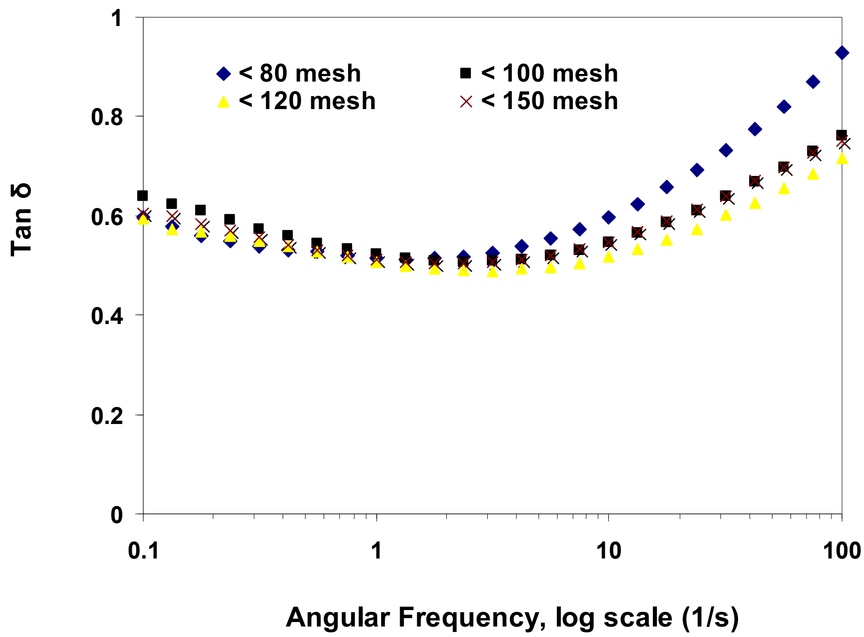


Figure 18 Change in Tan δ of batter with the frequency sweep test at various flour size.

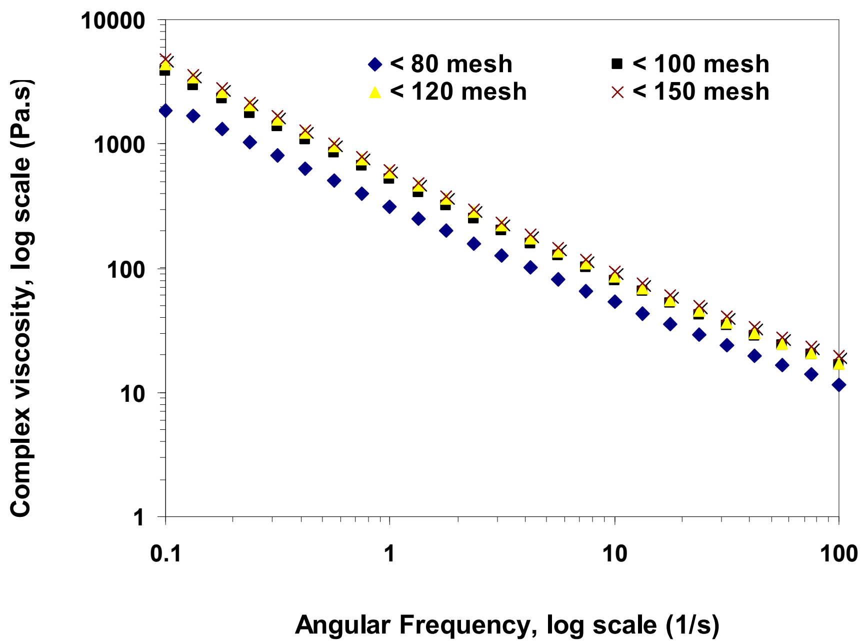


Figure 19 Change in complex viscosity of batter with the frequency sweep test at various flour size.

Table 14 Rhelogy properties[1/] of cake batter from Jasmine rice flour at various particle sizes.

Rheology properties	Frequency sweep test (rad/s)	Flour treatments			
		< 80 mesh	< 100 mesh	<120 mesh	<150 mesh
Storage Modulus (G′) (Pa x 10^2)					
	0.1	1.62 ^{b} (0.04)	3.23 ^{a} (0.27)	3.76 ^{a} (0.08)	4.07 ^{a} (0.32)
	1	2.50 ^{b} (0.07)	4.63 ^{a} (0.58)	5.19 ^{a} (0.28)	5.47 ^{a} (0.26)
	10	4.16 ^{b} (0.20)	7.03 ^{a} (0.71)	7.65 ^{a} (0.51)	8.20 ^{a} (0.18)
	100	8.13 ^{b} (0.81)	13.35 ^{a} (0.64)	13.95 ^{a} (0.24)	15.80 ^{a} (1.27)
Lose Modulus (G′′) (Pa x 10^2)					
	0.1	0.96 ^{c} (0.04)	2.07 ^{b} (0.14)	2.23 ^{ab}(0.03)	2.45 ^{a} (0.01)
	1	1.22 ^{b}(0.13)	2.41 ^{a} (0.27)	2.63 ^{a}(0.06)	2.81 ^{a} (0.07)
	10	2.27 ^{b} (0.43)	3.38 ^{a} (0.27)	3.96 ^{a} (0.22)	4.49 ^{a} (0.19)
	100	6.70 ^{b} (1.95)	10.15 ^{a} (0.07)	10.10 ^{a} (0.75)	11.90 ^{a} (1.48)
Tan δ ^{ns} (G′′/G′)					
	0.1	0.58 (0.00)	0.63 (0.00)	0.59 (0.00)	0.60 (0.00)
	1	0.48 (0.00)	0.51 (0.00)	0.50 (0.00)	0.51 (0.00)
	10	0.53 (0.00)	0.54 (0.01)	0.51 (0.00)	0.53 (0.00)
	100	0.80 (0.01)	0.76 (0.00)	0.71 (0.00)	0.75 (0.00)
Complex Viscosity (Pa.s x 10^2)					
	0.1	18.8 ^{c} (0.64)	38.4 ^{ab} (3.31)	43.7 ^{ab} (0.84)	47.5 ^{a} (2.87)
	1	2.78 ^{b}(0.12)	5.22 ^{a} (0.64)	5.82 ^{a} (0.28)	6.15 ^{a} (0.27)
	10	0.53 ^{b} (0.12)	0.80 ^{a} (0.07)	0.86 ^{a} (0.05)	0.93 ^{a} (0.02)
	100	0.16 ^{a}(0.03)	0.16 ^{a} (0.04)	0.17 ^{a} (0.00)	0.19 ^{a} (0.01)

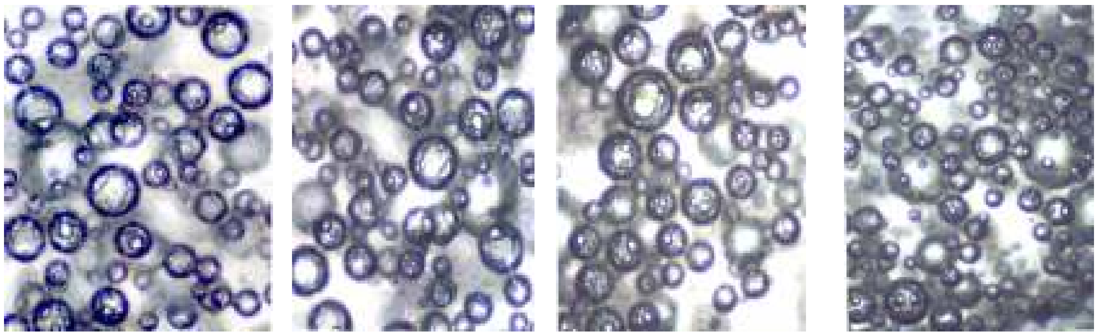
[1/] Mean values with different letters in each row are significantly different (*P*<0.05) as determined by Fisher's Least Significant Difference (LSD), and numbers in parenthesis represent standard deviation.

Constant strain amplitude at 0.1 % at 10 rad/s frequency sweep.

[ns] mean not significantly different (*P*>0.05).

1.2.3 Micro Structure of Batter Characterization

Cake batter is a complex macro emulsion system composed of the creamed mixture of sugar, fat and egg protein in water in oil emulsion, and air cell in fat (Paleg and Bagley, 1983). The incorporation of air in fat distribution in the media of flour and liquid improves the texture and volume of cake.



(a) : < 80 mesh (b) : < 100 mesh (c) : < 120 mesh (d) : < 150 mesh

Figure 20 Batter characterization of cake batter at various flour particle sizes marked on 100x magnification on microscope; (a): <80 mesh, (b): <100 mesh, (c): <120 mesh, and (d): <150 mesh.

To elucidated the effect of flour particle sizes on batter microstructure, the light microscope of batter is presented on Figure 20 (a) to Figure 20 (d). The cake batter samples imaged with a magnification of 100 times on microscopy showed effects of different flour particle sizes on batter characterization. The large and small air bubbles were seen and were not uniformly distributed among the batter samples. The finest flour cake batter had the small bubble size as expected, which was lowering interfacial tension and, hence, reduction in bubble size. As the previous result in Table 10, batter specific gravity of finer flour was lower and appeared to have a greater impact on the bubble size. Result of batter micro-structure was confirmed with the finer flour cake batter; as the size of air bubble in the structure of cake batter decreased, the cake batter specific gravity decreased. It was also explained by batter specific gravity**;** data (Table 13) show the change in specific gravity of rice cake batter at different flour particle sizes. In the Table, it was observed that the value varied from 1.22 to 1.39 cm^3/g as rice flour particle size decreased (<80 mesh to <150 mesh). As the batter specific gravity increased, the particle sizes decreased significantly (P<0.05).

1.3 Cake Properties

1.3.1 Physical Properties

The color L* value ranged from 59.53 to 61.37. The color a* and b* values of cake from various flour particle sizes were not significantly different (Table 15). The mean cake specific volume measured by sesame seeds, showed no significant effect of flour particles.

The lowest cake volume was observed in cake from the coarse flour (< 80 mesh) (Table 15). This was due to the expansion mechanism of gas and air bubbles in batter. The rate of CO_2 generation from baking powder components depends in part on the solubility of the ingredients in the aqueous phase in batter. The more soluble the component, the faster of reaction to release CO_2 gas. The optimum cake volume delays the release of gas until the batter reaches to the oven. For the rate of reaction of different flour particle sizes, the larger the particle size, the slower the rate of dissolution and reaction (Cauvain and Young, 2000).

Table 15 Physical properties 1/ of cake prepared from Jasmine rice flour at various particle sizes.

Flour Treatments (mesh)	Color values			Specific volume ns (cm^3/ g)	Volume of cake (cm^3)
	L*	a *ns	b* ns		
<80	59.53 b (0.71)	0.14 (0.43)	15.90 (1.36)	2.33 (0.00)	205.50 b (1.00)
<100	60.81 a (1.06)	0.06 (0.38)	16.06 (1.20)	2.33 (0.00)	210.00 ab (5.77)
<120	61.11 a (0.65)	0.23 (0.22)	15.70 (0.75)	2.38 (0.00)	214.25 a (2.87)
<150	61.37 a (1.16)	0.11 (0.33)	15.11 (1.22)	2.33 (0.00)	209.50 ab (4.23)

1/ Mean values with different letters in each column are significantly different (P <0.05) as determined by Fisher's Least Significant Difference (LSD), and numbers in parenthesis represent standard deviation

ns mean not significantly different (P>0.05).

3.2 Texture Properties

The texture attribute of cake is shown in Table 16. The coarse flour (<80 mesh) had the highest hardness (3.46 N). The finer the flour particle sizes, the lower the hardness of cake crumbs. There were no significant differences in cohesiveness and springiness. The cake from the finer flour size had the lower chewiness. Cohesiveness is the dimensionless unit obtained by dividing the energy consumed during the second compression by energy consumed during the first compression. Lower value of cohesiveness indicated that less energy is required during the second compression (Gujral, 2003).

Table 16 Texture profile analysis of cake.[1/]

Flour Treatments (mesh)	Hardness (N)	Cohesiveness [ns] (-)	Springiness Index [ns]	Chewiness (N)
< 80	3.46 a (0.88)	0.44 (0.04)	0.78 (0.01)	1.51 a (0.30)
< 100	2.76 b (0.38)	0.42 (0.03)	0.80 (0.05)	1.17 b (0.17)
<120	2.34 b (0.39)	0.47 (0.07)	0.82 (0.05)	1.10 b (0.23)
<150	1.38 c (0.42)	0.45 (0.04)	0.80 (0.02)	0.61 c (0.15)

[1/] Mean values with different letters in each column are significantly different (P <0.05) as determined by Fisher's Least Significant Difference (LSD), and numbers in parenthesis represent standard deviation

[ns] mean not significantly different (P>0.05).

3.3 Cake Crumb Cell Structure

Effects of Jasmine rice flour particle sizes on cell structure of cake crumb is shown in Figure 21. Cake from flour with coarse particle size (<80 mesh) had large and light open- air cell at the top of baked cake, but high density of air cell in the bottom of the cake plate. Cake from flour with finest particle size (<150 mesh) had small and numerous air cells of cake crumb; this was due to the characteristic of cake batter shown in Figure 20 (d). The batter from finest flour had small and numerous bubble size and, hence, affected the air cell structure of crumb.

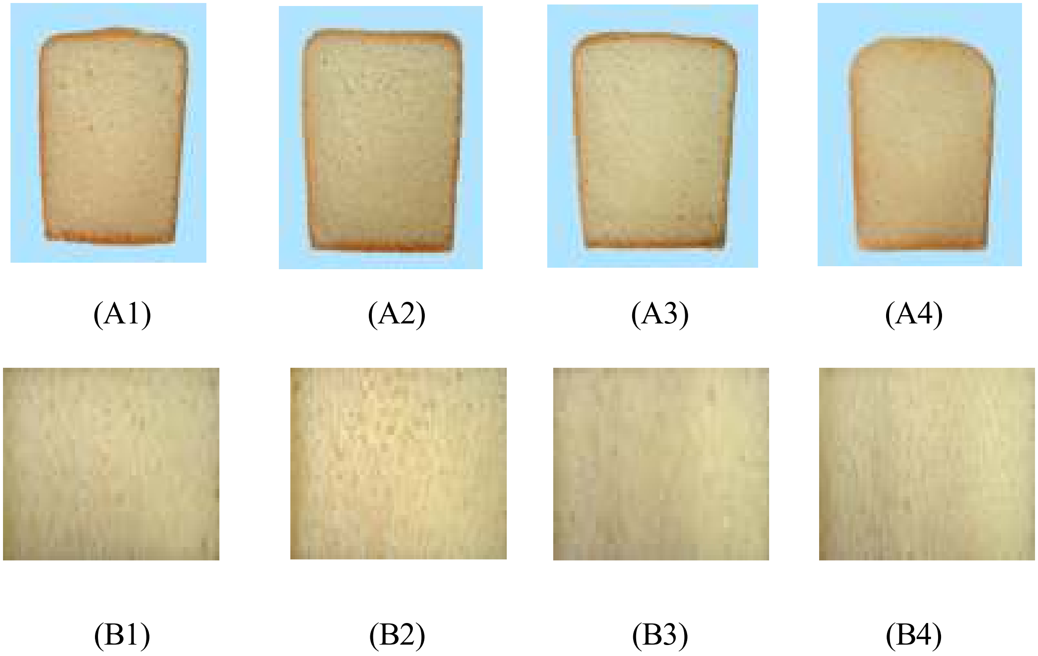


Figure 21 Cake structure characterization with various flour particle sizes. The upper row image; (A1): <80 mesh, (A2): <100 mesh, (A3): <120 mesh, and (A4): <150 mesh. The below row, cake crumb cell structure; (B1): <80 mesh, (B2): <100 mesh, (B3): <120 mesh, and (B4): <150 mesh.

1.4 Correlation Between Jasmine Rice Flour Particle Size and their Physicochemical Properties

The list in Table 17 showed the correlation between flour particle size and their physicochemical properties of flour, batter and cake. A negative correlations with flour particle size were observed on average compact coefficient of powder flow behavior (r = -0.853, P<0.01), Pasting properties on peak viscosity (r = -0.924, P<0.01) and break down properties (r = -0.892, P<0.01), gel hardness(r = -0.888, P<0.01), and cake hardness (r =-0.879, P<0.01). A positive correlations with flour particle size were observed on pasting properties on set back(r = 0.943, P<0.01) and pasting temperature (r = 0.853, P<0.01), starch damage (r = 0.984, P<0.01), and batter rheology on loss modulus (r = 0.996, P<0.01). The effect of particle size may be attributed partly to higher resistance force, hardness of gel and cake as the finer particle size increased. In contrast, the effect of particle size may be attributed partly to the lower starch damage, set back and pasting temperature as the finer particle size decreased.

A negative correlations with cake hardness were observed on average setback from peak (r = -0.836, P<0.01), starch damage (r = -0.883, P<0.01), G′ (r = -0.685, P<0.01), G′′ (r = -0.901, P<0.01). As set back on pasting properties, starch damage and the rheology properties on storage modulus and loss modulus decreased, cake hardness increased.

There were correlations among flour, batter and cake properties. Average compact coefficient on powder flow behavior of flour was measured by the force required to move. The larger the average compact coefficient, the higher the resistance force, as indicated by the flowing properties. The positive correlation of average compact coefficient with gel hardness, peak viscosity, break down and cake hardness were observed. The results indicated that higher resistance force of flour flowing and hardness of flour particle size may be attributed partly to increased hardness of gel and cake, whereas the starch damage, set back and pasting temperature decreased. Therefore, it can be concluded that flour, batter and cake properties were directly related one another via the effects of flour particle size.

Table 17 : Correlation between Jasmine rice flour particle size and their physicochemical parameter. [1/]

Parameter	Flour treatment (Particle size)	Av. Comp Coef	Av. Cohe Coef.	PV	BD	SB	PTM	Gel Hardness	Starch damage	G′	G′′	Cake hardness
Av.ComCoef.	-.853**	1	.747**	.681*	.660*	-.696*	-.855**	.616*	-.816**	-.759	-.931	.687*
Av.CoheCoef.	-.335	.747**	1	.172	.140	-.160	-.435	.072	-.296	-.497	-.714	.287
PV	-.924**	.681*	.172	1	.943**	-.991**	-.711**	.886**	-.895**	-.817	-.963*	.805*
BD	-.892**	.660*	.140	.943**	1	-.956**	-.822**	.848**	-.836**	-.661	-.851	.849*
SB	.943**	.696*	-.160	-.991**	-.956**	1	.750**	-.923**	.914**	.852	.977*	-.836*
PTM	.853**	-.855**	-.435	-.711**	-822**	.750**	1	-.668*	.804**	.582	.834	-.785*
Gel Hardness	-.888**	.616*	.072	.886**	.848**	-.923**	-.668*	1	-.902**	.948	-.948	.830*
Starch damage	.984**	-.816**	-.296	-.895**	-.836**	.914**	.804**	-.902**	1	.955*	.994**	-.833*
G′	.880	-.759	-.497	-.817	-.661	.852	.582	-.948	.955*	1	.919	-.685
G′′	.996**	-.931	-.714	-.963*	-.851	.977*	.834	-.948	.994**	.919	1	-.901
Cake hardness	-.879**	.687	.287	.805**	.849**	-.836**	-.785**	.830**	-.833	-.685	-.901	1

[1/] Abbreviation: Av. CompCoef = Average Compact Coefficient, Av. CoheCoef=Average Cohesion Coefficient, PV=Peak viscosity, BD=Break Down, SB= Set Back, PTM=Pasting Temperature, Storage modulus =G′ , and Loss modulus = G′′.

*and ** indicated significant at 0.05 and 0.01 respectively.

2. Thai Consumer Acceptability of Jasmine Rice Cake

2.1 Consumer Demographic Information

Demographic information about the consumers who participated in this study and recruited within Kasetsart University, Lardkrabang University and World Rice Expro'2005 at Muang Thong Thanee is shown in Table 18. Of 700 consumers who participated in this study, approximately 55.6% of the respondents were female and 44.4% were male. The age range of 17-21 years old (60.4%) was the majority of the consumers. The age ranges of 22-26 years and more than 31 years old had the similar proportion of 16.6% and 15.1%, respectively. The consumers in the age ranges of 27-31 years were 7.9%.

Table 18 Consumer demographic information.

Demographic information		**Response (%)**
1. Gender	Female	55.57
	Male	44.43
2. Age	17-21 years	60.43
	22-26 years	16.57
	27-31 years	7.90
	More than 31 years	15.10

2.2 Consumer Acceptability, Overall Product Acceptance and Purchase Intent

ANOVA indicated that overall appearance and crumb color were significantly different among four butter cake products (Table 19). The mean score of overall appearance for the R100 product was lower than that of R120 and R150 products. The mean acceptability score of crumb color for the R100 product was lower than the R80 product. No significant differences were observed for the acceptability scores for overall odor, butter odor, softness, flavor and overall liking among the four butter cake products. All four products had an overall liking score of greater than 6.0 (Table 19).

At least 71% of consumers indicated their positive overall acceptance for all products. Non-wheat rice butter cakes made from coarse flour (R100 products) had lowest positive overall acceptance whereas higher positive acceptance of cakes was made from finer flour (R120 and R150 products). No significantly difference on positive overall acceptance of cake from flour R120 and R150. Non-wheat rice butter cakes made from the finest flour (R150) had significantly highest positive purchase intent (P<0.05).

Table 19 Mean consumer scores for sensory acceptability and positive product acceptance and purchase intent (%) of four Jasmine rice butter cake products.1/

Attribute	Product 2/			
	R80	R100	R120	R150
Acceptability[a]				
Overall appearance	6.26 ab (1.62)	6.06 b (1.61)	6.37 a (1.52)	6.28 a (1.56)
Crumb color	6.56 a (1.46)	6.31 b (1.57)	6.48 ab (1.43)	6.49 ab (1.45)
Overall odor ns	6.57 (1.65)	6.51 (1.53)	6.50 (1.54)	6.51 (1.53)
Butter odor ns	6.38 (1.67)	6.34 (1.66)	6.37 (1.58)	6.41 (1.64)
Softness ns	6.27 (1.80)	6.32 (1.71)	6.42 (1.66)	6.50 (1.65)
Flavor ns	6.15 (1.84)	6.13 (1.76)	6.21 (1.68)	6.29 (1.69)
Overall liking ns	6.31 (1.70)	6.32 (1.71)	6.36 (1.64)	6.47 (1.59)
Positive (yes) overall acceptance (%)3/	75.29 b	71.14 c	76.86 ab	78.71 a
Positive (yes) purchase intent (%)3/	59.57 bc	56.29 c	60.86 b	64.71 a

1/ Mean value from 700 responses and based on a 9-point hedonic. Mean values in the same row not followed by the same letter are significantly different (P< 0.05) as determined by Fisher's Least Significant Difference (LSD) and number in parenthesis represent standard deviation.

2/ Product R80, R100, R120 and R150, respectively, contained difference flour particle size <80 mesh, <100 mesh, <120 mesh and <150 mesh.

3/ Based on the binomial (yes/no) scale, and on 700 responses. Data were analyzed by Cochran's Q Test.

ns mean not significantly different (P>0.05).

Table 20 The correlation between consumer demographic, acceptance and purchase decision of Jasmine rice butter cake.

Variables		**Acceptance (%)**		**Purchase decision (%)**	
		Yes	**No**	**Yes**	**No**
Gender	Male	34.6	9.8	25.7	18.7
	Female	40.9	14.7	34.7	20.9
	Pearson χ^2	7.35 (P =0. 007)		6.01 (P =0. 014)	
Age group	17-21 years	44.1	16.4	32.8	27.7
	22-26 years	12.2	4.3	10.0	6.5
	27-31 years	6.3	1.6	5.4	2.4
	Over 31 years	12.9	2.3	12.2	3.0
	Pearson χ^2	30.41 (P =0. 000)		105.24 (P =0. 000)	

The Pearson χ^2 value was significant at $P \leq 0.05$.

Results (Table 20) from acceptance indicated that approximately 34.6% of consumer who accepted the products were male and 40.9% were female. For age group, 44.1% of consumer who accepted the products were categorized in the 17-21 year of age group. The second age group (22-26 years old) including 12.2% of consumer who accepted the products and 6.3% of consumer who accepted the products were in the 27-31 year of age. The last, 12.9% of accepted consumer were over 31 years old. Next, purchase decision results indicated that 25.7% and 34.7% of consumer who would purchase the products were male and female, respectively. For consumer age, 32.8% of consumer who would purchase the products were categorized in the 17-21 year of age group. Only 5.4% of consumer who would purchase the products were categorized in the 27-31 year of age group.

Base on Chi-square results of acceptance on gender (the Pearson χ^2 statistic with P =0.007) and age (P=0.000), it could be concluded that there were a significant correlation between acceptance and consumer demographic (Table 20). The similar results could be explained by the Pearson χ^2 results of purchase decision on gender (P =0.014) and age (P =0.000). Therefore, consumer acceptance and purchase decision correlated with consumer demographic, particularly gender and age.

2.3 Overall Product Differences and Discriminating Sensory Attributes

Based on MANOVA results (the approximate F value of 1.77 and the Wilks' Lambda statistic with P =0.0163, data not shown in the Table), it can be concluded that the four butter cake products were significantly different when all seven sensory attributes were compared simultaneously. Since there were some differences among the four treatments of rice cake products, DDA was performed to determine which attributes were underlying the group differences.

Table 21 Canonical structure r's describing differences among Jasmine rice butter cake.[1/]

Attribute	Can 1	Can 2	Can 3
Overall appearance	0.8378[2/]	0.2532	-0.0152
Crumb color	0.6659[2/]	-0.2422	0.6243
Overall odor	0.0594	-0.2102	0.1678
Butter odor	0.1118	0.0723	0.2929
Softness	0.1621	0.6472	0.4089
Flavor	0.1841	0.3391	0.4884
Overall liking	0.1101	0.3869	0.6171
Cumulative Variance Explained	49.34%	89.45%	100%

[1/]Based on the pooled within group variances. Can 1, 2, and 3 refer to the first, second, and third canonical discriminant functions, respectively.

[2/] Indicates attributes which accounted for the group differences in the first dimension.

Results from DDA report the canonical structure r's (Huberty, 1994), which identifies constructs that largely accounted for the group difference. From the first dimension (Can 1) of the pooled within group variances with 49.34% explained variance, overall appearance (with a canonical correlation =0.8378) and crumb color (0.6659) were the two attributes that significantly contributed to the underlying differences among all four samples (Table 21). This result substantiates those from Table 19, and, therefore, it can be concluded that the main construct that accounted for the group differences was the appearance attribute.

2.4 Predicting Overall Acceptance and Purchase Intent using Logistic Regression Analysis

Results (Table 22) indicated that overall liking was the most critical attribute influencing overall acceptance, followed by flavor, overall appearance and crumb color. The odds ratio estimate of overall liking was 1.797 for overall acceptance, indicating the probability of the product being accepted is 1.797 times higher (than not being accepted, $P<0.0001$) with every 1-unit increase of the overall liking score (based on a nine-point hedonic scale).

For purchase intent, all sensory attributes, except butter odor, were influential. The odds ratio estimate of overall liking for purchase intent (1.613) was lower than that for overall acceptance (1.797), indicating that consumers perceived overall liking as more critical to overall acceptance than to purchase intent. However, odor and softness influenced purchase intent but not overall acceptance. Butter odor did not influence both overall acceptance and purchase intent.

Results (Table 23) from the correct classification table indicated that of 71.25% accepted consumer and 11.36% non-accepted consumer were observed and predicted as correct classification into a group. On the other hand, 13.14% of non-accepted consumer and 4.25% of accepted consumer were observed and predicted as incorrect classification. Therefore, the overall acceptance of Jasmine rice butter cake products could be predicted with 82.61% accuracy and 17.39% inaccuracy. The similar results could be explained when predicting the purchase decision with 76.30% prediction accuracy and 23.70% prediction inaccuracy.

Based on the full logit model with seven sensory attributes, overall acceptance and purchase intent of the butter cake products could be predicted with 82.6% and 76.3% accuracy, respectively (Table 24 and 25). Flavor or overall liking alone could be used to predict overall acceptance with 81.5% and 81.4% accuracy, respectively. Only overall liking, when served as a single predictor, could yield up to 74.9% prediction accuracy for purchase intent.

Table 22 Parameter estimates, probability, and odds ratio estimates for predicting overall acceptance and purchase intent of butter cake products.[1/]

Variables	**Overall Acceptance**			**Purchase Intent**		
	Estimate	**Pr > χ^2**	**Odds Ratio**	**Estimate**	**Pr > χ^2**	**Odds Ratio**
Overall appearance	0.1027	0.0255	1.108	0.0941	0.0201	1.099
Crumb color	-0.1076	0.0284	0.898	-0.1190	0.0063	0.888
Overall odor	-0.0048	0.9256	0.995	0.0974	0.0343	1.102
Butter odor	0.0607	0.2063	1.063	-0.0597	0.1667	0.942
Softness	0.0576	0.1605	1.059	0.1265	0.0008	1.135
Flavor	0.3736	<0.0001	1.453	0.3846	<0.0001	1.469
Overall liking	0.5862	<0.0001	1.797	0.4783	<0.0001	1.613

[1/]Based on the logistic regression analysis, using a full model with seven sensory attributes. The analysis of maximum likelihood estimates was used to obtain parameter estimates. Significance of parameter estimates was based on the Wald χ^2 value at $P< 0.05$.

Table 23 The correct classification of an unknown unit into group of overall acceptance and purchase decision of Jasmine rice butter cake products [1/]

Observed (%)	Predicted (%)					
	Overall acceptance			Purchase decision		
	Yes	No	Total	Yes	No	Total
Yes	71.25	4.25	75.50	51.93	8.43	60.36
No	13.14	11.36	24.50	15.25	24.39	39.64
Total	84.39	15.61	100.00	67.18	32.82	100.00
Correct prediction (%)		82.61			76.30	
Incorrect prediction (%)		17.39			23.70	

[1/] Based on the logistic regression analysis using a full model with seven sensory attributes (*P*-event of 0.5). Yes and/or No means either accepted vs. not-accepted and/or purchased vs. not-purchased.

Table 24 Correct prediction (% Hit Rate) of overall acceptance and purchase intent of products.[1/]

Attributes	% Hit Rate	
	Overall Acceptance	**Purchase Intent**
Full Model (7 variables)	82.6	76.3
A Single-Variable Model		
Overall appearance	75.8	65.3
Crumb color	75.8	63.4
Overall odor	76.3	66.5
Butter aroma	76.9	65.3
Softness	78.2	70.1
Flavor	81.5	74.2
Overall liking	81.4	74.9

[1/] Based on the logistic regression analysis at *P*-event of 0.5. Hit rate (%) is the correct classification of an unknown unit (product) into a group (either accepted vs. not-accepted and/or purchased vs. not-purchased).

Table 25 Full logistic regression models for predicting overall acceptance and purchase intent.

Attributes (Yi)	Predictive Model
Overall acceptance	y = - 5.1160+0.1027 (Overall appearance) -0.1076 (Crumb color) -0.0048 (Overall odor) +0.0607 (Butter odor) +0.0576 (Softness) +0.3736(Flavor) +0.5862 (Overall liking)
Purchase intent	y = -5.7870+0.0941 (Overall appearance) -0.1190 (Crumb color)+0.0974 (Overall odor) -0.0597 (Butter odor)+0.1265 (Softness) +0.3846 (Flavor) +0.4783 (Overall liking)

In conclusions, the study confirmed the importance of flour particle sizes that affected their flour properties, and, hence, end product properties. According to MANOVA and DDA techniques, sensory attributes contributing to the underlying group differences among four Jasmine rice butter cakes from difference flour particle sizes were appearance attributes. LRA technique identified flavor and overall liking as the two most critical attributes influencing acceptance and purchase intent of Jasmine rice butter cake.

Part II : Effects of Storage time on Flour Physicochemical Properties Jasmine Rice and Determine Thai Consumer Acceptability of Jasmine Rice Cake, and Determine the Effect of Storage Time on Major Volatile Compound (2AP)

1. Effect of Storage Times and Flour Particle Sizes

1.1 Effect of Storage Times on Flour Properties

Changes in physical and chemical properties for each of the four flour particle sizes at <80, <100, <120 and <150 mesh, during storage for 6 months are shown in Table 26 to Table 29, respectively.

1.1.1 Flour Color Change

Results of the effects of storage time on color of flour with <80 mesh size showed that L* color value ranged from 92.51 to 92.87 as flour stored up to 6 months. The L* color values of flours with <80, <100 and <150 mesh sizes slightly significantly ($P<0.05$) decreased with increased flour storage time. The L* color values of the <120 mesh size flour varied from 93.10 to 93.25. The color of a* and b* values, and the total color difference (ΔE) varied. Their values slightly changed with increased storage time for all flour sizes.

Aging slightly affected the b* color values in rice flour during storage. This study revealed that the b* color values from each flour particle size slightly changed during storage up to 6 months. In addition, aging increased in the color b* value of milled rice from the paddy rice storage. This was supported by the finding of the results of Wiset *et al.* (2005) and Siwapornluk *et al.* (2005) who studied the Jasmine paddy rice(Khao Dok Mali 105-variety) stored up to 7 months that was subsequently milled and ground into flour; the results indicated the significant increase of the color. The reason might be from the change of pigment at the hull and aluerone layer that migrated to the starchy endosperm of rice grain.

With regards to the observed differences in the whiteness of all flours during storage, whiteness of flour with <80, <120 and <150 mesh sizes significantly (P <0.05) decreased at flour storage at 2, 4 and 6 months, whereas values for the flour with <100 mesh size significantly (P <0.05) decreased in storage at 4 and 6 months.

1.1.2 Moisture Content Change

Moisture content of the flours varied during storage and was depended on flour particle size. The moisture content of flour stored from 0 to 6 months for flour at <80 mesh size ranged from 10.31% to 11.71%, flour at <100 mesh size from 10.40% to 11.73%, flour at <120 mesh size from 10.47% to 11.92% and flour at <150 mesh ranged from 10.48% to 12.16%. Flour properties, such as low moisture content which extends storage shelf life, slightly changed due to changes in partial vapor pressure around rice flour packaging. This was perhaps due in part to slight changes in moisture equilibrium and, to some extent, some amount of water vapor that escaped before or during sealing of the packages prior to storage. The change in moisture content was within the limit specified by Thai Industrial Standard, i.e., for which white rice flour, the moisture content should not be more than 13% (Thai Industrial Standard, 1987).

1.1.3 Water Activity Change

Water activity significantly increased with increased storage time. This pattern was observed for all flours (Table 26 to 29). However, increasing water activity during storage did not considerably affect all flour properties. According to Lacey and Magan (1991), water activity (a_w) is the most useful expression of water availability for microbial growth and enzyme activity. Water activity is only one of the environmental factors influencing growth of concentration, oxygen and carbon dioxide concentrations and preservatives (Pitt and Hocking, 1985).

1.1.4 Starch Damage Change

Starch damage significantly (P <0.05) increased with increased flour storage time for all flour particle sizes as shown in Tables 26 - 29. Starch hydrolysis probably occurred during rice storage which led to a proportional increased in monosaccharide and decreased in disaccharides (Cao *et al.,* 2004). The result agrees with that of the study by Tran *et al.* (2005) on reducing sugar content of stored rice which increased significantly during storage. After 6 months, sucrose and raffinose contents of milled rice samples declined, whereas glucose and fructose contents increased significantly. This suggests that starch and high molecular catalysis in part by some active de-branching enzymes, causes reduction of sucrose and raffinose content, whereas the monosaccharide (fructose and glucose) which are main components of reducing sugars, increased during storage at room temperature.

1.1.5 Gel Hardness and Cake Hardness Change

With our study, storage time affected changes in rice flour gel hardness for each of flour particle size. For the coarse flour size <80 mesh (Table 26), no significant (P <0.05) change in gel hardness was observed, whereas gel hardness from the finer flour mesh sizes <100 mesh, <120 mesh, and < 150 mesh (Table 27, 28 and 29, respectively) was significantly higher in flour stored for 6 months.

Ring (1987) suggested that starch and other flour constituents might affected the recrystallization behavior of amylopectin and interaction of crystal morphology, that could be responsible for aging of flour, which, in turn affected the texture of gel hardness. The other reason is that the increased of swelling and water absorption during flour storage affected gel texture.

However, effects on cake hardness prepared from each flour particle size was not significantly (P<0.05) different at 6 months storage. Changes in gel and cake hardness were not related. Gel hardness from rice flour with mesh sizes at <100, <120, and <150 were observed to increase at 6 months storage, whereas no significant changes in cake hardness of stored rice flour was observed. This was due to the fact that small amounts of rice flour proportions (17%) in the cake formulation had no apparent effect on the hardness of cake. It could then be concluded that texture change in rice flour gel hardness does not affect the change in cake hardness during flour storage. Rice flour stored up to 6 months could be prepared for rice butter cake with no change in cake harness.

Table 26 Effect of storage time during 0 - 6 months on the physicochemical properties [1/] of Jasmine rice flour at <80 mesh.

Properties	Storage time(months)			
	0	2	4	6
Color value L*	92.87 a (0.04)	92.64 a (0.05)	92.63 a (0.00)	92.51 b (0.02)
a *	-0.37 a (0.02)	-0.37 a (0.00)	-0.40 ab (0.00)	-0.41 b (0.00)
b*	6.12 c (0.06)	6.30 b (0.05)	6.48 a (0.00)	6.13 c (0.02)
ΔE [2/]	0.00 c (0.00)	0.30 b (0.07)	0.43 a (0.00)	0.37 b (0.06)
Whiteness [3/]	85.65 a (0.49)	83.82 b (0.54)	83.79 b (0.40)	82.02 b (0.12)
Moisture content (%)	11.71 a (0.01)	11.53 b (0.06)	10.31 c (0.10)	11.50 b (0.02)
Water activity	0.434 d (0.00)	0.475 c (0.00)	0.492 b (0.00)	0.520 a (0.00)
Starch damage [4/] (%)	10.58 d (0.15)	12.16 c (0.00)	13.05 b (0.00)	13.25 a (0.00)
Gel hardness (N)	7.39 a (0.63)	7.35 a (0.64)	7.35 a (0.53)	7.44 a (0.59)
Cake hardness(N)	2.34 a (0.35)	2.59 a (0.23)	2.29 a (0.39)	2.32 a (0.43)

[1/] Means values with different letters in each row are significantly different (P <0.05) as determined by Fisher's Least Significant Difference (LSD), and numbers in parenthesis represent standard deviation.

[2/] Total color difference was compare with flour stored at 0 month.

[3/] Whiteness in Kett scale unit.

[4/] Magazyme starch damage unit

Table 27 Effect of storage time during 0 - 6 months on the physicochemical properties [1/] of Jasmine rice flour at <100 mesh.

Properties	Storage time(months)			
	0	**2**	**4**	**6**
Color value L*	93.18 a (0.02)	93.18 a (0.01)	93.17 a (0.00)	92.98 b (0.02)
a *	-0.35 b (0.01)	-0.31 a (0.01)	-0.32 a (0.00)	-0.40 c (0.01)
b*	5.74 b (0.02)	6.02 a (0.02)	6.01 a (0.01)	6.00 a (0.05)
ΔE [2/]	0.00 b (0.00)	0.28 a (0.01)	0.28 a (0.01)	0.33 a (0.03)
Whiteness [3/]	84.95 a (0.07)	84.88 a (0.07)	83.95 c (0.11)	84.30 b (0.00)
Moisture content (%)	11.73 a (0.05)	11.27 b (0.04)	10.40 c (0.17)	11.23 b (0.02)
Water activity	0.459 d (0.00)	0.476 c (0.00)	0.501 b (0.00)	0.505 a (0.00)
Starch damage [4/] (%)	12.16 d (0.00)	12.74 c (0.28)	13.61 b (0.07)	13.79 a (0.00)
Gel hardness (N)	5.65 b (0.20)	5.63 b (0.20)	5.75 b (0.03)	6.81 a (0.36)
Cake hardness(N)	2.18 a (0.39)	2.23 a (0.36)	2.09 a (0.24)	2.20 a (0.31)

[1/] Means values with different letters in each row are significantly different (P <0.05) as determined by Fisher's Least Significant Difference (LSD), and numbers in parenthesis represent standard deviation.

[2/] Total color difference was compare with flour stored at 0 month.

[3/] Whiteness in Kett scale unit.

[4/] Magazyme starch damage unit.

Table 28 Effect of storage time during 0 - 6 months on the physicochemical properties [1/] of Jasmine rice flour at <120 mesh.

Properties	Storage time(months)			
	0	2	4	6
Color value L*	93.25 a (0.06)	93.11 b (0.02)	93.19 ab (0.00)	93.10 b (0.00)
a *	-0.37 b (0.00)	-0.34 a (0.00)	-0.40 c (0.00)	-0.40 c (0.00)
b*	5.56 b (0.05)	5.80 a (0.00)	5.81 a (0.00)	5.73 a (0.01)
ΔE [2/]	0.00 b (0.00)	0.28 a (0.01)	0.27a (0.00)	0.22 a (0.01)
Whiteness [3/]	85.53 a (0.00)	84.43 b (0.04)	84.35 b (0.11)	84.20 b (0.00)
Moisture content (%)	11.92 a (0.14)	11.69 b (0.06)	10.47d (0.03)	11.39 c (0.04)
Water activity	0.453 d (0.00)	0.491 c (0.00)	0.505 b (0.00)	0.521 a (0.00)
Starch damage [4/] (%)	13.05 d (0.00)	13.49 c (0.15)	14.29 b (0.00)	14.57 a (0.00)
Gel hardness (N)	5.67 b (0.38)	5.93 b (0.42)	5.55 b (0.23)	6.52 a (0.19)
Cake hardness(N)	1.80 a (0.23)	1.75 a (0.16)	1.74 a (0.08)	1.97 a (0.10)

[1/] Means values with different letters in each row are significantly different (*P* <0.05) as determined by Fisher's Least Significant Difference (LSD), and numbers in parenthesis represent standard deviation.

[2/] Total color difference was compare with flour stored at 0 month.

[3/] Whiteness in Kett scale unit.

[4/] Magazyme starch damage unit

Table 29 Effect of storage time during 0 - 6 months on the physicochemical properties [1/] of Jasmine rice flour at <150 mesh.

Properties	Storage time(months)			
	0	**2**	**4**	**6**
Color value L*	93.34 a (0.03)	93.32 a (0.06)	93.29 a (0.01)	93.16 b (0.01)
a *	-0.36 a (0.00)	-0.34 a (0.00)	-0.34 a (0.01)	-0.38 a (0.04)
b*	5.33 c (0.01)	5.65 a (0.02)	5.65 a (0.01)	5.49 b (0.02)
ΔE [2/]	0.00 b (0.00)	0.32 a (0.01)	0.32 a (0.01)	0.24 a (0.02)
Whiteness [3/]	85.49 a (0.02)	85.27 b (0.05)	85.05 b (0.07)	85.05 b (0.07)
Moisture content (%)	12.16 a (0.10)	11.55 b (0.02)	10.48 d (0.02)	11.37 c (0.04)
Water activity	0.454 d (0.00)	0.483 c (0.00)	0.504 b (0.00)	0.520 a (0.00)
Starch damage [4/] (%)	14.24 b (0.02)	14.35 b (0.14)	14.77 a (0.16)	14.96 a (0.00)
Gel hardness (N)	4.37 c (0.16)	4.77 bc (0.25)	4.85 b (0.16)	5.62 a (0.12)
Cake hardness(N)	1.69 a (0.18)	1.73 a (0.07)	1.67 a (0.17)	1.66 a (0.23)

[1/] Means values with different letters in each row are significantly different (P <0.05) as determined by Fisher's Least Significant Difference (LSD), and numbers in parenthesis represent standard deviation.

[2/] Total color difference was compare with flour stored at 0 month.

[3/] Whiteness in Kett scale unit.

[4/] Magazyme starch damage unit.

1.2 Effect of Particle Sizes and Storage Times on Flour and Cake Properties

The experiment was conducted to investigate the effect of particle size and storage time on of Jasmine rice flour. The particle size ranged was <80, <100, <120 and <150 mesh and storage time of 0, 2, 4 and 6 months. The effect of flour particle size and storage time were analyzed statistically by MANOVA (Table 30). Based on MANOVA results (the approximate F value of particle size, storage time and the interaction of were 73.039, 125.567 and 6.508, respectively, and all Wilks'lambda statistic values with P=0.00), it can be concluded that when all physicochemical properties were compared simultaneously, its was affected by particle size, storage time and their interactions.

The results on Table 30 demonstrated that the main effects (particle size, storage time), and their interaction effects (interaction of particle size and storage time). Considering individual physicochemical parameters, results show particle size affected on all parameters, whereas storage time affected on all parameters except for cake hardness. Similarly, considering an interaction of particle size and storage time, cake hardness was not significantly different (P>0.05). Therefore, storage time and the interaction of particle size and storage time did not affect cake hardness.

1.2.1 Regression Analysis and Predictive Model

Regression analysis yielded the predictive models of all parameters and adjusted R^2 in Table 31. The particle size and storage time and their interaction affected physicochemical properties which were observed by the coefficient in predictive models. The adjusted R^2 values of all parameters were more than 0.7, except for the color a* value, moisture content and cake hardness when adjusted R^2 values were 0.388, 0.634, and 0.516 respectively. The models for moisture content, color a* value and cake hardness could be explained at 38.80, 63.40 and 51.60%, respectively. Therefore, the models of all parameters (except color a*) could predict the response.

Table 30 The main and interaction effects of particle size and storage time on physicochemical properties of Jasmine rice flour.

Source	Wilks' lambda[1/]		Individual variable[1/]		
	F- value	*P* -value	Dependent variable	F- value	*P* -value
1. Particle size	73.039	0.00	1.Color of L* value	1177.504	0.00
			2.Color of a* value	46.806	0.00
			3.Color of b* value	1576.754	0.00
			4.Whiteness	56.046	0.00
			5.Moisture content	25.387	0.00
			6.Water activities	23.144	0.00
			7. Starch damage	1100.740	0.00
			8. Gel hardness	73.330	0.00
			9.Cake hardness	31.617	0.00
2. Storage time	125.567	0.00	1.Color of L* value	161.932	0.00
			2.Color of a* value	37.091	0.00
			3.Color of b* value	175.831	0.00
			4.Whiteness	72.767	0.00
			5.Moisture content	847.171	0.00
			6.Water activities	633.629	0.00
			7. Starch damage	613.520	0.00
			8. Gel hardness	21.070	0.00
			9.Cake hardness	1.701	0.185 [ns]
3. Particle size x Storage time	6.508	0.00	1.Color of L* value	18.472	0.00
			2.Color of a* value	7.557	0.00
			3.Color of b* value	6.033	0.00
			4.Whiteness	10.527	0.00
			5.Moisture content	8.698	0.00
			6.Water activities	9.677	0.00
			7. Starch damage	41.339	0.00
			8. Gel hardness	1.322	0.264 [ns]
			9.Cake hardness	1.318	0.267 [ns]

[1/] The Wilk's lambda statistic and individual variable values with P>0.05 was not significantly different.

[ns] mean not significantly different (P>0.05).

Table 31 Predictive models of Y_i (response) and particle size(x_1) and storage time (x_2) of Jasmine rice flour.

Y_i	Predictive Model	Adjusted R^2	*P* –value
Color of L* value	$= 90.038+0.05\ x_1-0.061x_2$	0.891	0.00
Color of a* value	$= -0.5+0.002\ x_1-0.00001\ x_1^2-0.004\ x_2^2$	0.388	0.00
Color of b* value	$= 11.275-0.056\ x_1+0.176\ x_2 + 0.02\ x_2^2$	0.968	0.00
Whiteness	$= 85.066-0.888\ x_2+0.004x_1\ x_2+0.041\ x_2^2$	0.776	0.00
Moisture content	$=11.719-0.503\ x_2 +0.083\ x_2^2$	0.634	0.00
Water activities	$= 0.437 +0.011\ x_2$	0.907	0.00
Starch damage	$= 8.863+0.033\ x_1+0.282\ x_2$	0.900	0.00
Gel hardness	$=8.701-0.029\ x_1+0.175\ x_2$	0.768	0.00
Cake hardness	$=3.325-0.011\ x_1$	0.516	0.00

1.2.2 Contour Plot of Predictive Models

The effects of particle size and storage time on flour and cake properties could be explained on contour plots as follows;

1) The color L* value

The particle size and storage time affected color L* values. The color L* values increased when particle size increased. Similarly the color L* values slightly increased when storage time increased (Fig. 22 a).

2) The color a* value

The particle size and storage time affected color a* values. The color a* values decreased when particle size increased. Similarly the color a* values decreased when storage time increased (Fig. 22 b).

3) The color b* value

The particle size and storage time affected color b* values. The color b* values increased when particle size increased. In contrast, the color b* values decreased when storage time increased (Fig. 22 c).

4) Whiteness

The particle size and storage time affected whiteness. The interactions of the whiteness increased when particle size increased. In contrast the whiteness decreased when storage time increased (Fig 22 d).

5) Moisture content

Storage time affected moisture content (Fig 22 e). However, increased moisture content did not affect flour properties (Table 26-29).

6) Water activity

Storage time affected water activity. Water activity increased when the storage time increased (Fig. 22 f). The results support the predictive model. However, increased water activity did not affect on flour properties (Table 26-29).

7) Starch damage

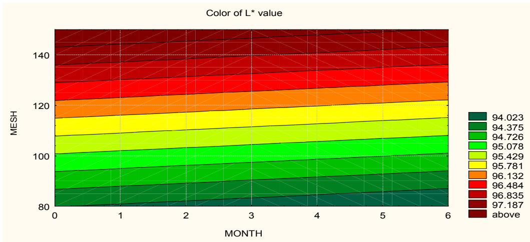
Both particle size and storage time affected starch damage. The starch damage increased when particle size increased. Similarly, the starch damage increased when storage time increased (Fig. 22 g).

8) Gel hardness.

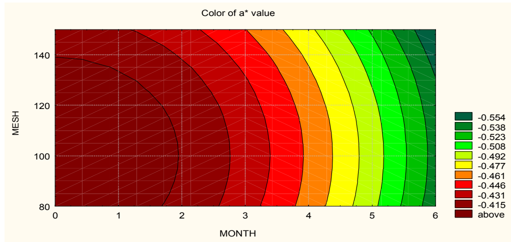
Both particle size and storage time affected gel hardness. The gel hardness decreased when particle size increased. In contrast, the gel hardness increased when storage time increased (Fig. 22 h).

9) Cake hardness

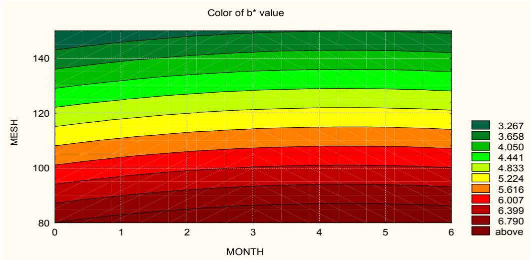
The particle size affected cake hardness. The cake hardness increased when particle size increased. In contrast, the cake hardness was not affected by storage of rice flour (Fig. 22 i).



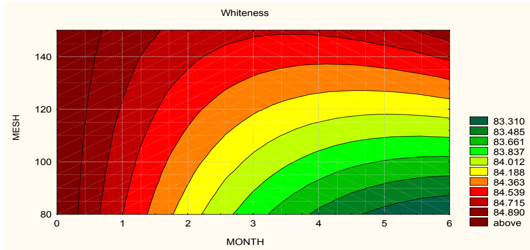
(a) Color L* value



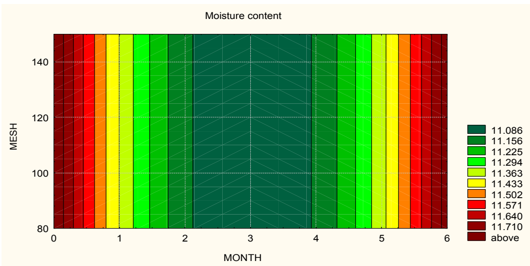
(b) Color a* value



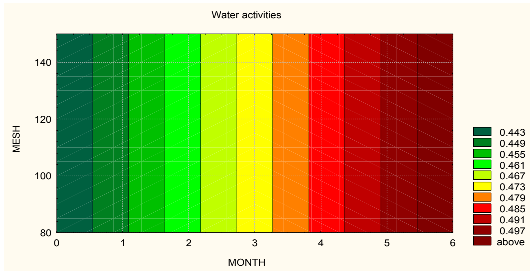
(c) Color b* value



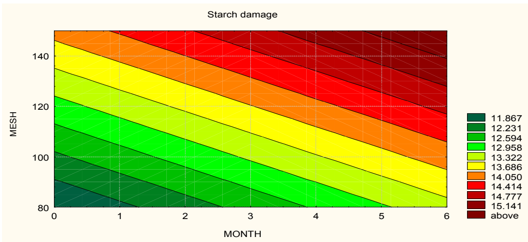
(d) Whiteness



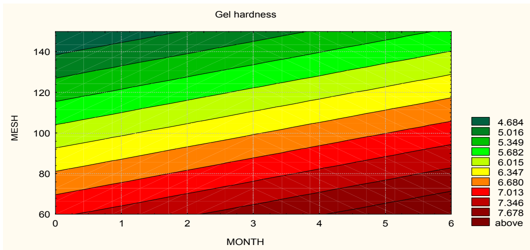
(e) Moisture content



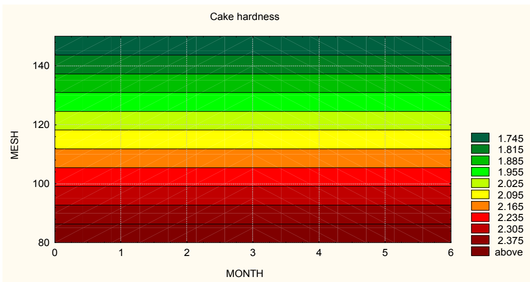
(f) Water activity



(g) Starch damage



(h) Gel hardness



(i) Cake hardness

Figure 22 Contour plot of predictive models explaining the effect on particle size and storage time on flour (a-h) and cake (i) properties

2 Effects of Storage Times on Consumer Acceptance of Jasmine Rice Cakes

2.1 Effect of Storage Times on Consumer Acceptance of Cake

Consumer acceptance of cake prepared from various flour particle sizes and storage times is presented in Table 32. Results indicated consumer acceptability of the different cakes from the different flour storage times on aroma, softness, flavor and overall liking .

For Jasmine rice butter cake from flour at <80 mesh, the mean acceptability scores of softness, flavor and overall liking were significantly different at 4 and 6 months. The mean acceptability scores for four sensory attributes in Jasmine rice butter cake from flour at <100 mesh were lowest at 2 months. For Jasmine rice butter cake from flour at <120 and <150 mesh during 6 months storage, the mean acceptability scores for flour sensory attributes were not significantly different. Therefore, the results indicated that using flour at <120 and <150 from 0 to 6 months to prepared into butter cake would yield acceptable products by consumers. At least 76% of the consumers accepted all cake products (from all flour sizes) with overall liking score greater than 5.70.

Table 32 Mean consumer scores of sensory attributes of Jasmine rice butter cake from various flour particle sizes and storage duration.

Product		**Attributes score[1/]**				**Acceptance[2/]**
Mesh	**Month**	**Aroma**	**Softness**	**Flavor**	**Overall liking**	**(%)**
< 80	0	6.40^{a} (1.62)	6.60^{a} (1.20)	6.34^{ab}(1.08)	6.42^{ab} (0.99)	76
	2	6.52^{a} (1.37)	6.68^{a} (1.31)	6.46^{ab}(1.38)	6.44^{ab} (1.28)	76
	4	6.50^{a} (1.25)	7.12^{a} (1.27)	6.76^{a} (1.36)	6.64^{a} (1.07)	86
	6	6.52^{a} (1.51)	6.02^{b} (1.67)	6.00^{b} (1.44)	6.04^{b} (1.29)	94
< 100	0	6.72^{a} (1.13)	6.86^{a} (1.23)	6.76^{a} (1.17)	6.86^{a} (1.21)	92
	2	6.18^{b} (1.37)	5.70^{b} (1.37)	5.96^{b} (1.16)	5.78^{b} (1.07)	94
	4	6.64^{ab}(1.35)	6.94^{a} (1.04)	6.86^{a} (0.99)	6.68^{a} (1.25)	94
	6	6.96^{a} (1.12)	6.94^{a} (1.45)	6.72^{a} (1.34)	6.84^{a} (1.30)	86
< 120^{ns}	0	6.86 (1.26)	6.94 (1.32)	6.82 (1.04)	6.96 (1.11)	90
	2	6.66 (1.33)	6.92 (1.29)	6.58 (1.21)	6.62 (1.29)	82
	4	6.62 (1.41)	6.96 (1.16)	6.90 (1.18)	6.88 (1.26)	94
	6	6.64 (1.35)	6.56 (1.23)	6.70 (1.11)	6.66 (1.08)	84
< 150^{ns}	0	6.84 (1.25)	7.06 (1.31)	6.92 (1.38)	6.88 (1.29)	96
	2	6.52 (1.42)	6.50 (1.43)	6.76 (1.06)	6.56 (1.18)	88
	4	6.86 (1.13)	6.60 (1.39)	6.98 (1.09)	6.80 (1.18)	100
	6	6.82 (1.17)	6.96 (1.19)	6.88 (1.11)	6.92 (1.00)	94

[1/] Mean values from 50 participants and based on a 9-piont hedonic scale. Value with different letters in the same column are significantly different (P<0.05) as determined by Fisher's Least Significant Difference (LSD), and numbers in parenthesis represent standard deviation.

[2/] Based on binomial (yes/no) scale and on 50 participants.

[ns] mean not significantly different (P>0.05).

2.2 Effect of Particle size and Storage Times on Consumer Acceptance

The experiment was conducted to investigate the effect of particle size and storage time on consumer sensory attributes. The particle size was in a ranged of <80, <100, <120 and <150 mesh and storage time in a range of 0, 2, 4 and 6 months. The effect of flour particle size and storage time were analyzed statistically by MANOVA (Table 33). Based on MANOVA results (the approximate F value of particle size, storage time and their interaction of were 2.028, 2.701 and 1.702, respectively and all Wilks'lambda statistic values with $P<0.05$), it can be concluded that when all sensory attributes were compared simultaneously, its was affected by particle size, storage time and their interactions.

The results Table 33 demonstrated the main effects of particle size, storage time, and their interaction (interaction of particle size and storage time). Considering individual sensory parameters, results showed particle size and storage time affected taste and overall liking. In contrast, an interaction of particle size and storage time affected softness and overall liking.

Table 33 The main and interaction effects of particle size and storage time on sensory attributes of Jasmine rice cake.

Source	Wilks' lambda[1/]		Individual variable[1/]		
	F- value	***P* -value**	**Dependent variable**	**F- value**	***P* -value**
1. Particle size	2.028	0.01	1. Aroma	1.588	0.19 [ns]
			2. Softness	1.703	0.17 [ns]
			3. Taste	6.261	0.00
			4. Overall liking	4.171	0.00
2. Storage time	2..701	0.00	1. Aroma	1.615	0.19 [ns]
			2. Softness	5.321	0.19 [ns]
			3. Taste	4.817	0.00
			4. Overall liking	6.177	0.00
3. Particle size x Storage time	1.702	0.00	1. Aroma	0.872	0.55[ns]
			2. Softness	4.825	0.00
			3. Taste	1.830	0.06 [ns]
			4. Overall liking	2.976	0.00

[1/] The Wilk's lambda statistic and individual variable values with P>0.05 was not significantly different.

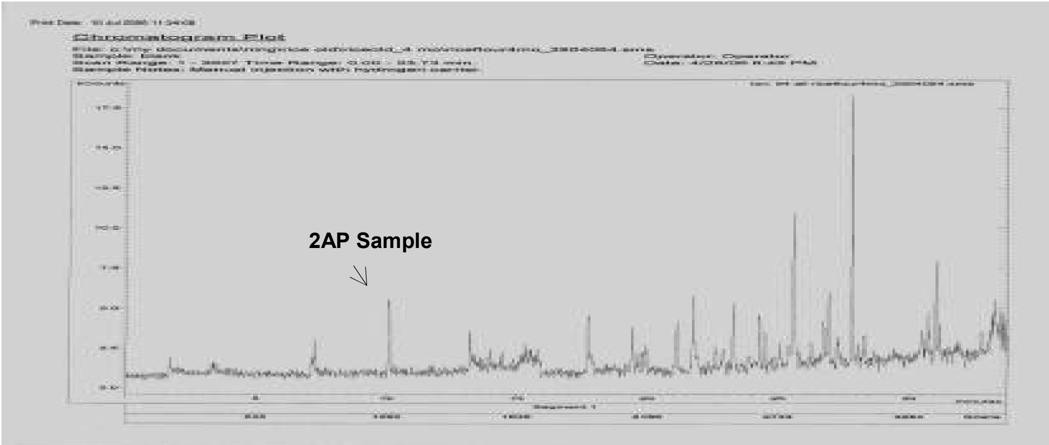
[ns] mean not significantly different (P>0.05).

3. Effect of storage time on the major volatile compound, 2-Acethyl -1-Pyrroline (2AP)

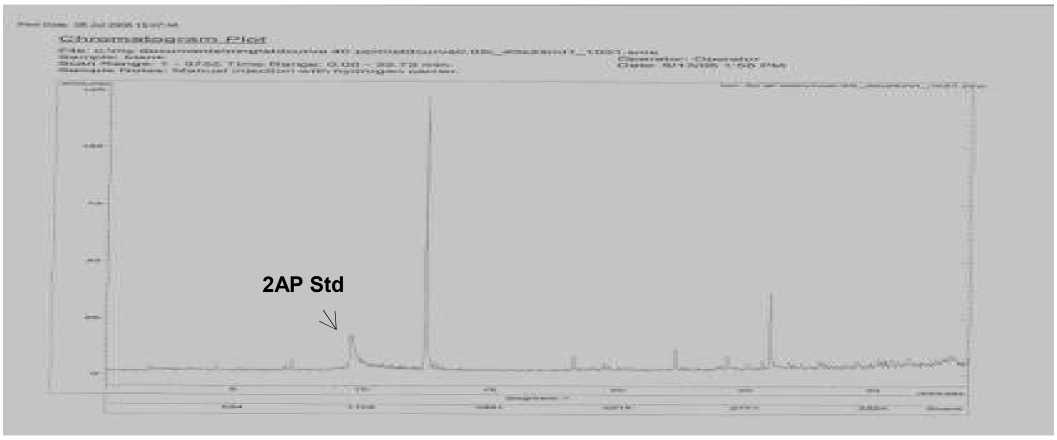
The extracted volatile components obtained by using solid phase micro extraction method and detected using GC-MS, are shown in the ion chromatrogram (Figure 23). The 2AP standard and compounds identified for Jasmine rice flour are shown in Figure 23 a and Figure 23 b. GC-MS identified a gas chromatography peak for 2AP, eluted at the retention time of 10 min. The 2AP obtained from Jasmine rice sample and internal standard has a clear separate peak. The internal standard (4-methyl -2 pentanone) eluted at the retention time at 8 min (Figure 23 c). The intensity of the 2AP in rice flour sample was expressed as the ratio of the peak height of 2AP to the peak height of internal standard the amount of 2AP in rice sample was calculated using the peak height ratios of 2AP in rice flour sample and internal standard and plot them on 2AP standard curve (Figure 24). Because the amount of 2AP standard was known, then the amount of 2AP in rice flour sample could be read on them.

The 2AP concentration in rice flour samples during storage was shown in Table 34. The results of major volatile compound were not significantly difference (P>0.05) during storage from 7 to 12 months. The 2AP in storage flour was in a range of 336.96 to 390.91 ppb of 5 g rice flour sample.

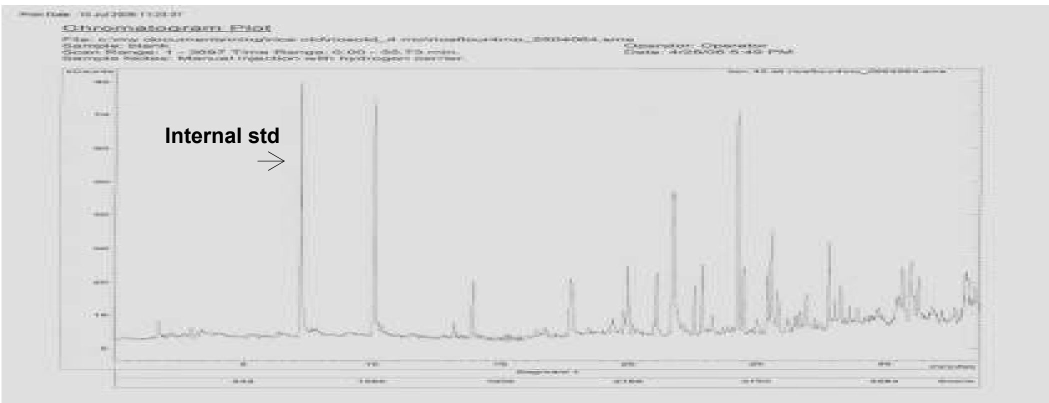
The environment of production area and the cultivated method, as well as the differences in detection method on 2AP cause the differences in aromatic rice quality. This reason supported by Yoshihari *et al*. (2004) who studied on uncooked Khao Dawk Mali 105 brown rice of 7 areas in Thailand. The results revealed the 2AP were in a range of 87 to 525 ppb of 2 g rice sample. Also, Mahatheeranont *et al*. (2001) extracted the volatile compound of uncooked Khao Dawk Mali 105 brown rice by using stream distillation method. The results revealed the 2AP were 340 and 120 ppb of 0.5 g rice sample in fresh brown rice and 12 months stored brown rice, respectively.



(a) 2AP in Jasmine rice flour sample at the ion characters: 84 (RT= 10 min)



(a) Standard of 2AP at the ion characters: 84 (RT= 10 min)



(c) Internal standard (4- methyl -2 pentanone) at the ion character:43 (RT= 8 min)

Figure 23 GC-MS ion chromatograph of (a) 2AP of Jasmine rice flour at ion character: 84, (b) 2AP of standard at ion character: 84, and (c) internal standard at ion character: 43.

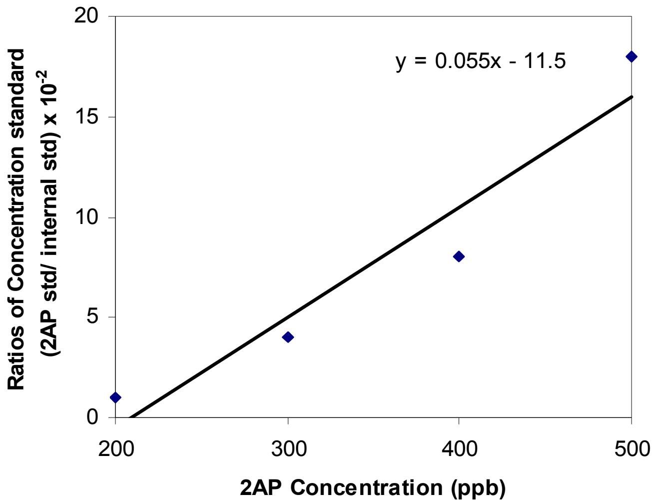


Figure 24 : Relationship between the 2AP concentration and the ratio of concentration of 2AP standard and Internal standards (4- methyl -2 pentanone)

Table 34 The recovery of 2-Acethyl -1- Pyrroline (2AP) of rice flour sample during storage.

Storage time(months)	Concentrate rations (2AP/Internal std)	Concentrate of 2AP ^{ns} (ppb)
7	0.07	336.36
8	0.08	354.55
9	0.10	390.91
10	0.10	390.91
11	0.08	355.55
12	0.09	372.73

^{ns} mean not significantly different (*P*>0.05).

4. Justification for Selection of Jasmine Rice Flour Particle Size

Flour particle size plays a significant role in the baking quality of a cake product. Thus, the selection of a suitable flour particle size determines the end product. In comparison with results from Thai consumer acceptance test on flour particle size (n = 700) in study Part I, section 1.4, rice butter cake that was focused on positive overall acceptance and purchase intent; and study Part II, section 2 on Thai consumer acceptance test on flour particle sizes and storage stability (n = 50), flour with <120 and <150 mesh size received a much higher sensory score on some attributes and higher score on softness for rice butter cakes. Rice flour with <120 and <150 mesh sizes are best to use. Although the finest rice flour has more advantage, yet it also has some disadvantages. The major disadvantage with the finest flour is that it is relatively expensive in terms of cost of raw materials and milling process.

In conclusions, particle sizes and storage times affected flour and their properties. Physicochemical properties of Jasmine rice flour changed during storage for 6 months. The significant changes of flour include color, starch damage and gel hardness, but not cake hardness. In addition, Jasmine rice flour stored for 7 to 12 months did not affect the major volatile compound (2AP). For sensory evaluation, Jasmine rice butter cake prepared form flour stored up to 6 months was accepted by consumer. In order to produce a good quality cake product with great consumer acceptance, results from this study showed that Jasmine rice flour at <120 mesh size is most suitable for further study.

Part III : Develop and Characterize Cake Using Powdered Emulsifier Mixed and Determine American Consumer Acceptability of Jasmine Rice Cake

1. American Consumer Acceptance on Cake Using Powdered Emulsifier Mixed Formulation

Four Jasmine rice cake formulas; 0% (product A), 7.5% (product B) and 15% (product C) of margarine content in formula and commercial wheat butter cake as a control (product D) were used to evaluate the consumer acceptance.

1.1 Consumer Demographic Information

Of 400 consumers who participated in the study, 42.5% were male and 57.50% were female. They were between 19-65 years of age.

1.2 Overall Product Differences and Discriminating Sensory Attributes

Based on MANOVA results as shown in Table 35 (the approximate F value of 18.26 and the Wilks' lambda statistic with $P < 0.0001$), it can be concluded that the four butter cake products (A, B, C, and D) were significantly different when all nine sensory attributes were compared simultaneously. Since there were some differences among the four butter cake products, DDA was performed to determine which attributes were responsible for the group differences (Pavon, 2003; Bond, 2004; Soler, 2005; Sae-Eaw *et al.,* 2007).

Table 35 Multivariate statistics and F approximations.

MANOVA	Test Criteria and F Approximations for the Hypothesis of No Overall Form Effect				
H = Type III SSCP Matrix for Forms ,E = Error SSCP Matrix S = 2 M = 2.5 N = 786.5					
Statistic	**Value**	**F-Value**	**Numerator DF**	**Denominator DF**	**Pr > F**
Wilks' Lambda	0.7428	18.26	27	4600.5	<0.001
Pillai's Trace	0.2709	17.39	27	620	<0.001
Hotelling-Lawley Trace	0.3281	19.13	27	491.05	<0.001
Roy's Greatest Root	0.2611	45.75	9	310	<0.001

Results from DDA (Table 36) report the canonical structure r's (Huberty 1994), which identifies constructs that largely accounted for the group differences. Analysis of dimensionality indicated that three dimensions (Can 1, 2, and 3) shown in Table 36 were needed to explain the total variance. According to the pooled within group variances, the first dimension (Can 1), which accounted for 79.57% explained variance, identified overall texture (with a canonical correlation = 0.7903), softness (0.729), moistness (0.7135), overall liking (0.6795), and taste (0.6031) as sensory attributes contributed to the underlying differences among all four products. Based on the canonical correlation values, we may conclude that the main construct that accounted for the group differences was the texture attribute, a composite of overall texture, softness and moistness.

Table 36 Canonical Structure r's describing group differences among four butter cake products.[1/]

Attribute	Can 1	Can 2	Can 3
Overall appearance	0.2517	-0.7560	0.4167
Visual puffiness	0.3329	-0.5979	0.3403
Crumb color	0.0435	-0.3545	0.5045
Odor	-0.0014	0.0726	0.7012
Softness	0.7290[2/]	-0.1473	0.1984
Moistness	0.7135[2/]	0.0210	-0.0959
Overall texture	0.7903[2/]	0.0737	0.4558
Taste	0.6031[2/]	0.0975	0.5769
Overall liking	0.6795[2/]	-0.0261	0.5103
Cumulative Variance Explained	79.57%	97.15%	100.00%

[1/] Based on the pooled within group variances. Can 1, 2, and 3 refer to the first, second, and third canonical discriminant functions, respectively.
[2/] Indicates attributes which accounted for the group differences in the first dimension.

The PCA biplot analysis using PC 1 and PC 2 (Figure 25) revealed the relationship between products and sensory acceptability. Products B and C (containing 7.5 and 15% emulsifier gel, respectively) were closely positioned to each other, but distant from product A (0 % emulsifier gel) and the control. The biplot revealed five discriminating attributes including softness, moistness, overall texture, taste and overall liking, similar to those obtained from DDA in the first dimension (Can 1) (Table 36). Implications of the results from Table 38 and Figure 25 must be made with caution because the purpose of DDA and PCA used here was to identify the sensory attributes which accounted for group differences, rather than those attributes which influenced the overall acceptance and purchase intent. The latter will be further discussed.

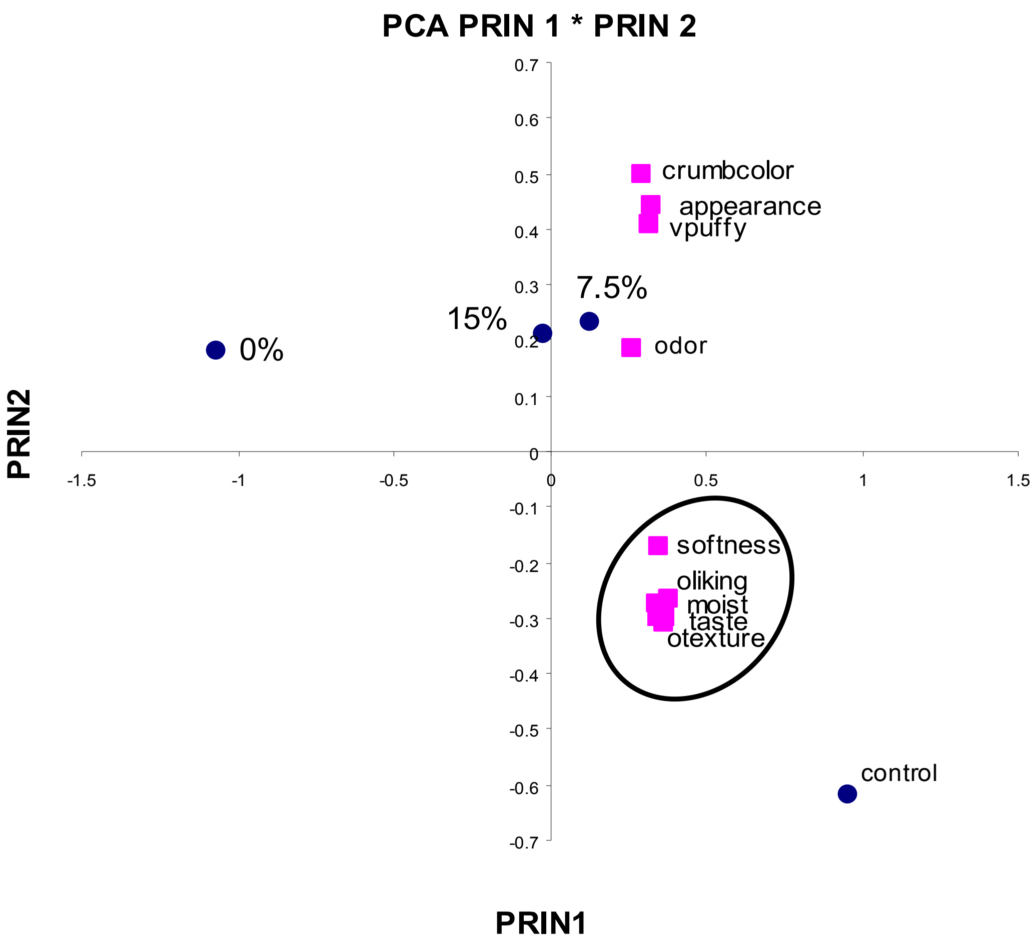


Figure 25 The PCA product-attribute biplot involving Principal Component 1 and Principal Component 2; Product, 0%, 7.5%,and 15%, respectively contained w/w emulsifier gel (propylene glycolester:diacetyltartaric acid ester of monoglyceride, PGMS:DATEM, 8:2)based on the margarine content in the total formulation. Product control was thecommercial sample.Nine sensoryattributes:crumbcolor,appearance, vpuff,odor, softness,oliking, moist, taste,and otexture are, respectively, crumbcolor, overall appearance, visual puffiness, odor, softness, moistness, overall taste, and overall texture.

Since the texture attribute (Table 36) was critical to product differences, we further compared the moistness and softness intensities (obtained from the JAR scale) of the following product pairs: A/B, A/C, A/D, B/C, B/D and C/D. The Stuart-Maxwell statistic equation for a three-category classification (Fleiss and Everitt 1971) was used to calculate the $\chi 2$ value, which was then compared to the critical value of 5.99 at df = 2 and α = 0.05. The results (see Appendix Table E1) indicated that there was a significant difference in the distribution of responses for all product pairs. Therefore, the data matrix was collapsed into two categories (i.e., not enough and other), and the McNemar test was used to determine individual scale categories for which differences were significant (Stone and Sidel 1993). Results (Table 37) indicated that, for five product pairs (A/B, A/C, A/D, B/D and C/D), the latter product was more moist and softer than the former product. For example, for the A/B pair, product B was more moist and softer than product A. There were no significant differences in moistness and softness between products B and C.

Table 37 Comparison of moistness and softness of product pairs using the McNemar test.[1/]

Product pairs[2/]	**χ^2 value for moistness**	**χ^2 value for softness**
A/B	12.01	46.20
A/C	9.60	21.05
A/D	111.19	153.09
B/C	0.0073[ns]	2.69 [ns]
B/D	80.44	73.14
C/D	74.23	87.95

[1/] The critical χ^2 value = 5.99 at df = 2 and α = 0.05.

[2/] Product A, B, and C, respectively, contained 0, 7.5 and 15 % w/w emulsifier gel (propylene glycol ester:diacetyl tartaric acid ester of monoglyceride, PGMS:DATEM, 8:2) based on the margarine content in the total formulation. Product D was the commercial sample.

[ns] mean not significantly different (P>0.05) between products B and C

1.3 Consumer Acceptability, Overall Product Acceptance and Purchase Intent

Based on the overall liking and sensory acceptability profile (Table 38), consumers preferred the commercial product (D) more than the non-wheat rice butter cake products. They also preferred products B (7.5% emulsifier gel) and C (15%) equally but more than product A (0% emulsifier gel). The DDA analysis identified softness, moistness, overall texture, taste, and overall liking as discriminating attributes (Table 36). According to Table 38, the mean consumer acceptability scores for these five discriminating sensory attributes for product A (0% emulsifier gel) were lowest among the four products; these five mean consumer acceptability scores for products B (7.5%) and C (15%) were not significantly different from each other, but they were significantly lower than those of product D (control). The lowest acceptability score for overall texture (5.44) of product A was likely due to the lowest scores for softness (5.56) and moistness (5.42); this was attributed to the least moistness and softness of the product according to the McNemar test results (Table 37). The overall liking and sensory acceptability profile (Table 38) supports the results from the PCA biplot (Figure 25) in that products B and C were closely positioned to each other, but distant from product A (0 % emulsifier gel) and the control, and that product A was most distant from product D.

At least 81% of consumers indicated their positive overall acceptance for products B, C and D, whereas only 69% for product A (Table 38). Non-wheat rice butter cakes made from 0% powdered emulsifier(product A) had significantly (P<0.05) lowest positive overall acceptance and purchase intent whereas the positive acceptance and purchase intent of cakes made from 7.5% and 15% powdered emulsifier (product B and C) were not significantly (P>0.05) different. Commercial-wheat butter cakes had significantly highest positive overall acceptance and purchase intent (P<0.05).

Table 38 Mean consumer scores for sensory acceptability and positive product acceptance and purchase intent (%) of four butter cake products.

Attribute	Product[2/]			
	A	B	C	D
Acceptability[1/]				
Overall appearance	6.03 b (1.8)	6.93 a (1.4)	6.92 a (1.5)	6.71 a (1.8)
Visual puffiness	5.90 b (1.8)	6.73 a (1.4)	6.75 a (1.6)	6.74 a (1.6)
Crumb color	6.49 b (1.6)	6.93 a (1.4)	6.79 a (1.5)	6.66 ab (1.7)
Odor	6.82 ab (1.5)	6.98 a (1.4)	6.66 b (1.5)	6.84 ab (1.8)
Softness	5.56 c (1.9)	6.42 b (1.7)	6.44 b (1.7)	7.32 a (1.4)
Moistness	5.42 c (1.8)	6.07 b (1.7)	6.18 b (1.7)	7.16 a (1.6)
Overall texture	5.44 c (1.8)	6.26 b (1.7)	6.14 b (1.7)	7.33 a (1.5)
Taste	5.46 c (1.9)	6.17 b (1.7)	5.95 b (1.8)	7.00 a (1.7)
Overall liking	5.39 c (1.8)	6.20 b (1.5)	6.06 b (1.7)	7.03 a (1.7)
Positive (yes) overall acceptance (%)[3/]	69.0 c	83.7 b	81.5 b	90.8 a
Positive (yes) purchase intent (%)[3/]	31.1 c	42.1 b	47.0 b	74.3 a

[1/] Mean(standard deviation) from 400 responses and based on a 9-point hedonic scale (1 = dislike extremely, 5 = neither like nor dislike, 9 = like extremely). Mean values in the same row not followed by the same letter are significantly different ($P < 0.05$) as determined by the Tukey's studentized range test.

[2/] Product A, B, and C, respectively, contained 0, 7.5 and 15 % w/w emulsifier gel (propylene glycol ester:diacetyl tartaric acid ester of monoglyceride, PGMS:DATEM, 8:2) based on the margarine content in the total formulation. Product D was the commercial sample.

3/ Based on the binomial (yes/no) scale, and on 400 responses. The positive overall acceptance and purchase intent values in the same row not followed by the same letter are significantly different (P< 0.05) as determined by Cochran's Q test.

Table 39 Mean overall liking score for consumer acceptability, positive product acceptance (%), purchase intent (%) and rank sum of three butter cake products.

Attributes	Product[2/]		
	A	B	C
Overall liking[1/]	5.39 ^{b} (1.8)	6.20 ^{a} (1.5)	6.06 ^{a} (1.7)
Positive (yes) overall acceptance (%)[3/]	69.0 b	83.7 a	81.5 a
Positive (yes) purchase intent (%)[3/]	31.1 b	42.1 a	47.0 a
Rank Sum [4/, 5/]	294 b	398 a	310 a

1/ Mean (standard deviation) from 400 responses and based on a 9-point hedonic scale. Mean values in the same row not followed by the same letter are significantly different (P < 0.05) as determined by Fisher's Least Significant Difference (LSD).

2/ Product A, B, and C, respectively, contained 0, 7.5 and 15 % w/w emulsifier gel (propylene glycol ester:diacetyl tartaric acid ester of monoglyceride, PGMS:DATEM, 8:2) based on the margarine content in the total formulation.

3/ Based on the binomial (yes/no) scale, and on n=400 responses. The positive overall acceptance and purchase intent values in the same row not followed by the same letter are significantly different (P < 0.05) as determined by Cochran's Q test.

4/ Product A, B, and C, respectively ranked 3 orders (raw data were 9-point hedonic scale transformed) where 1= most preferred(or the highest hedonic score) and 3= least preferred (or the lowest hedonic score) and rank orders were transformed into score where 1= 3 scores, 2= 2 scores and 3= 1 score, based on n=167 responses.

5/ The rank sum score in the same row not followed by the same letter are significantly different (P < 0.05) as determined by Friedman test.

1.4 Consumer Acceptability, Positive Acceptance and Purchase Intent and Product Rank Sums among Three Jasmine Rice Butter Cake Products

According to Table 39, when compared product A (0% emulsifier gel), B (7.5% emulsifier gel) and C (15% emulsifier gel) without product D (control), the mean consumer acceptability score for product A (0%) was lowest among the three products; the overall liking scores for products B (7.5%) and C (15%) were not significant different from each other, but they were significantly higher than those of product A.

At least two samples (Product B and C) gave the significant difference on the positive overall acceptance. At least 81% of consumers indicated their positive overall acceptance for products B and C which were higher than product A (whereas only 69% for product A). Product B and Product C had higher purchase intent than that of product A. Product B and C was not significantly different on the positive purchase intent.

Consumers (n=167) indicated the significant difference of product ranking. Product A had the lowest rank sum meaning that consumers rated the liking score on product A with lowest rank. The ranking scores, for product B and C were not significantly different. Product B and C could be selected for the further study.

1.5 Predicting Overall Acceptance and Purchase Intent using Logistic Regression Analysis

In this study, the logistic regression analysis was used (1) to identify sensory attributes that influenced overall acceptance and purchase intent of the butter cake products and (2) to predict overall acceptance and purchase intent based on those identified sensory attributes. Results (Table 40) indicated that overall liking was the most critical attribute influencing overall acceptance, followed by taste. The odds ratio of overall liking was 2.453 for overall acceptance, indicating the probability of the product being accepted is 2.453 times higher (than not being accepted, $P<0.0001$) with every 1-unit increase of the overall liking score.

For purchase intent, odor, taste, and overall liking were influencing attributes with the odds ratio estimate of 0.826, 1.376, and 3.462, respectively. The odds ratio estimate of overall liking for purchase intent (3.462) was higher than that for overall acceptance (2.453), indicating that consumers perceived overall liking as more critical to purchase intent than to overall acceptance. Likewise, consumers also perceived taste as a somewhat more critical attribute to purchase intent than to overall acceptance, with the odds ratio estimate increasing from 1.323 to 1.376. However, odor influenced purchase intent ($P = 0.0014$), but not overall acceptance.

Table 40 Parameter estimates, probability, and odds ratio estimates for predicting overall acceptance and purchase intent of butter cake products [1/]

Variables	Overall Acceptance			Purchase Intent		
	Estimate	**Pr > χ^2**	**Odds Ratio**	**Estimate**	**Pr > χ^2**	**Odds Ratio**
Intercept	-6.2403	<.0001	N/A	-8.5876	<.0001	N/A
Overall appearance	0.0354	0.6907	1.036	-0.00847	0.9139	0.992
Visual puffiness	0.0711	0.3974	1.074	-0.0360	0.6259	0.965
Crumb color	-0.1094	0.1844	0.896	-0.0680	0.3512	0.934
Odor	0.0351	0.5764	1.036	-0.1913	0.0014	0.826
Softness	0.1138	0.1138	1.121	-0.0333	0.6049	0.967
Moistness	-0.0208	0.7828	0.979	0.0402	0.5391	1.041
Overall texture	0.1398	0.0685	1.150	0.1142	0.1325	1.121
Taste	0.2799	0.0023	1.323	0.3190	0.0003	1.376
Overall liking	0.8974	<0.0001	2.453	1.2417	< 0.0001	3.462

[1/] Based on the logistic regression analysis, using a full model with nine sensory attributes. The analysis of maximum likelihood estimates was used to obtain parameter estimates. Significance of parameter estimates was based on the Wald χ^2 value at $P < 0.05$. N/A refers to "not applicable."

When overall liking was used as a sole predictor variable in a single-variable logistic regression model, the odds ratio estimate for overall acceptance and purchase intent ranged from 2.327-4.047 (Table 41). Except for product A, increasing a one-unit score for overall liking would increase a greater chance that the products B and C would be accepted (up to 1.14 times higher) and purchased (up to 0.743 times higher) more than product D.

Table 41 Parameter estimates, probability, and odds ratio estimates for predicting overall acceptance and purchase intent of each butter cake product.[1/]

Product [2/]	Overall Acceptance			Purchase Intent		
	Estimate	**Pr > χ^2**	**Odds Ratio**	**Estimate**	**Pr > χ^2**	**Odds Ratio**
A	0.8481	<0.0001	2.335	0.8447	0.0002	2.327
B	1.2461	<0.0001	3.477	1.3980	<0.0001	4.047
C	0.8824	0.0001	2.417	1.3513	<0.0001	3.863
D	0.8458	0.0031	2.330	1.1953	<0.0001	3.304

[1/] Based on the logistic regression analysis, using a single-variable model with overall liking as a sole predictor variable. The analysis of maximum likelihood estimates was used to obtain parameter estimates. Significance of parameter estimates was based on the Wald χ^2 value at $P < 0.05$.

[2/] Product A, B, and C, respectively, contained 0, 7.5 and 15 % w/w emulsifier gel (propylene glycol ester:diacetyl tartaric acid ester of monoglyceride, PGMS:DATEM, 8:2) based on the margarine content in the total formulation. Product D was the commercial sample.

Based on the full logit model (Table 43) with nine sensory attributes, overall acceptance and purchase intent of the butter cake products could be predicted with 89.3% and 83.3% accuracy, respectively (Table 42). Overall liking or taste alone could be used to predict overall acceptance with 89.4% and 86.6% accuracy, respectively. Only overall liking, when served as a single predictor, could yield up to 83% prediction accuracy.

Table 42 Correct prediction (% Hit Rate) of overall acceptance and purchase intent of butter cake products. [1/]

Attributes	% Hit Rate	
	Overall Acceptance	**Purchase Intent**
Full Model (9 variables)	89.3	83.3
A Single-Variable Model		
Overall appearance	82.1	62.9
Visual puffiness	81.7	62.6
Crumb color	81.1	60.3
Odor	81.2	61.0
Softness	83.1	67.5
Moistness	82.7	70.6
Overall texture	83.7	73.9
Taste	86.6	79.6
Overall liking	89.4	83.7

[1/] Based on the logistic regression analysis at *P*-event of 0.5. Hit rate (%) is the correct classification of an unknown unit (product) into a group (either accepted vs. not-accepted and/or purchased vs. not-purchased).

Table 43 Full logistic regression models for predicting acceptability and purchase Intent.

Attributes (Yi)	Predictive Model
Acceptability	y = -6.2403+ 0.0354 (Overall appearance) + 0.0711 (Visual puffiness) -0.1094 (Crumb color) + 0.0351 (Odor) + 0.1138 (Softness) -0.0208 (Moistness) + 0.1398 (Overall texture)+ 0.2799 (Taste) + (Overall liking)0.8974
Purchase Intent	y = -8.5876 - 0.00847 (Overall appearance) – 0.0360 (Visual puffiness) -0.0680 (Crumb color) - 0.1913 (Odor) - 0.0333 (Softness) + 0.0402 (Moistness) + 0.1142 (Overall texture)+ 0.3190 (Taste) + 1.2417(Overall liking)

1.6 Cake Formula Justification

Based on the acceptance on four cake formulations, consumers rated product B and C with higher overall liking than product A. Also comparison of sensory attributes on the softness indicated that product B and C had lower cake hardness more softness).

. Based on overall liking, the positive product acceptance, the positive purchase intent and the product ranking, product B and C were not significantly different from each other, but differed from product A.

When comparing the amount of powdered emulsifier mixed in cake formulation, product B (7.5%) required less amount than product C (15%). Thus, product B was selected for further storage study.

In conclusions, the study demonstrated feasibility of completely substituting wheat flour with Jasmine rice flour for production of butter cake that are acceptable to American consumer. According to MAOVA, DDA and PCA techniques, sensory attributes that separated wheat flour butter cake product from those containing Jasmine rice flour were softness, moistness overall texture and overall liking. LRA identified taste and overall liking as the two critical attributes influencing overall acceptance and purchase intent. Jasmine rice cake contained 7.5% was selected for the Jasmine rice cake mixed for the further study.

Part IV : Effects of Storage Times on Physicochemical Properties of Cake Mixed and Determine American Consumer Acceptability of Jasmine Rice Cake Prepared from Cake Mixed during Storage.

1. Effects of Storage Times on Physicochemical Properties of Cake Mixed

1.1 Packing of Cake Mixed Flour and Storage Study

According to the study results from Part III, cake containing 7.5% of powdered emulsifier mixed with margarine was used to formulate for the cake mixed packing. The amount of cake ingredients in their various combinations was shown in percentages and its conversion into the scale unit of gram, as in Table 44. Eight out of the thirteen ingredients could be grouped into 3 packages. The rest of the ingredients, margarine, evaporated milk butter essence and eggs were left out to be added by the user. The amount of them (in gram weight) was showed as Table 45. The cake mixed bag consisted of three small sachet packs. This included Jasmine rice cake mixed, sugar mixed, and powered emulsifier mixed. Each pack of ingredients was individually mixed and packed (1)- 15.5 x 15.5 cm packing, rice flour mixed that contained Jasmine rice flour, maltodextrin, salt and baking powder sifted for the uniformity and mixed, (2)- 13 x 15 cm packing, sugar mixed that consisted on powdered sugar and guar gum sifted for uniformity and mixed, and (3)- 7.5 x 8.5 cm package, powdered emulsifier mixed, a combination of PGMS and DATEM sifted for uniformity and mixed. Then, all ingredients mixed packaging were packaged into a large size 18 x 21 cm packing. All packaging material type was the Food Sarver® Vacloc® vacuum packaging system (Jarden Cooperation, Korea).

Table 44 Rice butter cake formulations.[1/]

Ingredients	Amount of Ingredients	
	%	G
Part I: Emulsifier gel		
PGMS	0.98	6.17
DATEM	0.24	1.51
Margarine	1.62	10.20
Part II: Other ingredients		
Jasmine rice flour	17.89	112.71
Maltodextrin	8.77	55.25
Baking powder	0.66	4.16
Salt	0.49	3.09
Powdered sugar	18.60	117.18
Guar gum	0.51	3.28
Margarine	14.65	92.23
Evaporated milk	6.44	40.54
Butter essence	0.52	3.27
Egg white	25.20	158.66
Egg yolk	3.41	21.47

[1/] Formulation contained 7.5w/w emulsifier gel (propylene glycol ester:diacetyl tartaric acid ester of monoglyceride, PGMS:DATEM, in ratios of 8:2) based on the margarine content in the total formulation.

Table 45 Ingredients of cake mixed product packing.

Ingredients	Amount (g)
1. Sachet No 1: Rice flour mixed	
Jasmine rice flour	112.71
Maltodextrin	55.25
Baking powder	4.16
Salt	3.09
2. Sachet No 2 : Sugar mixed	
Powder sugar	117.18
Guar gum	3.28
3. Sachet No 3 : Powder emulsifier mixed	
PGMS	6.17
DATEM	1.51

1.2 Storage Stability of Cake Mixed

The cake mixed was used to study the effect of storage time on the physiochemical properties. Physicochemical properties of the cake mixed stored from 0 to 6 months, is listed in Table 46.

1.2.1 Rice Flour Mixed Properties

During 6 months storage, slight changes in moisture content, a_w and color were observed. However, no significant change in microbial count was found. Total plate count ranged from 3.51 to 3.69 log cfu/g; Yeast and Mold counts were < 1 log cfu/g. Overall product was microbiologically safe.

1.2.2 Sugar Mixed Properties

They were no significant changes in moisture content and the color a* value but slight changes in a_w and the color L* and b* values were observed. Moisture content ranged from 0.85 to 0.90% and the water activity ranged from 0.39 to 0.42.

1.2.3 Powdered Emulsifier Mixed Properties

There were no significant changes in moisture content and the color L* and a* values, but slight changes in a_w and the color b*value were observed. Moisture content of the powder emulsifier mixed was less than 1% that confirmed the supplier product specifications. Water activity ranged from 0.30 to 0.34 during storage, which implied that the product being microbiologically safe.

There was no significant change in cake hardness prepared from cake mixed stored for 6 months. Cake hardness ranged from 5.14 to 5.25 N. Thus, cake mixed could be stored for 6 months without adverse effects on physiochemical properties and could be used to prepare cake with similar cake properties.

Table 46 Effect of storage time of cake mixed properties [1/] on chemical, physical and microbiological properties.

Storage time (months)	Rice flour mixed							Sugar mixed					Powdered emulsifier mixed				Cake from cake mixed
	MC (%)	a_w	Color			TPC [ns] (log CFU/g)	YM (log CFU/g)	MC [ns] (%)	a_w	Color			a_w	Color			Hardness [ns] (N)
			L*	A* [ns]	b*					L*	a* [ns]	b*		L* [ns]	a* [ns]	b*	
0	9.23 b	0.33 b	97.20 ab	-0.56	5.23 a	3.51	< 1 est.	0.85	0.34 c	98.84 ab	0.19	2.72 b	0.30 b	96.66	-0.10	4.03 c	5.20
	(0.19)	(0.02)	(0.19)	(0.01)	(0.19)	(0.23)		(0.10)	(0.02)	(0.81)	(0.23)	(0.69)	(0.05)	(0.17)	(0.03)	(0.32)	(0.67)
1	9.47 a	0.35 a	96.31 cd	-0.56	5.05 ab	3.69	< 1 est.	0.87	0.35 bc	97.47 ab	0.17	2.79 b	0.30 b	95.94	-1.13	4.30 bc	5.21
	(0.08)	(0.01)	(0.60)	(0.17)	(0.27)	(0.19)		(0.04)	(0.00)	(0.57)	(0.08)	(0.08)	(0.02)	(0.42)	(0.17)	(0.11)	(0.70)
2	9.29 ab	0.35 a	96.99 ab	-0.57	4.34 de	3.51	< 1 est.	0.89	0.42 ab	98.95 a	0.16	2.78 b	0.31 ab	96.30	0.04	4.30 bc	5.14
	(0.85)	(0.09)	(0.31)	(0.23)	(0.28)	(0.15)		(0.08)	(0.00)	(0.45)	(0.27)	(0.82)	(0.02)	(0.38)	(0.00)	(0.74)	(0.48)
3	9.34 a	0.33 b	96.82 bc	-0.54	4.67 cd	3.55	< 1 est.	0.89	0.39 ab	98.77 ab	0.18	3.21 a	0.30 b	96.22	-0.83	4.78 ab	5.27
	(0.27)	(0.05)	(0.34)	(0.10)	(0.19)	(0.13)		(0.05)	(0.01)	(0.40)	(0.30)	(0.96)	(0.01)	(0.88)	(0.23)	(0.68)	(0.71)
4	9.48 a	0.35 a	96.03 d	-0.59	4.73 cd	3.63	< 1 est.	0.90	0.40 a	97.11 c	0.19	3.21 a	0.33 a	96.66	-0.10	4.64 ab	5.25
	(0.07)	(0.05)	(0.50)	(0.35)	(0.20)	(0.18)		(0.06)	(0.00)	(0.63)	(0.08)	(0.36)	(0.05)	(0.17)	(0.03)	(0.32)	(0.56)
5	9.20 b	0.35 a	97.50 a	-0.69	4.87 bc	3.63	< 1 est.	0.90	0.38 ab	98.79 ab	0.20	3.06 a	0.34 a	95.94	-1.13	5.22 a	5.18
	(0.12)	(0.01)	(0.19)	(0.11)	(0.31)	(0.22)		(0.05)	(0.01)	(0.99)	(0.08)	(0.55)	(0.02)	(0.42)	(0.17)	(0.11)	(0.79)
6	9.35 a	0.34 ab	96.85 bc	-0.69	4.53 de	3.63	< 1 est.	0.90	0.38 ab	98.77 ab	0.19	3.14 a	0.34 a	96.30	0.04	5.04 a	5.16
	(0.06)	(0.00)	(0.83)	(0.19)	(0.18)	(0.22)		(0.01)	(0.01)	(0.99)	(0.22)	(0.24)	(0.02)	(0.38)	(0.00)	(0.74)	(0.66)

[1/] Mean values in the same column not followed by the same letter are significantly different ($P < 0.05$) as determined by Fisher's Least Significant Difference (LSD), and numbers in parenthesis represent standard deviation. Moisture content for powdered emulsifier mixed was based on Danisco USA Inc.'s specification (obtained by personal communication); both PGMS and DATEM less than 1 % of moisture content.

[ns] mean not significantly different ($P > 0.05$), MC = Moisture content in dry basis; a_w = Water activity; TPC = Total Plate Count; YM = Yeast and Mold.

1.3 The American Consumer Acceptance of Jasmine Rice Butter Cake Prepared from Cake Mixed Storage

1.3.1 Consumer Demographic Information

Consumers were recruited within the Louisiana State University campus and the general Baton Rouge area. Out of 400 consumers who participated in this study, approximately 47 % were male and 53% were female, and in general all were between 19-65 years of age.

1.3.2 Consumer Acceptability, Overall Product Acceptance and Purchase Intent

Based on the overall liking and sensory acceptability profile (Table 47), consumers slightly liked the product prepared from the cake mixed after 6 months (ranged 6.5-6.9) of storage, except for butter odor/aroma that was moderately accepted at 7.7 out of a 9.0 scale score.

At least 84% of the consumers indicated their positive overall acceptance for products and up to 58% indicated that they would purchase the product if commercially available.

Table 47 Mean consumer scores for sensory acceptability and positive product acceptance and purchase intent(%) of cake products.[1/]

Attributes	Response
Acceptability (score)[2/]	
Overall appearance	6.96 (1.17)
Visual puffiness	6.97 (1.21)
Crumb color	6.92 (1.20)
Odor	7.70 (1.28)
Softness	6.93 (1.19)
Moistness	6.68(1.28)
Overall texture	6.60 (0.88)
Taste	6.54 (1.20)
Overall liking	6.69 (1.55)
Positive (yes) Overall acceptance (%)[3/]	84.9
Positive (yes) Purchase intent (%)[3/]	58.0

[1/] Product prepared from cake mixed stored for 6 months

[2/] Mean values from 400 responses and numbers in parenthesis represent standard deviation, and based on a 9-point hedonic scale.

[3/] Based on the binomial (yes/no) scale, and on 400 responses.

1.3.3 Comparison of consumer Acceptability of Cake Prepared from Cake Mixed with Storage between 0 and 6 Months

Consumer test results (Table 48) showed that the overall liking scores of rice butter cakes prepared from cake mixed stored for 0 month and commercial butter were significantly different. Commercial butter cake had a higher overall liking score. Similarly, overall liking scores for commercial butter cake was significantly higher compare to cake from cake mixed stored for 6 months. The commercial butter cake sample and cake form cake mixed store for 6 months had scores higher in the second time test than the first time, but different groups of consumers were used. In addition, cake mixed stored for 6 months was similarly preferred to the 0 month. Although the scores were only about 0.4 points higher, this may have been due to variations from the consumer group used. It could be concluded that rice butter cakes prepared from cake mixed flour stored at 0 and 6 months were similarly accepted by American consumers. Thus, cake prepared from cake mixed stored for 6 month was accepted by consumer.

Table 48 The mean overall liking [1/] of Jasmine rice cake prepared from cake mixed compared with commercial butter cake.

Sample cake	Evaluation time	
	First (0-month)	**Second (6-month)**
Rice butter cake [2/]	6.20 b (1.54)	6.69 b (1.55)
Commercial butter cake [3/]	7.03 a (1.66)	7.40 a (1.21)

[1/] Mean score of 400 responses based on a 9-point hedonic scale. Mean values in the same column not followed by the same letter are significantly different ($P< 0.05$) and numbers in parenthesis represent standard deviation. The letter indicates the dependent t-test.

[2/] Rice butter cake evaluated first and second time prepared from 0 and 6 months of cake mixed flour storage, respectively.

[3/] The commercial Sara Lee brand cake served during the 0 and 6 months testing as a control.

In conclusions, cake mixed product stored up to 6 months was not affected by physicochemical properties and it could be prepared for Jasmine rice butter cake accepted by American consumers.

Part V : Develop Cake Mixed Using Rice Bran Oil, and Develop Cake Making Process and Determine Thai Consumer Acceptability of Cake Mixed by Testing its Performance.

1. Development of Jasmine Rice Cake Using Rice Bran Oil Formula

Replacement of margarine and butter with rice bran oil in Jasmine rice cake formulation was performed. Table 49 reported the mean consumer acceptance scores for sensory attributes of Jasmine rice cake from butter and rice bran oil formula. Consumers rated the liking for four cake samples based on five sensory attributes. There was no significant difference in butter odor among four samples. Consumer acceptability scores for sweetness, softness, moistness and overall liking for product formulated with RBO 70% were higher than those of with formula RBO 80%. Consumer acceptability score for softness for formula with RBO 60% and RBO 70% were not significantly different but both of them were higher than the one with RBO 80%. The hardness for rice bran oil cake (data not shown in Table) for formula RBO with 60% (2.53 N) was highest whereas those with RBO 70% (2.34 N) and RBO 80% (2.24 N) were not significantly different. Moreover, the highest overall liking score was observed for product formula RBO 70%, whereas formula RBO 60%, RBO 80% and butter (control) samples were not significantly different either.

On this regard, substituting butter with rice bran oil is feasible for Jasmine rice butter cake with similar acceptance. Thus, formula RBO 70% was subsequently performed.

Table 49 Mean consumer scores [1/] for sensory attributes of Jasmine rice cake product.

Attributes	Formulations[2/]			
	Butter	RBO 60%	RBO 70%	RBO 80%
Butter odor	6.49 a (1.83)	6.58 a (1.68)	6.68 a (1.43)	6.49 a (1.54)
Sweetness	6.31 ab (1.87)	6.31 ab (1.75)	6.62 a (1.53)	6.14 b (1.53)
Softness	6.52 ab (1.64)	6.75 a (1.58)	7.14 a (1.54)	6.27 b (1.51)
Moistness	6.22 b (1.54)	6.13 b (1.64)	6.64 a (1.51)	5.96 b (1.49)
Overall liking	6. 56 b (1.52)	6.52 b (1.60)	6.96 a (1.52)	6.21 b (1.57)

[1/] Mean values from 109 responses and based on a 9-point hedonic scale. Mean values in the same row not followed by the same letters are significantly different ($P < 0.05$) as determined by Fisher's Least Significant Difference (LSD), and numbers in parenthesis represent standard deviation.
[2/] Formula RBO 60%, RBO 70%, and RBO 80% were 60, 70 and 80 % as rice bran oil content in formula and Butter was control formula.

2 Optimum Process of Jasmine Rice Cake

2.1 Batter Properties

The batter properties of four treatments are shown in Table 50. The longer the mixing time of the batter consisting of rice bran oil, the lower of the batter flow distance and the higher the batter specific gravity. Batter flow distance control batter (from butter formula) was the lowest, whereas batter specific gravity of the control batter and rice flour batter mixed for 20 min were not significantly different. Batter properties are explained by the lower density batter that is related to batter flow distance. The results agree with the cake batter microstructure for four formulas as shown in Figure 26. The results indicated that extending mixing time increased small air sizes and added more air cell sizes in cake batter. This led to a higher interfacial tension that affects batter flowability and hence, decreased distance of batter flow. As air bubbles become smaller and numerous in the batter due to increased mixing time, they did not, however, affect cake crumb cell structure, cake appearance (Figure 27) and cake hardness (Table 52).

Table 50 Cake batter properties [1/] of rice bran oil formula with various mixing times

Mixing time (min)	Batter flow distance (cm)	Batter specific gravity(cm^3/g)
0	11.23 a (0.13)	1.01 c (0.005)
10	10.67 b (0.25)	1.06 b (0.005)
20	9.11 c (0.33)	1.12 a (0.006)
Control[2/]	7.46 d (0.09)	1.12 a (0.005)

[1/] Mean values in the same column not followed by the same letters are significantly different (*P*< 0.05) as determined by Fisher's Least Significant Difference (LSD), and numbers in parenthesis represent standard deviation.
[2/] Batter of Jasmine rice batter from butter (control) formula

2.2 Effect of Mixing Time and Baking Time on Cake Properties

Based on MANOVA results (the approximate F value of mixing time, baking time and the interaction of mixing time, baking time were 2.028, 2.701 and 1.702, respectively and all Wilks'lambda statistic values with *P*>0.05, data not show in Table), it can be concluded that when two cake properties (specific volume and hardness) were compared simultaneously, They were not affected by mixing time, baking temperature and their interactions.

The factorial design analysis results of mixing time and baking temperature and their interaction (interaction of mixing time and baking temperature) are shown on Table 51. Considering individual cake properties results, the mixing time did not affect specific volume and cake hardness whereas baking temperature affected only cake hardness. In contrast, an interaction of mixing time and baking temperature affected both specific volume and cake hardness.

Table 51 The main and interaction effects of mixing time and baking temperature on cake properties of Jasmine rice cake.

Source	Individual variable[1/]		
	Dependent variable	**F -value**	***P*-value**
1. Mixing time	1. Specific volume 2. Hardness	0.483 1.847	0.62 [ns] 0.02 [ns]
2. Baking temperature	1. Specific volume 2. Hardness	1.128 1.213	0.33 [ns] 0.00
3. Mixing time x Baking temperature	1. Specific volume 2. Hardness	5.132 11.235	0.00 0.00

[1/] The individual variable values with P>0.05 was not significantly different.

[ns] mean not significantly different (P>0.05).

Considering individual cake properties results on Table 52 and 53, baking temperature affected cake hardness whereas it did not affect specific volume. Cake hardness was highest when baked at 190°C where it was lowest at 150°C (mean values as shown in the column). There were no significantly differences (mean values as shown in the row) in cake hardness and specific volume as the mixing time changed.

Table 52 Cake hardness[1/] at varying mixing time and baking temperature.

Baking temp (^oC)	Mixing time(min) 0	10	20	Mean
150	2.33 (0.26)	2.29 (0.18)	2.23 (0.10)	2.29 C (0.27)
170	2.52 (0.07)	2.70 (0.15)	2.65 (0.12)	2.62 B (0.29)
190	3.01 (0.17)	2.91 (0.20)	2.91 (0.18)	2.92 A (0.21)
Mean	2.62 a (0.23)	2.63 a (0.21)	2.48 a (0.18)	

[1/] Mean values in the same row with small letters and in the same column with capitalized letters not followed by the same letters are significantly different ($P < 0.05$) as determined by Fisher's Least Significant Difference (LSD), and numbers in parenthesis represent standard deviation.

Table 53 Cake specific volume[1/] at varying mixing time and baking temperature.

Baking temp (^oC)	Mixing time(min) 0	10	20	Mean
150	1.91 (0.19)	1.93 (0.14)	1.82 (0.19)	1.89 A (0.17)
170	1.92 (0.15)	1.82 (0.16)	1.71 (0.16)	1.81 A (0.17)
190	1.81 (0.09)	1.74 (0.10)	2.03 (0.25)	2.03 A (0.20)
Mean	1.88 a (0.15)	1.83 a (0.15)	1.86 a (0.24)	

[1/] Mean values in the same row with small letters and in the same column with capitalized letters not followed by the same letter are significantly different ($P < 0.05$) as determined by Fisher's Least Significant Difference (LSD), and numbers in parenthesis represent standard deviation.

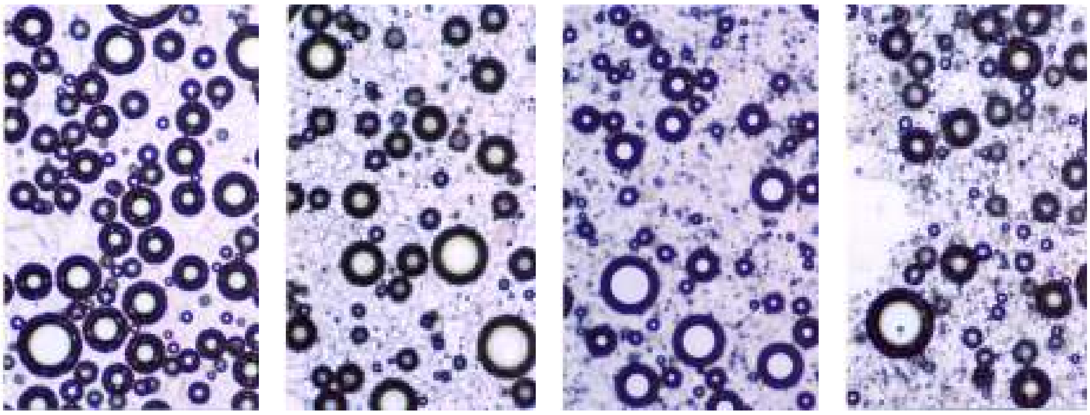
ANOVA results of cake properties at various mixing times and baking temperatures are shown in Table 54. The hardness of treatment 2, 5 and 8 were not significantly different from cake formula 10 (control formula). Treatment 8 had shorter baking time (35 min) than the other formulations. The higher baking temperature affects or increases cake hardness. This effect is due to rapid heat transfer in the oven. Total processing time of optimized rice bran oil cake was 42 min (7 min from mixing time and 35 min from baking time) whereas process time for rice butter cake was 77 min (42 min from mixing time and 35 min from baking time). Processing time decreased by more than 50% compared with rice butter cake formula. Thus, in order to determine the process time of rice bran oil cake, treatment 8 was subsequently performed.

Table 54 Cake properties[1/] of rice bran oil formula at various mixing and baking times and baking temperature.

Treatments			Baking time (min)	Specific volume (cm^3/g)	Hardness (N)
No.	Mixing time(min)	Baking temp(^oC)			
1	20	150	60	1.82 bc (0.19)	2.23 d (0.13)
2	20	170	35	1.71 c (0.16)	2.65 bc (0.12)
3	20	190	25	2.03 a (0.25)	2.91 a (0.18)
4	10	150	60	1.93 ab (0.14)	2.29 d (0.20)
5	10	170	35	1.82 bc (0.16)	2.70 b (0.15)
6	10	190	25	1.74 bc (0.10)	2.91 a (0.18)
7	0	150	60	1.91 ab (0.19)	2.33 d (0.30)
8	0	170	35	1.92 ab (0.15)	2.52 c (0.07)
9	0	190	25	1.81 bc (0.09)	3.01 a (0.17)
10[2/]	15	170	35	1.87 ab (0.17)	2.58 bc (0.10)

[1/] Mean (standard deviation), Mean values in the same row not followed by the same letters are significantly different ($P< 0.05$) as determined by Fisher's Least Significant Difference (LSD), and numbers in parenthesis represent standard deviation.

[2/] Formula 10 was control formula (rice butter cake).



(a) (b) (c) (d)

Figure 26 Micro structure of Jasmine rice batter from rice bran oil and butter formula with various mixing time; (a): Butter formula (control), (b): rice bran oil formula/mixing for 0 min, (c): rice bran oil formula/mixing for 10 min, and (d): rice bran oil formula/mixing for 20 min.

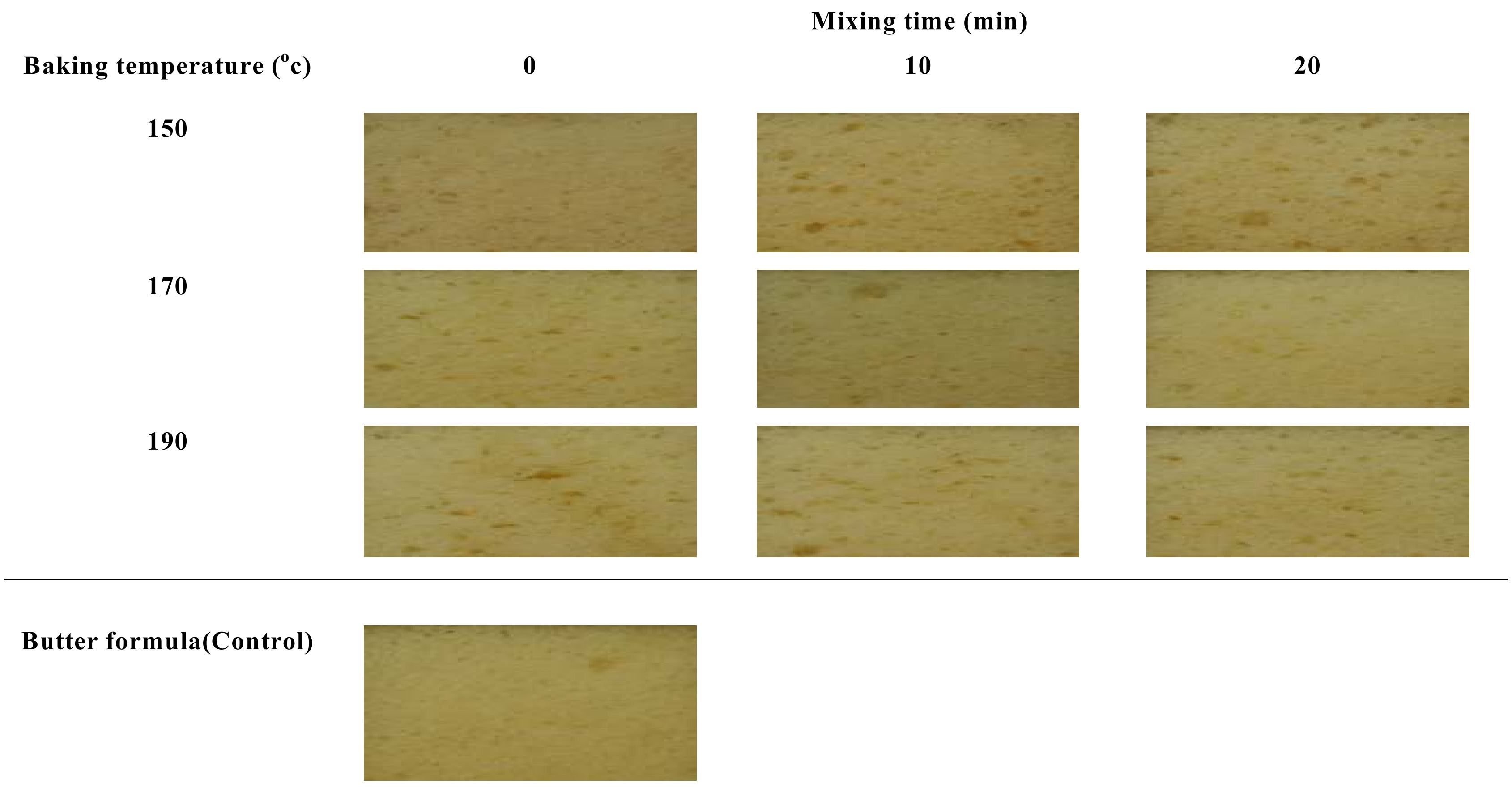


Figure 27 Cake crumb cell structure with vary mixing times and baking temperatures and butter cake as control formula.

3. Cake Mixed Packaging Design

3.1 Replacing Laboratory Use Formula with Household Use Formula

Consumer test results on the sensory attribute scores for softness, flavor and overall liking scores for rice bran oil cake are shown in Table 55. All sensory attribute scores from laboratory use formula and household use formula were not significantly (P>0.05) different. Rice bran oil cake was prepared from laboratory formula and household formula was equally acceptable. Thus, the household use formula of rice bran oil cake sample was subsequently subjected to cake mixed packing design.

Table 55 Mean consumer liking scores[1/] of cake with laboratory use formula and household use formula.

Attributes	**Formula**	
	Laboratory Use	**Household Use**
Softness	7.10 a (1.16)	7.06 a (1.20)
Flavor	7.04 a (0.86)	7.16 a (0.93)
Overall liking	7.10 a (0.74)	7.18 a (0.87)

[1/] Mean values from 50 responses and based on a 9-point hedonic scale. Mean values in the same row not followed by the same letter are significantly different (P<0.05) as determined by the dependent t-test, and numbers in parenthesis represent standard deviation.

3.2 Ingredients of Cake Mixed and Procedure Instructions on Packing Design

3.2.1 Ingredients of Cake Mixed Packing Design

The approved formulation from the previous study on household use cake formulation (Table 56) was selected for packing ingredients design testing. The amount of ingredients and three specific sachets were prepared as shown in Table 57. Nine out of eleven ingredients could be grouped into 3 groups. These included flour mixed ingredients, sugar mixed ingredients, and rice bran oil mixed ingredient. Each of the ingredient group was individually mixed and packed as shown in Figure 28; (1)-PE bag, rice flour mixed that contained Jasmine rice flour, maltodextrin, salt and baking powder, all sifted for the uniformity and mixed, (2)- PE bag, sugar mixed that consisted of powdered sugar and guar gum, all sifted for uniformity and mixed, and (3)-Laminated Aluminum foil bag, oil mixed containing rice bran oil, emulsifier and flavoring that were mixed for 5 min. Then, all three sachets of ingredients mixed packing were packed in a High Density Polyethylene bag of cake mixed package. The rest of the other ingredients such as eggs and evaporated milk were left out to be added by the consumer or user.

Table 56 The household use formula for cake mixed.

Ingredients	Household use formula
1.Jasmine rice flour	97.50 g
2.Maltrodextrin	47.50 g
3.Baking powder	3.50 g
4.Salt	2.00 g
5.Powdered sugar	96.50 g
6.Guar gum	3.50 g
7.Emulsifier EC 25®	22.50 g
8. Rice bran oil	61.92 g
9.Butter flavoring	5.00 g
10.Evaporated milk	1/6 cup
11.Egg yolk	1 egg of egg yolk
12.Egg white	4 eggs of egg white

Table 57 Ingredients of cake mixed design

Ingredients	Quantities (g)
1 Sachet No. 1 : Rice flour mixed	
Jasmine rice flour	97.50
Maltrodextrin	47.50
Baking powder	3.50
Salt	2.00
Total	150.50
2. Sachet No. 2 : Sugar mixed	
Powder sugar	96.50
Guar gum	3.50
Total	100.00
3. Sachet No. 3 : Rice bran oil mixed	
Rice bran oil	61.98
Emulsifier (EC 25®)	22.50
Butter essence	5.00
Total	89.48

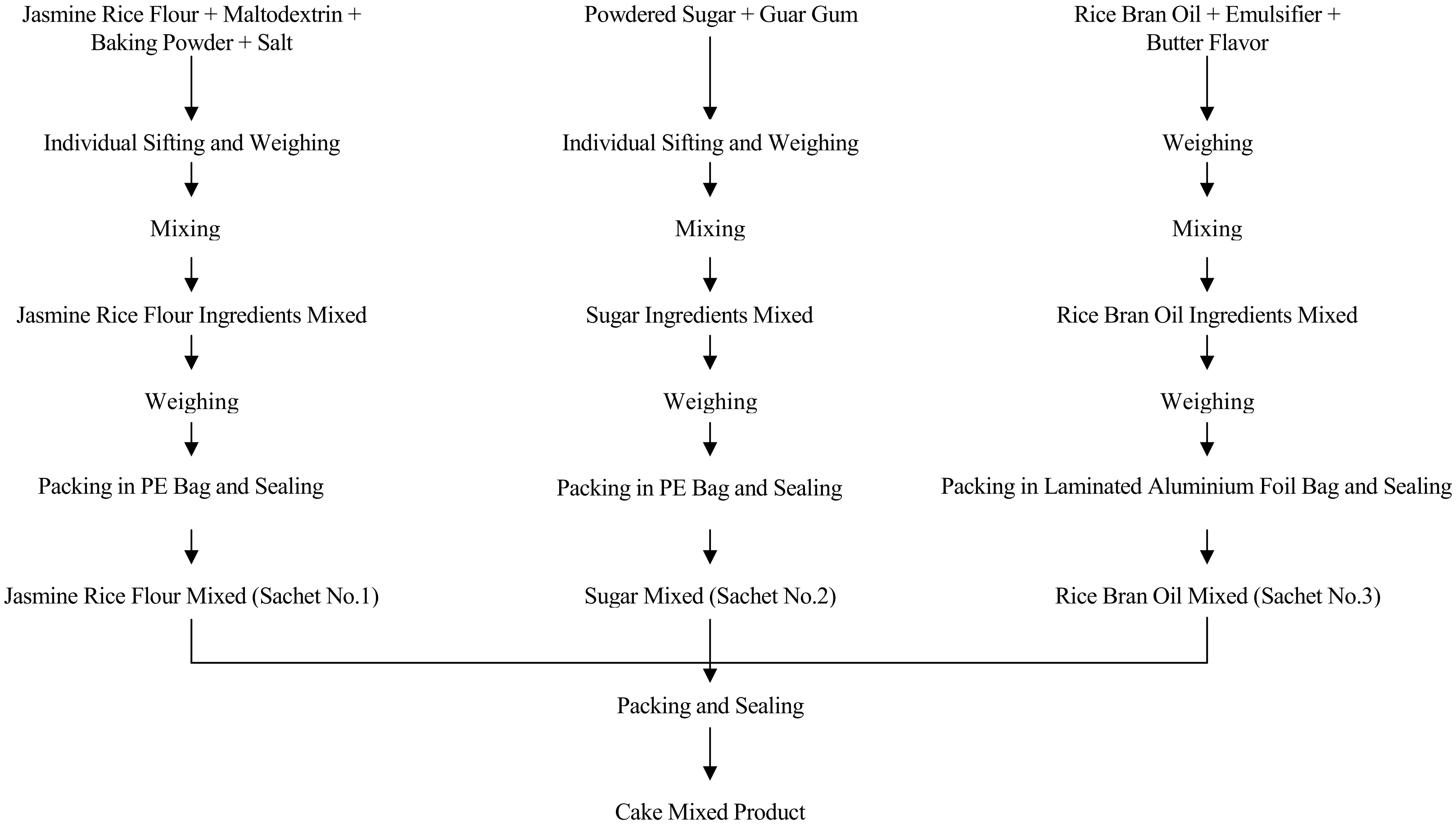


Figure 28 Process of mixing ingredients for cake mixed product

3.2.2 Procedure Instructions of Cake Mixed and Packing Design

The approved process from the above process optimization study of cake making (section 2 above) were selected following the procedure instruction in Figure 29. Total processing and cake making time including the baking time, was 47 min. After packing ingredients for cake mixed packages, the processing time was 42 min, a difference of 5 min from before (47 min) and after packing comparison.

The packing design, including package label on front view and back view side, that showed procedure instructions used to prepare Jasmine rice cake as in Figure 29 and cake mixed product and cake from the cake mixed as shown in Figure 30 were marked behind the cake mixed package for the next product laboratory use testing.

(a) : Front view side

(b) : Back view side

Figure 29 Packaging of cake mixed product (a): front view and (b): back view, showing instructions to prepare Jasmine rice cake.

3.3 Quality of Cake Mixed and Cake

3.3.1 Cake mixed

The properties of Jasmine rice flour mixed, sugar mixed and rice bran oil mixed from cake mixed product are shown in Table 58.

1) Flour Mixed

The color L*, a* and b* of cake mixed flour were 98.00, -0.16 and 5.14, respectively. Water activity (a_w) was considered safe for microbial growth, and moisture content was within recommended specifications (Thai industrial standard for moisture content of flour mixed was less than 14%). Yeast & Mold count was less than 1 log cfu/g which was also within specification (Thai industrial standard for yeast & mold of flour mixed was less than 0.78 log cfu/g). *B. Cereus* was also at a safe level. Thus, the product was potentially microbiologically safe.

2) Sugar Mixed

The color L*, a* and b* values of sugar mixed were 98.00, -0.16 and 5.14, respectively. Water activitiy (0.45) and moisture content (0.52%) implied microbiologically safe.

3) Rice Bran Oil Mixed

The color L*, a* and b* values of cake mixed flour were 58.90, -1.89 and 9.5, respectively. Yeast and Mold counts were less than 1 log cfu/g. Thus, the product was microbiologically safe.

Table 58 : Physicochemical and microbiological properties of cake mixed.

Properties	Flour mixed	Sugar mixed	Rice bran oil mixed
1.Physicochemcial properties [1/]			
Color value L*	98.00 (0.16)	98.03 (0.14)	58.90 (0.99)
a*	-0.16 (0.01)	-0.05 (0.02)	-1.89 (0.20)
b*	5.14 (0.11)	4.92 (0.26)	9.5 (1.12)
Water activity (a_w)	0.30 (0.00)	0.45 (0.01)	NA
Moisture content (%)	8.32 (0.10)	0.52 (0.02)	NA
2. Microbiological properties			
Aerobic plate count (log cfu/g)	2.57	2.71	2.73
Yeast & Mold (log cfu/g est.)	<1	<1	<1
B. Cereus (log cfu/g)	1.30	NA	NA

[1/] Mean values for physicochemical properties and numbers in parenthesis represent standard deviation.
NA mean not analyze.

3.3.2 Cake Properties Prepared from Cake Mixed

The properties of cake prepared from cake mixed are shown in Table 59. Based on the baked cake product, energy and cholesterol contents of cake were 399.41 kcal/100 g and 30.17 g/100 g, respectively. Energy and cholesterol decreased 19.43 and 70.66% compared with rice butter cake (regular formula) which had 495.72 kcal/100 g and 102.83 g/100 g respectively. The color L*, a* and b* value of cake mixed flour were 64.69, -0.95 and 13.21, respectively. Cake hardness was 1.91 N and specific volume was 1.89 cm^3/g.

Table 59 Product quality of cake prepared from cake mixed**.**

Cake qualities	Response
1. Nutrition value/Chemical composition	
Energy (kcal/100g)	399.41
Cholesterol (mg/100 g)	30.17
Carbohydrate (g/100g)	46.90
Protein (g/100g)	7.57
Fat (g/100g)	20.17
Fiber(g/100g)	0.71
Ash (g/100g)	1.16
2. Physical properties [1/]	
Color value L*	64.69 (1.42)
a*	-0.95 (0.20)
b*	13.21 (0.77)
Cake hardness (N)	1.90 (0.52)
Specific volume (cm^3/g)	1.89 (0.01)

[1/] Mean values of physicochemical properties and numbers in parenthesis represent standard deviation.

(a) Cake mixed

(b) Jasmine rice cake prepare from cake mixed

Figure 30 Cake mixed (rice bran oil formula) product and Jasmine rice cake

3.4. Consumer Acceptability Test on Cake Mixed Using Laboratory Use Test

3.4.1 Demographic Characteristics

Fifty consumers participated in the performance test. Their demographic characteristics are presented in Table 60. Consumer population predominantly consisted of females who made up 96% of the total population. Forty eight percent of the participants were 46 years of age and over, which was expected since the target consumers were pre-recruited. With regards to marital status, married and single consumers were practically equal in portion. Thirty six percent of consumers were employed and 34% participants were unemployed. Fifty two percent of the consumers had completed their bachelor's degree and 26 % had post graduate degrees (above bachelor degree). Income data revealed that 46 % earned 10,000 baht/month and below. Most households comprised of 2 - 4 persons (70%). Family member demographic characteristics showed approximately 52% of consumers were female and 48% were male, and 30% of the participants were categorized in the 46 years or over of age group.

Table 60 Consumer and their family's member demographic information.

Factor	Response (%)	Factor	Response (%)
Consumer response			
1. Gender		5. Education	
- Female	96	- High school	16
- Male	4	- Diploma	6
2. Age (yr)		- Bachelor's degree	52
- 15-25 yrs	18	- Post graduate and higher 's degree	26
- 26-35 yrs	8	6. Income	
- 36-45 yrs	26	- <5,000 bath	22
- 46-55 yrs	30	- 5,001-10,000 baht	24
- >55 yrs	18	- 10,001-15,000 baht	8
3. Status		- 15,001-20,000 baht	18
- Single	54	- 20,001-25,000 baht	10
- Married	46	- >25,000 baht	18
4. Occupy		7. Total of members in Family	
- Employed	36	- 2 persons	18
- Unemployed	34	- 3 persons	20
- Business owner	12	- 4 persons	32
- Student	18	- 5 persons	14
		- >5 persons	16
Family's member response			
1. Gender		2. Age (years)	
- Female	52	- 15-25 years	24
- Male	48	- 26-35 years	18
		- 36-45 years	14
		- 46-55 years	30

3.4.2 Consumer Acceptability

The percentage of positive response for product acceptability and purchase intent can be found in Table 61. The number of positive responses from product laboratory use test for Easiness of Instructions and Procedure was 100%, Convenient to Make at Home Place was 98%, and Convenient to finding the additional Ingredients was 100%. Consumer rating for overall liking of cake prepared from cake mixed, and cake mixed (mean value = 7.8 and 7.9, respectively) indicated that product was moderately to very much accepted. All of consumers (100%) accepted the cake mixed which received the highest percentage of positive response for purchase intent (96%). When consumer were asked if they would purchase the product after knowing the information from their family's member, the purchase intent did not change (96%). Family member's response on overall liking was 7.24, and purchase intent was 94 %. The positive purchase intent for product cost at 60 - 80 baht and 81 - 100 bath were 54% and 46%, respectively.

Table 61 Consumer and their family's member acceptance and purchase intent from product performance

Factor	Response
Consumer response	
1. Positive (yes)	
- Easiness of procedure instruction (%)	100
- Convenient to make at home place (%)	98
- Convenient to find the additional ingredients (%)	100
2. Overall liking score [1/] (cake form)	7.78 (0.89)
3. Overall liking score[1/]	7.92 (0.85)
4. Positive (yes) overall acceptance (%)	100
5. Positive (yes) purchase intent (%)	96
6. Positive (yes) purchase intent (%)	
- 60- 80 baht	54
- 81-100 baht	46
7. Positive (yes) purchase intent (%)	
- Due to family member 's influence	96
Family's member response	
1. Overall liking[1/] (cake form)	7.24 (0.69)
2. Positive (yes) overall acceptance (%)	94

[1/] Mean values for overall liking score and numbers in parenthesis represent standard deviation.

In conclusions, Jasmine rice cake could be formulated with up to 70% rice bran oil as a replacement of butter in cake formula, yielding similar products. Jasmine rice cake mixed package comprised of three sachets: (1) Jasmine rice cake mixed, (2) sugar mixed, and (3) rice bran oil mixed. Cake mixed ingredients were within recommended specification and microbiology safe. The resulting cake prepared from cake mixed contained 19.43% and 70.66%, reduced, respectively energy and cholesterol compared to Jasmine rice cake (butter formula). Cake mixed was performed in the laboratory use testing, and it could be used to prepare Jasmine rice cake accepted by tested consumers.

CONCLUSION AND RECOMMENDATION

Conclusions

From the experimental results and discussions of this study, the conclusions can be drawn as follow:

1. The flour particle size affected their properties. Physicochemical properties significantly changed in different four flour sizes which affected flour, batter and cake properties. The finer flour particle sizes showed significantly higher starch damage, water soluble index and swelling power but lower resistance force. Pasting properties measured by RVA of the finer flour showed significantly lower in peak viscosity and breakdown whereas set back and pasting temperature were higher. The observation on SEM micro-structure of the coarser flour showed the tighter pack and the lesser erosion than the finer flour; this affected size distribution, water absorption capacity and damage starch on flour. Hardness of rice flour gel and cake from the finer flour were significantly lower. Flour sizes affected batter rheology; the storage modulus (G') and the loss modulus (G") of the finer flour were significantly different from those of the coarse flour. The cake batter characterization observed on light microscope most likely affects cake softness and cake crumb appearance. The statistical data indicated the correlation between flour particle size and their physicochemical properties of flour batter and cake properties. Effect of particle size may be attributed partly to lower resistance force, peak viscosity and breakdown of pasting profile, gel and cake hardness as the particle size increased (negative correlation). On the other hand, it may be attributed partly to the higher set back and pasting temperature of pasting profile, starch damage and storage modulus as the particle size increased (positive correlation). Thus, this study confirmed the importance of flour particle sizes that affect flour properties and its product quality. Next, the study on Thai consumer (n=700) acceptance of rice butter made from four difference flour sizes showed that the liking scores of overall acceptance were not significantly different with the mean score range of 6.31- 6.47. Cake from flour at <120 and <150 mesh also received highest % positive response for acceptability and purchase intent of 82.50% and 76.40%, respectively. Using

Descriptive Discriminant Analysis, it was determined that product appearance (overall appearance and crumb color) were the two attributes that contributed mostly to the underlying differences among the four samples. The logistic regression analysis identified overall liking and flavor, as the two most critical attributes influencing overall acceptance and purchase intent of the butter cake products. These two attributes should be focused on further product refinement and commercialization. This finding indicates the feasibility of completely substituting wheat flour with Jasmine rice flour for preparation of butter cake products that is acceptable to the Thai consumers. Therefore, flours at <120 and <150 mesh were subsequently performed to select flour particle sizes in order to determine the end product used.

2. Rice flour particle sizes during a 6-month storage affected flour and their properties. Physicochemical properties of Jasmine rice flour changed during 6 months of storage. The properties changed for each of flour particle sizes; there were slight changes in color during 6 months of storage. The significant change in whiteness, water activity, and starch damage and gel hardness did not affect cake properties. Cake hardness from each of flour particle sizes during stored did not significantly differ. This was due to the fact that small amounts of rice flour portion (17%) in cake formula had no apparent effects on cake hardness. For sensory evaluation of cake, the sensory acceptability score of aroma, softness, flavor and overall liking of rice cake from flour with <120 and <150 mesh size in four storage times were not significantly different. For the positive response percentage of acceptability, at least 76% of consumers accepted all cakes samples. Thus, Jasmine rice cakes prepared from flour particle sizes <120 mesh and <150 mesh, stored up to 6 months, were accepted by the consumers. The results revealed that Jasmine rice flour could be stored for an extended period to supply a year-round utilization.

3. The study demonstrated feasibility of completely substituting wheat flour with Thai Jasmine rice flour for production of butter cake products that are acceptable to the American consumers. Development of the gluten-free butter cake products made from Jasmine rice flour using powdered emulsifier and margarine provides an alternative for utilization of broken Jasmine rice. Replacing powdered emulsifier at

7.5% in rice cake was accepted by consumers. The logistic regression analysis identified overall liking, taste, and, to a lesser extent, odor as the critical attributes influencing overall acceptance and purchase intent of the butter cake products. Cake mixed from Jasmine rice flour using 7.5% powdered emulsifier mixed (PGMS and DATEM) was developed. One cake mixed package consisted of three individual packages, consisting of rice flour mixed (Jasmine rice flour, maltodextrin, baking powder and salt), sugar mixed (powdered sugar and guar gum) and powdered emulsifier mixed (PGMS and DATEM ratio 8:2).

4. The storage time study on cake mixed showed no significant changes in the softness of cake. Results of microbial count on cake mixed indicated the product was microbiologically safe. Then, cake mixed product stored up to 6 months was not affected on physicochemical properties. For sensory evaluation of cake prepared from 0 and 6 months cake mixed storage, the sensory acceptability score for 6 months was significantly different, about 0.4 units higher than that of 0 month. This may have been due to the variation in consumers. Thus, cake mixed flour stored for 6 months could be prepared for Jasmine rice butter cake that would be accepted by American consumers.

5. Cake mixed from Jasmine rice flour and rice bran oil was developed. Replacing butter with rice bran oil up to 70% was feasible. One cake mixed package consisted of three individual package; rice flour mixed (Jasmine rice flour, maltodextrin, baking powder and salt), sugar mixed (powdered sugar and guar gum) and rice bran oil mixed (rice bran oil, emulsifier and butter flavor). Rice bran oil cake was prepared by one cake mixed package and two additional ingredients; 1/6 measuring cup of evaporated milk and 4 eggs (separated and removed 3 egg yolks). Cake making process follows the package instruction. The optimum process for cake making was mixing for 7 min (rice bran oil mixed, sugar mixed and egg whipping for 2 min, followed by rice flour mixed and evaporated milk and then mixing for 5 min) and baking in oven at 170^{o}C for 35 min. Results of the quality measurement of rice bran oil cake mixed were as follows; product was microbiologically safe, energy and cholesterol of cake prepared from cake mixed flour were 399.41 kcal/100g and 30.17 mg/100 g, respectively. Energy and cholesterol was decreased by 19.43% and 70.66%

respectively, compared with rice butter cake product. The study on product acceptability by the laboratory use test method from consumers (n=50), showed that they accepted product with a moderate level (7.92 of 9 score). All of them (100%) accepted for cake mixed product and 96% of them would purchase this product at the price equal to that of commercial ones. After informed by the family's member (after they had evaluated cake), no significant difference in purchase intent of consumer was observed. Thus, consumer performance test indicated that the product could be used and accepted with market potential.

Recommendations

1. Increasing a board range of flour with different mesh sizes in the future study, it can increase different changes in flour physicochemical properties. Then, the results may reach better interpretation and better conclusions.

2. Storage extension of Jasmine rice flour (from Part I) should be conducted to 1 year to provide a year round rice supply before it is processed for the specific end user.

3. Shelf life study on Jasmine rice cake mixed (from Part V) needs to be completed for commercialization, in order to confirm its reliable product safety and maintain product quality.

4. Determination and characterization of the consumer sensory quality of rice butter cake product should be focused on product refinement, scale-up production for product launch, and further market research for commercialization.

5. Feasibility to replace Jasmine rice flour with other flour such as, Jasmine brown rice flour and tapioca flour, include adding other functional ingredients in cake formula to increase variations of new products with nutrition and health benefits.

LITERATURE CITED

AACC. 1998. **Approved Methods of the American Association of Cereal Chemists, Vol 2.** St. Paul, MN.

______. 2000. **Approved Methods of the American Association of Cereal Chemists.** St. Paul, MN.

Abdullah, N., A. Nawawi and I. Othaman. 2000. Fungal spoilage of starch- base foods in relation to its water activity (a_w). **J. Storage Prod. Res.** 36: 47-54.

Agricultural and Consumer Protection Department. 1996. **Propylene glycol esters of fatty acids.** Available source: http://www.fao.org/docrep/W6355E/w6355e0v.htm, July 25, 2007.

Agriculture Economic Office. 2003. Quality and Value of Agricultural Exporting 2002-2003. Ministry of Agriculture, Bangkok.

Agresti, A. 1996. **An Introduction to Categorical Data Analysis.** Wiley and Sons., New York.

Aichyawanich, S. 2002. **Approach to Improve The Rheological Properties of Dry Milled Rice Flour.** M.S. Thesis, King Mongkut's University of Technology Thonburi.

Allison, P.D. 1999. **Logistic Regression Using the SAS System: Theory and Application.** Cary N.C.: SAS Inst.

American Gastroenterological Association. 2001. American gastroenterological association medical position statement: celiac spruce. **Gastroenterology.** 120: 1522-1525.

Anonymous. 2007a. **Vegetable fats and oils.** Available Source: http://en.wikipedia.org/wiki/Vegetable_oil, October 2, 2007.

Anonymous. 2007b. **Shortening.** Available Source: http://en.wikipedia.org/wiki/Shortening, November 2, 2007.

A0AC. 2000. **Official Method of Analysis.** 17 th ed. The Association of Official Analytical Chemistry, Arlington, Verginia.

Aokor. 2000. **Maltodextrin.** Available source: http://www.chemicalland21.com, July 25, 2007

Azom. 2007. **Particle size – US sieve series and Tyler mesh size equivalents.** Available Source: http://www.azom.com/details.asp?ArticleID=1417, November 1, 2007.

BAM. 2001. **Bacteriological analytical manual online.** Available Source: http://www.cfsan.fda.gov/~ebam/bam-18.html, December 12, 2001.

Bakal, A.I. 1991. Fat reduction in baked goods, pp 185-191. *In* C. Haberstorh and C.E. Morris, eds. **Fat and Cholesterol Reduced Foods.** Portfolio, Houston.

Baker, J.E. and S.M. Woo. 1992. Digestion of starch granules by α amylase from the rice weevil*, Sitophilus Oryzae*: effect of starch type, fat extraction, granule size, mechanical damage, and detergent treatment. **Insect Biochem. Biol.** 22(6): 529-537.

Barber, S. 1972. Milled Rice and Change During Ageing, pp. 215-223. *In* D.F. Houston, ed. Rice : Chemistry and Technology. **AACC.** St Paul, MN.

Barbosa-Canovas, G.V. and M. Peleg. 1985. Microstructure of selected binary food powder mixtures. J. Food Sci. 50: 437-477.

Barbosa-Canovas, G.V. and H. Yan. 2003. Powder characteristics of preprocessed cereal flours, pp. 173-208. *In* G. Kaletunc and K. J. Breslauer, eds. **Characterization of Cereals and Flour.** Marcel Dekker Inc., New York.

Bean, M.M., E.A. Elliston-Hoops and K.D. Nishita. 1983. Rice flour treatment for cake baking applications. **Cereal Chem.** 60(6): 445-449.

______ and K.D. Nishita. 1985. Rice flour for baking. *In* B.O. Julino, ed. **Rice Chemistry and Technology.** St. Paul, MN.

______. 1986. Rice flour-its functional variations. **Cereal Food World.** 31: 477-481.

Becker, A., S.E. Hill and J.R. Mitchell. 2001. Milling-a further parameter affecting the Rapid Visco Analyzer(RVA) profile. **Cereal Chem.** 78: 166-172.

Bennion, E.B. and G.S.T. Bamford. 1997. **The Technology of Cake Making**. Blackie Academic & Professional, Chapman Hall, India.

Biliaderis and Zawistowski. 1990. Viscoelastic behavior of aging starch gel: effects of concentration, temperature, and starch hydrolysis on network properties. **Cereal Chem.** 67(3): 240-246.

Bogue, J.C., C.M. Delahunthy, M.K. Henry and J.M. Murray. 1999. Market-oriented methodologies to optimize consumer acceptability of cheddar-type cheeses. **Brit Food J.** 101(4): 301-316.

Bond, A. 2004. **Consumer Sensory Characteristics of Butter Cake Made from Wheat and Rice Flour.** M.S. Thesis, Louisiana State University.

Bor, S. L. 1980. **Rice: Production and Utilization.** AVI Publishing Company Inc., West Connecticut.

Bourne, M.C. 1978. Texture Profile Analysis. **Food Tech.** 32(7), 62-66.

Bus, A.E.M. and A. Worsley. 2002. Consumer's health perception of three types of milk: a survey in Australia. **Appetite.** 40(2): 93-100.

Bushuk, W. 1998. Interaction in wheat dough, pp.1-16. *In* R.J. Hammer and R.C. Hosney, eds. **Interaction : the Key to Cereal Quality.** American Association of Cereal Chemists Inc., Minnesota.

Buttery, R.G., B.O. Julino., L.C. Ling and J.G. Turnbaugh. 1983. Cooked Rice Aroma and 2- Acetyl -1-pyroline. **J. Agric. Food Chem.** 31: 823-828.

______, J.G. Louisa and R.M. Thomas. 1986. Quantitative analysis of 2-Acetyl-1-Pyrroline in Rice. **J. Agric. Food Chem.** 1986. 34: 112-114.

Cagampang, G.B., C.M. Perex and B.O. Juliano. 1973. A gel consistency test for eating quality of rice. **J. Sci. Food Agric.** 24: 1589-1549.

Cao, Y., Y. Wang, X. Chen and J. Ye. 2004. Study on sugar profile of rice during aging by capillary electrophoresis with electrochemical detection. **Food Chem.** 86(1): 131-136.

Carlos, A.O., P.T. Marcela and S. Constantino. 2000. Modeling starch gelatinization kinetics of milled Rice flour. **Cereal Chem.** 77(2): 145-147.

Cauvain, S.P. and D.D. Muir. 1974. High-ratio yellow cakes: effect of flour particle size. **FMBRA Report No 61.** CCFRA, Chipping Camden.

Cauvain, S.P. and L. Young. 2000. **Bakery Food Manufacture and Quality : Water Control and Effects.** Backwell Science Ltd., Oxford.

Cauvain, S.P. and Cyster, J. 1996. **Sponge Cake Technology.** Chipping Campden, U.K.

Charoenratanasisuk, L. 2004. **Development of Ready to Use High Protein and Fiber Bread Flour.** M.S. Thesis, Kasetsart University.

Chemicalland21. 2006. **Propylene Glycol Monostearate.** Available Source: http://chemicalland21.com/industrialchem/solalc/PROPYLENE%20GLYCOL%20MONOSTEARATE.htm, January 24, 2006.

Chen, A.C. 1994. Ingredient technology by the sugar cocrystallization. **Process Int. Sugar J.** 96: 493-495.

Chen, J.J., S. Lu and C.Y. Lii. 1999. Effect on the physicochemical characteristics by milling methods of waxy rice in Taiwan. **Cereal Chem.** 76: 796-799.

______, Y.L. Cheng and L. Shin. 2004. Relationship between grain physicochemical characteristic and flour particle size distribution for Taiwan rice cultivars. **J. Food Drug Analysis.** 12(1): 52-58.

Chen, Z., H.A. Schols and A.G. J. Voragen. 2003. Starch granule size strongly determines starch noodle processing and noodle quality. **J. Food Sci.** 68: 1584-1586.

______, H.A. Schols, A.G. J. Voragen, L. Sagis, A. Leggar and J.P.H. Linssen, 2003. Evaluation of starch noodle made from three typical Chinese sweet potato starch. **J. Food Sci.** 67(9): 3342-3347.

Chrastil, J. 1990a. Chemical and physicochemical changes of rice during storage at different temperatures. **J. Cereal Sci.** 11: 71-85.

Chrastil, J. 1990b. Protein-starch interaction in rice grains influence of storage on oryzenin and starch. **J. Agric. Food Chem.** 38: 1804-1809.

Chrastil, J. and Z.M. Zarins. 1992. Influence of storage on peptide subunit composition on rice oryzenin. **J. Agric. Food Chem.** 40: 927-930.

Chemblink. 2007. **Maltodextrin Identification.** Available source: http://www.chemblink.com/products/9050-36-6.htm, July 25, 2007.

Chumminkwan, P. 2006. **Product Development of Batter from Cassava Flour Hom Mali Rice Flour and Thao Yai Mom flour.** M.S. Thesis, Kasetsart University.

C.M.D. 2000. **Shelf-Life Evaluation of Foods.** 2nd ed. Aspen Publisher, Inc., USA.

Cochran, W.G. and G.M. Cox. 1957. **Experimental Designs.** 2nd ed. John Wiley & Sons Inc., New York.

Cramer, A.J., D.S. Mattinson, J.K. Fellman and B.K. Baik. 2005. Analysis of Volatile Compounds from Various Types of barley Cultivar. **J Agric. Food Chem.** 53: 7526 -7531.

Cruz, S., M.C. Matinez and G. Hough. 2002. Descriptive analysis, consumer clusters and preference mapping of commercial mayonnaise in Argentina. **J. Texture Studied.** 17: 309-325.

Daniel, Y.C. and F.M. Richard. 1991. **Instrumental Methods for Quality Assurance in Food.** Macle Dekker, Inc., USA.

Danisco. 2005. **Emulsifier : Datem.** Available source: http://www.danisco.com/cms/connect/corporate/products%20and%20services/product%20range/emulsifiers/datem/datem_en.htm., May 28, 2006.

David, A.V., B. Dendy and J. Dobraszczyk. 2002. **Cereal and Cereal Products Chemistry and Technology.** An ASPEN Publication, USA.

Debile, N., A.M. Laustsen., M. Mortens., R. Bro and J. DeBaerdemaeker. 2002. Use of physico-chemical methods for assessment of sensory changes in carrot texture and sweetness during cooking. **J. Texture Studied.** 33: 367-388.

Deis, R.C. 1997. Functional ingredients from rice. **Food Prod. Design.** 7: 46-56.

Delaney, C., T. Twomey and M.K. Keogh. 2004. Effect of powder properties and storage conditions on the flowability of milk powders with different fat contents. **J. Food Eng.** 64: 435-444.

Delwiche, S.R., K.S. McKenzie and B.D. Webb. 1996. Quality characteristics in rice by Near-Infrared reflectance analysis of whole-grain milled sample. **Cereal Chem.** 73: 415-420.

Dengele, H.N. 1984. Swelling pasting and gelling of wheat starch advance in cereals science and technology. **AACC.** 6: 49-82.

Department of Agriculture, Ministry of Agriculture and Cooperatives. 2001. **Standard of Thai Hom Mali Rice.** Department of Agriculture Press, Bangkok.

Department of Foreign Trade. 2007. **Thai Hom Mali Rice Standard.** Available Source: http://www.dft.moc.go.th/level4Frame.asp?sPage=the_files, August 14, 2007.

Devaux, M.F. and Monredon. 1998. Particle size distribution of breaking, sizing and middling wheat flour by laser diffraction. **J. Sci. Food Agric.** 78: 237-244.

Dhaliwal, Y.S., K.S. Sekhon and H.P.S. Nagi. 1991. Enzymatic activities and rheological properties of stored rice. **Cereal Chem.** 68: 8-21.

Dwyer, E. and E. Gallagher. 2001. **Functional ingredients as fat replacer in cakes and pastries.** Available Source: http//www. Teagasc.ie/researchreport/food processing/46004/eopr4604.htm, October 12, 2006.

Elaine,K. 1998. **Going with the grain.** Available source: http://www.foodproductdesign,com., October 15, 2005.

Eliasson, A. C. 2003. Utilization of thermal properties for understanding baking and staling processes, pp. 65-117. *In* G. Kaletunc and K. J. Breslauer, eds. **Characterization of Cereals and Flour.** Marcel Dekker Inc., New York.

FAO. 2007. **Guar Gum.** Available Source: http://www.fao.org/ag/agn/jecfa-additives/specs/monograph3/additive-495.pdf, October 16, 2007.

Fan, J. and B.P. Marks. 1999. Effects of rough rice storage conditions on gelatinization and retrogradation properties of rice flour. **Cereal Chem.** 76: 894-897.

Favoritebrandrececipes. 2006. **Cake.** Available source: http://www.favoritebrandrececipes.com/ECguide/ECGhtml/67120.htm., July 27, 2006.

Finney, P.L., J.E. Kinney and J.R. Donelson. 1988. Prediction of damaged starch in straight- grade flour by near-infrared reflectance analysis of whole ground wheat. **Cereal Chem.** 65(6): 449-459.

Fleiss, J.L. and B.S Everitt. 1971. Comparing the marginal totals of square contingency tables**. Brit. J. Math Statistic Psychol.** 24: 117-123.

Fleming, V. S. and K. Niels. 2004. Propylene glycol fatty acid ester, pp. 186-204. *In* J.W. Robert, ed. **Emulsifier in Food Technology**. Blackwell Publishing Ltd., Northampton.

Foyed. A. C. and L. Otten. 1984. **Handbook of Powder Science and Technology.** Van Nostrand Reinhold Company, New York.

Fredriksson, J., J. Silverio, R. Andersson, A.C. Eliasson and P. Aman. 1998. The influence of amylose and amylopectin characteristics on gelatinization and retrogradation properties of different starches. **Carbohydrate Polymer.** 35: 119-134.

French, D. 1984. Organization of starch granules. *In* Whistler, R.L., J.N. BeMiller, and E.F. Paschall, eds. **Starch: Chemistry and Technology.** Academic Press, Orlando.

Gacula, M.C. and J. Singh. 1984. **Statistical Methods in Food and Consumer Research.** Academic Press, Inc., New York.

Gallagher, E., T.R .Gormley and E.K. Arendt. 2003. Crust and crumb characteristics of gluten free breads. **J. Food Eng.** 56 (2/3): 153-161.

______. 2004. Recent advances in the formulation of gluten-free cereal-based products. **Trends in Food Sci Tech**. 15: 143-152.

Georage, C. 1992. **Off-Flavor in Rice and Rice Products in Off- Flavor in Foods and Beverages.** Elseverier Science Publishers, B.V., Netherlands.

Glenn, G.M. and R.M. Saunders. 1990. Physical and structural properties of wheat endosperm associated with grain texture. **Cereal Chem.** 67: 176-182.

Gopala Krishna, A.G. 2002. Nutritional components of rice bran oil in relation to processing. **Lipid Technology.** 14:80-84.

Gopala Krishna, A.G., K.V. Raghavendra, S. Khatoon, P.A. Prashanth and A. Pragasam. 2003. Unsaponificable matter and oxidative stability of commercially produced Indian rice bran oils. **J. Food Lipids**. 10(4): 329-344.

Grain, C.S., R.E. Miller, J.R. Donson and M.M. Bean. 1987. Optimizing grinder types and methods of expressing wheat meal particle size for wheat texture (hardness or softness) measurement and near-infrared reflectance spectroscopy. **Cereal Chem.** 64: 46-49.

Grant, L.A. 1998. Effect of starch isolation, drying, and grinding techniques on its gelatinization and retrogradation properties. **Cereal Chem.** 7: 590-594.

Gujral, H.S., C.M. Rosell and S. Singh. 2003. Effect of sodium lauryl sulphate on the texture of sponge cake. **Food Sci. Tech. Int.** 9(2): 89-93.

Gunasekaran, S. and M.M. Ak. 2000. Dynamic oscillatory shear testing of foods selected applications. **Trends in Food Sci. Tech**. 11: 115-127.

Halick, J. V. and V.J. Kelly. 1959. Gelatinization and pasting characteristics of rice varieties as related to cooking behavior. **Cereal Chem.** 36: 91-98.

Halick, J. V., H.M. Beachell., J.W. Stansel and H.H. Kramer. 1960. A note on the determination of gelatinization temperature on rice varieties. **Cereal Chem**. 37: 670-672.

Haruthaithanasan, V., P. Chompreeda and A. Soontrunnarudrungsri. 2002. Development of butter cake from Jasmine rice flour, pp.391-398. *In* **The Proceedings of 40 th Kasetsart University Annual Conference.** Kasetsart University, Bangkok.

Hamaker, B.R., F.J. Siebenmorgen and R.H. Dilday. 1993. Aging of rice in first six months after harvest. **Ark farm Res.** 42: 8-9.

______ and V.K. Griffin. 1990. Changing the viscoelastic properties of cooked rice through protein disruption. **Cereal Chem**. 67: 261-264.

Hatcher, D.W., M.J. Anderson., R.G. Desjardins., N.M. Edwards and J.E. Dexter. 2002. Effect of flour particle size and starch damaged on processing and quality of white salted noodles. **Cereal Chem.** 79: 64-71.

_______ and T. Naes. 1995. Selection of dry fermented lamb sausages for consumer testing. **Food Qual Prefer.** 6: 109-120.

Helgesen, H., R. Solheim. and T. Naes. 1997. Consumer preference mapping of dry fermented lamb sausages. **Food Qual. Preference.** 8(2): 97-109.

______. 1998. Consumer purchase probability of dry fermented lamb sausages. **Food Qual. Prefer.** 9: 295-301.

Hizukuri, S. T. Kaneko and Y. Takeda. 1983. Measurement of the chain length of amylopectin and its relevance to the origin of crystalline polymorphism of starch granules. **Biochimica Biophysica Acta.** 760: 188-191.

Houston, D.F. 1972. **Rice Chemical and Technology.** AACC, St Paul, Minnesota.

______, A. Mohammad., T., Wasserman and E.B. Kester. 1964. High protein rice flours. **Cereal Chem.** 14: 514.

Hoseney, R.C. 1998. **Principle of Cereal Science and Technology.** 2 nd ed. AACC. St Paul, Minnesota.

Huberty, C.J. 1994. **Applied Discriminant Analysis.** John Wiley & Sons, Inc., New York.

Hui, Y.H. 1992. **Encyclopedia of Food Science and Technology Vol 4.** John Wiley and Sons, Inc., New York .

______. 2007. **Handbook of Food Products Manufacturing Principles, Bakery, Beverages, Cereals, Cheese, Confectionary, Fats, Fruits, and Functional Foods.** A John Willey & Sons, Inc., Publication, New Jersey.

Hsu, S., S. Lu and C. Huang. 2000. Viscoelastic changes of rice starch suspensions during gelatinization. **J. Food Sci.** 65(2): 215-220.

Indudhara, Y.M., C.M. Swamy, K.R. Sowbhagya. and C. Bhalata. 1978. Change in physicochemical properties of rice with aging. **J. Sci. Food Agric.** 29: 627-639.

Intae, P. 2002**. Feasibility Study of Using RD6 Glutinous Rice in Developing Glutinous Rice Wine Production: and Comparative Study between Applying Yeast Cake and Selected Microorganism in Wine Production.** M.S. Thesis, Mahidol University.

IRRI. 2007. **The modern milling process.** Available Source:http://www.knowledgebank.irri.org/postproductioncourse/factsheetsNRefences/Milling/Modern%20Rice%20Milling.doc, October 2, 2007.

Issa, B. 2005. **Analysis of Variance (ANOVA).** Available source: http://www.sixsigmafirst.com/Statanova.htm., July 28, 2007.

Itoh, T., T. Tamura and T. Matsumoto. 1973. Sterol composition of 10 vegetable oils. **J American Oil Chem. Soc.** 50: 122-125.

Jenkin, H.L. and M.G. Adams. 1989. Progressive evaluation of skin irritancy of cosmetics using human volunteers. **International Journal of Cosmetic Science.** 11: 141-149.

Jenkins, P. J. and A.M. Donald. 1995. The influence of amylose on starch granule structure. **International Journal of Biological Macromolecules.** 17: 315-321.

Jenlike, A.W. 1964. Storage and flow of solids. **Bull. Eng. Ext. Station 123.** University of Utah, USA.

Jomduang, S. and S. Mohamed. 1994. Effect of amylose/amylopecctin content, milling methods, particle size, sugar, salt and oil on the puffed products characteristics of a traditional Thai rice-based snack food (Khao Krip Waue). **J. Sci. Food Agric.** 65: 85-93.

Jone, S. A. 1996. Classified list of fat replacer and their application, pp 275-397. *In* S. Roller and S.A. Jones, eds. **Handbook of Fat Replacers.** CRC Press, Baca Roton, USA.

Jones, G., J.M.C. Aughtrie and K. Cunningham. 1997. Sugar, pp 84-99. *In* A. Bent, ed. **The Technology of Cake Making.** Blackie Academic and Professional, London.

Juliano, B.O. 1979. The chemical basis of rice grain quality. *In* IRRI, ed. **Proceeding of the Workshop on Chemical Aspects of Rice Grain Quality**. Los Banos, Philippines.

_______. 1985. **Rice Chemistry and Technology.** AACC. St Paul, MN.

______. 1998. Varietal impact on rice quality. **Cereal Food World.** 43(4): 207-222.

Juliano, B.O., C.M. Perez., A.B. Blakeney., D.T. Castillo., N. Kongseree., B. Laignelet., E.T. Lapis., V.V.S. Murty., C.M. Paul and B.D. Webb. 1981. International cooperative testing on the amylose content of milled rice. **Starch/Starke.** 33: 157-162.

Juliano, B.O., C.M. Perez., S. Barber., A.B. Blakeney., T. Iwasaki., N. Shibuya., K.K. Kenerster., S.Chung., Laignelet and B. Launay. 1981. International cooperative comparison of instrument methods for cooked rice texture. **J. Texture Studies.** 12: 7–38.

Juliano, B.O., G.B. Cagampang and R.G. Santiago. 1964. Some physicochemical properties of rice in southeast Asia. **Cereal Chem.** 41: 275-286.

Jyuotsna, R., P. Prabhasankar., D. Indrani and V.G. 2004. Improvement of rheological and baking properties of cake batter with emulsifier gels. **J. Food Sci.** 69(1): 16-19.

Kaletunc, G., M.D. Normad., E.A. Johnson and M. Peleg. 1991. Degree of elasticity determination in solid foods. **J. Food Sci.** 56(4): 950-953.

Kamel, B.S. and C.E. Stauffer. 1993. **Advance in Baking Technology.** Blackie Academic & Professor, North America VCH Publishers, Inc., New York.

Kohlwey, D.E., J.H. Kendall and R.B. Mohindra. 1995. Using the physical properties of rice as a guide to formulation. **Cereal Foods World.** 40(10): 728-732.

Kongseree, N. 2002. **Rice Product.** Available Source: http://www.charpa.co.th/bulletin/rice_product.html., October 16, 2007.

Kunathum, T. 2003. **Effect of Particle Size and Damage Starch of Rice Flour on Properties of Rice Noodle.** M.S. Thesis, King Mongkut's University of Technology Thonburi.

Lacey, J. and N. Magan. 1991. Fungi in cereal grains: their occurrence, water and temperature relationships, pp 77-118. *In* J. Chelkowski, ed. **Cereal Grain Mycotoxins, Fungi and Quality in Drying and Storage.** Elservier, Amsterdam.

Lam, H.S. 2001. A Rapid Method for Milled Rice Surface Total Lipid Free Fatty Acid Determination. **Cereal Chem.** 78: 498-499.

Lawless, H.T. and B.P. Klein. 1991. **Sensory Science Theory and Applications in Foods.** Mercel Dekker, Inc., New York.

______ and H. Heymann. 1998. **Sensory Evaluation of Food: Principles and Practices.** Chapman & Hall/International Thomson Pub., New York.

Lindeboom, N., P.R. Chang and R. T. Tyler. 2004. Analytical, biochemical and physicochemical aspects of starch granule size, with emphasis on small granule starches: a review. **Starch/Starke.** 56: 89-99.

Line, B. 1984. The starch granule: organization and properties. **Bakers Digest.** 58: 16-21.

Liu, H. and J. Lelievre. 1992. Differential scanning calorimetric and rheological study of the gelatinization of starch granule embedded in gel matrix. **Cereal Chem.** 69(6): 597-599.

Loewer R. 1993. Role of ingredient in batter system. **Cereal Food World.** 38: 673-677.

Luh, B.S. 1991. **Rice Volume II. Utilization.** 2 nd ed. Van Nostrand Rieinhold Inc., New York.

Luh, B.S. and Y.K. Liu. 1980. Rice flour in baking, pp. 470-485. *In* B.S. Luh, ed. **Rice : Production and Utilization.** AVI, Westport.

Maga, J.A. 1984. Lysinoalanine in foods. **J. Agric. Food Chem.** 32: 955-964.

Mahatheeranont, S., S. Keawsa-ard and K. Dumri. 2001. Quantification of the rice aroma compound, 2-Acetyl-1-pyrroline, in uncooked Khao Dawk Mali 105 brown rice. **J. Agric. Food Chem.** 49(2): 773-779.

Manothum, C. 2006. **Product Development of Kanom Sali from Wheat flour and Fragrance Rice Flour.** M.S. Thesis, Kasetsart University.

Mao, Y. and R.A. Flores. 2001. Mechanical starch damage effects on wheat flour tortilla texture. **Cereal Chem.** 78(3): 286-293.

Marshall, W.E. 1992. Effect of degree of milling of brown rice and particle size of milled rice on starch gelatinization. **Cereal Chem.** 69(6): 632-636.

Marshall, W.E., F.L. Normand and W.R. Goynes. 1990. Effect of lipid and protein removal on starch gelatinization in whole grain milled rice. **Cereal Chem.** 67: 458-463.

McEwan, J.A. 1997. A comparative study of three product acceptability trials. **Food Qual. Prefer.** 9: 295-301.

______, P.J. Earthy and C. Ducher. 1998. **Preference Mapping: A Review No. 3, Project No. 29742.** Camder and Choleywood, Food Res., Assoc., Chipping, Campden, UK.

Meilgaard, M., G.V. Civill and B.T. Carr. 1999. **Sensory Evaluation Techniques**. 2nd ed. CRC Press., Boca Raton.

Meullenet, J.F., B.P. Marks, K. Griffin and M.J. Daniels. 1999. Effect of rough rice drying and storage condition on sensory profiles of cooked rice. **Cereal Chem.** 76(4): 483- 486.

______, J.A. Hankins, V.K. Griffin and M.J. Daniels. 2000. Sensory quality of cooked long- grain rice as affected by rough rice moisture content, storage temperature and storage duration. **Cereal Chem.** 77: 259-263.

Michael, E., S. David and N.A. Robinson. 2001. **Food Shelf Life Stability Chemical, Biochemical and Microbiological Change.** CRC Press LLC., USA.

Ministry of Commerce. 2007. **Thailand treading report**. Available Source: http://www.2.ops2.moc.go.th/export/recode_export/report.asp, August 21, 2007.

Mok, C. and J.W. Dick. 1991. Response of starch of different wheat classes to ball milling. **Cereal Chem.** 68: 409-412.

Moonsoor, M.A., and A. Proctor. 2003. Relative FFA formulation and lipid oxidation of commercially milled unseparated. head, and broken rice. **AOCS.** 80: 1183-1186.

_____. 2004. Volatile component analysis of commercially milled head and broken rice. **J. Food Sci.** 69: 623-636.

Moore, C.O., J.V. Tuschoff., C.W. Hastings and R.V. Schanefelt. 1984. Application of starches in foods, pp 577-590. *In* R.L. Whistler, J.N. BeMiller, and E. F. Paschall, eds. **Starch Chemistry and Technology.** Academic Press, New York.

Moore, M.M., M. Heinbockel., P. Dockery., H.M.Ulmer and E.K Arendt. 2006. Network formation in gluten-free bread with application of transglutaminase. **Cereal Chem.** 83(1): 28-36.

______, T.J. Schober., P. Dockery and E.K. Arendt. 2004. Texture comparisons of gluten-free and wheat-base dough, batter and breads. **Cereal Chem.** 81(5): 567-575.

Moritaka, S and K. Yasumatsu. 1972. Studied on cereals and the effects of sulfhydryl groups on storage deterioration. *In* Z. Zhou., K. Robards., S. Helliwell and C. Blanchard, eds. Aging of storage rice : change in chemical and physical attributes. **J. Cereal Sci.** 35: 65-78.

Morrison, W.R., R.F. Tester., C.E. Snape., R.V. Law and M.J. Gidley. 1993. Swelling and gelatinization of cereal starches IV some effects of lipid-complexed amylose and free amylose in waxy and normal barley starches. **Cereal Chem.** 70: 385-391.

Moskowitz, H. R., J. H. Beckley., and A.V.A. Resurreccion. 2006. **Sensory and Consumer Research in Food Product Design and Development.** Blackwell Publishing Professional IFT Press, Iowa.

Mukprasirt A., T.J. Herald and R.A. Floris. 2000. Rheology characterization of rice–floor–based. **Batter.** 65(7): 1183-1186.

Multon, J.L., H. Bizot and B. Savet. 1980. Water absorption in cereal foods and water activities measurement, pp 100-120. *In*. G.B. Inglertt and L. Munch, eds. **Cereal for Food and Beverage.** Acadamic Press, New York.

Murray, J.A. 1999. The widening spectrum of celiac disease. **American J. Clinical Nutri.** 69: 354-365.

Naivikul, O. 2004. **Rice : Science and Technology.** Kasetsart University, Bangkok.

Nicolaas, M.F., J. Mojet and A.A.M. Poleman. 2003. Simple improvement of consumer fit in external preference mapping. **Food Qual. Preference.** 14: 455-461.

Nickols, F.W. 1997. Concerning performance and performance standards: An opinion. **NSPI Journal.** 16(1):14-17.

Nishita, K.D. and M.M, Bean. 1979. Physicochemical properties of rice in relation to rice bread. **Cereal Chem.** 56: 185-189.

______. 1982. Grinding methods: the impact on rice flour properties. **Cereal Chem.** 59(1): 46-49.

Noomhorm, A., N. Kongseree and M. Apintanapong. 1997. Effect of aging on the quality of glutinous rice cracker. **Cereal Chem.** 74: 12-15.

Nonaka, H. 1997. Plant carbohydrate-derived products as fat replacers and calorie reducer. **Cereal Food Word.** 42(5): 377-378.

Nukit, N. 2006. **Development of Reduce Calories and Reduce Sugar Butter Cake from Brown Rice Flour Jasmine 105 Variety.** M.S. Thesis, Kasetsart University.

Nukit, N., P. Chompreeda, T. Suwonsichon and V. Haruthaithanasan. 2006. Acceptability test of no sugar added butter cake from brown rice flour, pp.405-412. *In* **The Proceedings of 44 th Kasetsart University Annual Conference.** Kasetsart University, Bangkok.

Oh, N.H., P.A. Seib., A.B. Ward and C.W. Deyoe. 1985. Noodles, influence of flour protein, extraction rate, particle size, and starch damage on the quality characteristics of dry noodles. **Cereal Chem.** 62: 441-446.

Okabe, M. 1979. Texture measurement of cooked rice and its relationship to the eating quality. **J. Texture Study.** 10: 131-152.

Onwulata, C. 2005. **Encapsulation and Powdered Foods.** CRC Press Book.

Painter, K.A. 1981. **Emulsifier and their physicochemical properties. J. Amer. Oil Chem. Soc.** 58: 92.

Panya, P. 2001. **Development of Bread from Wheat-Fragrance Rice Composite Flour.** M.S. Thesis. Kasetsart University.

Park, K.H. 1976. **Elucidation of Extrusion Puffing Process.** Ph.D. Thesis. University of Illinois Urbana.

Patrick, O. H., K. Hassapidis., A. Coder., H. Helsing and G. Pokrajac. 2005. Particle analysis of food powder, pp 215-245. *In*, C. Onwulata, ed. **Encapsulated and Powdered Food.** CRR Taylor & Francis Press, USA.

Paule, C.M. and J. Power. 1989. Sensory and chemical examination of aromatic and nonaromatic rices. **J. Food Sci.** 54: 343-347.

Pavon, N.R. 2003. **Sensory Characteristics of Flavored Milk Candies.** M.S. Thesis, Louisiana State University.

Peleg, M. 1977. Flowability of food powders and methods for its evaluation. **J. Food Process Eng.** 1: 303-328.

Perce, M.D., B.P. Marks and J.F. Meullenet. 2001. Effect of post harvest parameter on functional change during rough rice storage. **Cereal Chem.** 78: 354-357.

Perdon, A.A., B.P. Marks, T.J. Siebenmorgen and N.B. Reid. 1997. Effect of rough rice storage condition on the amylograph and cooking properties of medium-grain rice c.v. Bengal. **Cereal Chem.** 74: 864-867.

Peryam, D.R. and F.J. Pilgrim. 1957. Hedonic scale method of measuring food preferences. **Food Tech.** 11(9): 9-14.

Petchmak, P., P. Chompreeda., V. Haruthaithanasa., K. Sriroth and C. Changchenkit. 2004. Development of reduced calories butter cake from cassava flour KU-50 variety, pp.582-589. *In* **The Proceedings of 42nd Kasetsart University Annual Conference.** Kasetsart University, Bangkok.

Pihlsgard, P., M. Larssion., A. Leufven and H. Lingnert. 1999. Chemical and sensory properties of liquid beet sugar. **J. Agric. Food Chem.** 47: 4346-4352.

Pitt, J.I. and A.D. Hocking. 1985. **Fungi and Food Spoilage.** Academic Press, Australia.

Piyachomkwan, K., P. Chatakanoda, R. Wansuksri and K. Sriroth. 2004. Grain quality index for evaluating the textural properties of cooked rice, pp 235-244. *In* P.Tomasik, V.P. Yoryev,. and E. Bertoft, eds. **Starch Progress in Structural Studies, Modification and Applications**. Polish society of food technologists, Poland.

Pomeranz, Y. 1992. Biochemical, functional, and nutritive changes during storage. *In* D.B. Sauer, ed. **Storage of Cereal Grains and their Products.** AACC, St Paul, MN.

Podmore, J and K.K. Rajah. 1997. Baking fats, pp 25-49. *In* A. Bent, ed. **The Technology of Cake Baking.** Blackie Academic and Professional, London.

Qiu, M.F., T.C. Jin and R.F. Zhou. 1998. The change of oryzenin and starch components during rice aging process. **The Chinese Cereal and Oil Assoc.** 13(1): 12-15.

Rajendra, K, A.S. Zakiuddin. 1991. Properties of rice starch from paddy stored in cold and at room temperature. **Starch/Starke.** 43: 165-168.

Ranhotra, G.S., J.A. Gelroth, G.R. Eisenbraun. 1993. Correlation between chopin and AACC methods of determining damaged starch. **Cereal Chem.** 70 : 235-236.

Rao, M.A. 1999. **Rheology of Fluid and Semisolid Foods. Principles and Application.** An ASPEN Publication, Maryland.

______ and R.C. Anantheswaran. 1982. Rheology of fluids in food processing. **Food Tech.** 36(6): 116-126.

Ravi, R., R.S. Manohar, and P.H. Roa. 1999. Use of Rapid Visco Analyzer(RVA) for measuring the pasting characteristics of wheat flour as influenced by additives. **J. Sci. Food Agric.** 79: 1571-1576.

Resurreccion, A.V.A. 1998. **Consumer Sensory Testing for Product Development.** Aspen Publishers, Inc., Gaithersburg.

Rice Research Institutes. 2004. **The Tale of Thai Rice.** Department of Agriculture, Bangkok.

Rico. 2006. **What is rice bran oil.** Available source: http://www.ricebranoil.info/, July 25,2007.

Riken, V. 2000. **Emulsifier**. Available source: http://www.rikenvitamin.jp., July 25, 2007.

Ring, S.G., Colonna, P., Anson, K.J., Kalichevsky, M.T., Miles, M.J., Morris, V.J. and Orford, P.D. 1987. The gelation and crystallization of amylopectin. **Carbohydrate. Res.** 162: 277-293.

Robert, J. W. 2004. **Emulsifiers in Food Technology.** Blackwell Publishing, Northampton.

Rolf, G. and A. Walfgang. 2004. DATEM and associated emulsifier in breadmaking, pp.86-109. *In* J. W. Robert, ed. **Emulsifier in Food Technology.** Blackwell publishing Ltd., Northampton.

Roller, S. and S.A. Jones. 1996. **Handbook of Fat Replacers.** CRC Press, Baca Roton, USA.

Rousset, S and J. Martin. 2001. An effective hedonic analysis tool: weak/strong points. **J. Sensory Studied.** 16: 643-661.

Russel, P.L. and B.O. Juliano. 1983. Differential scanning calorimetry of rice starches. **Starch/Starke.** 31: 382-386.

Sae-Eaw, A., P. Chompreeda., W.Prinyawiwatkul., V. Haruthaithanasan., T. Suwonsichol., J.E. Saidul and Z. Xu. 2007. Acceptance and purchase intent of US consumers for nonwheat rice butter cakes. **J. Food Sci.** 72(2): S92-S97.

SAS Inst. 2003. **SAS/STAT user's guide. Ver. 9.1.3.** Cary, N.C.:SAS Inst.

Sahlstrom, S., P. Brathen and K. Autiot. 1998. Influence of starch granule size distribution on bread characteristics. **J. Cereal Sci.** 28: 157-164.

Sammel, A. 1992. **Bakery Technology and Engineering.** 3 rd ed. AVI book Van Nostrand Reinhold., New York.

Samutkrut, N. 2003. **Development of Frozen Doughnut using Fragrance Rice Flour to Substitute Wheat Flour Topping with Pizza Sauce.** M.S. Thesis, Kasetsart University.

Sarabjit, S.S. and M.A. Juan. 2003. Functionality of emulsifiers in sponge cake production. **J. Sci. Food Agric.** 83: 1419-1429.

Sarkarung, S., B. Ronrith, and C. Chitrakorn. 2000. Aromatic rice of Thailand, pp 180-183. *In* R.K. Singh, U.S. Singh, and G.S. Khusy, eds. **Aromatic Rices.** Oxford and IBH Publishing Co. Pvt, Ltd., India.

Schober, T.J., C.M.O.Brien., D. McCarthy., A. Darnedde and E.K. Arendt. 2003. Influence of gluten-free flour mixes and fat powders on the quality of gluten-free biscuits. **European Food Res. Tech.** 216: 369-376.

Schoch, T.J. and E.C. Maywald. 1956. Microscopic examination of modified starches. **Analytical Chem.** 28: 382-387.

Scudamore, K.A., and M.T. Hetmanski. 1995. Natural occurrence of mycotoxins and mycotoxigenic fungi in cereals in the United Kingdom. **Food Additives and Contaminants.** 12: 377-382.

Seetharamaiah, G.S. and J.V. Prabhakar. 1986. Oryzanol content of Indian rice bran oil and its extraction from soapstock. **J. Food Sci .Tech.** 23: 270-274.

Shan, L., O. Molberg., I. Parrot., F. Hausch., F. Filiz., G.M. Gray., L.M. Solid and C. Khosla. 2002. Structural basis for gluten intolerance in celiac spruce. **Science.** 297: 2257-2279.

Sharma, S. 1996. **Applied Multivariate Techniques**. John Wiley & Son Inc., University of South Carolina.

Shaw, R. 1996. **Product Development Guide for the Food industry.** Gloucestershire: Campden & Chorleywood Food Research Association.

Shih, F. and K. Daigle. 2002. Preparation and characterization of low oil uptake rice cake donuts. **Cereal Chem.** 79(5): 745-748.

Shubert, H. 1987. Food particle technology part I, properties of particles and particulate food systems. **J. Food Eng.** 6: 1-32.

Siamvara, A. 1990. **Rice Knowledge**. Thailand Development Research Institute, Bangkok.

Singh, R.K., U.S. Singh and G.S. Khusy. 2000. **Aromatic Rices**. Oxford and IBH Publishing Co. Pvt, Ltd., India.

Sivaramakrishnan, H.P., B. Senge and P.K. Chattopadhyay. 2004. Rheological properties of rice dough for making rice bread. **J. Food Eng.** 62(1): 37-45.

Siwapornluk, P., S. Potchamachai, and J. Kongkiattikajorn. 2005. Physicalchemical properties of aged milled rice starch, pp 243-246. *In* **The 3 rd Conference on Starch Technology.** Bangkok, Thailand.

Smith, R.J. 1964. Viscosity of starch paste. *In* Whistler, R.L., R.J. Smith., J.N. BeMiller and M.L. Wolform, eds. **Carbohydrate Chemistry Volume 4: Starch Section 3: Physical Analyses.** Academic Press, New York.

Soler L. 2005. **Development of Non-Dairy Frozen Dessert Containing Soy Protein and Coconut Milk.** M.S. Thesis, Louisiana State University.

Sonthornrangsri, A. 2002. **Development of Butter Cake from Fragrance Rice.** M.S. Thesis, Kasetsart University.

Sowbhagya, C. M. and K.R. Bhattacharya. 2001. Change in pasting behavior of rice during aging. **J. Cereal Sci.** 34: 115-124.

Stanley, C. and L. Young. 2006. **Baked Products Science, Technology and Practice.** Blackwell Publishing Ltd., Northampton.

Stauffer, C.E. 1990. **Functional Additives for Bakery Foods.** An AVI Book, New York.

Steffe, J.F. 1996. **Rheological Methods in Food Process Engineering.** Freeman Press., USA.

Stolovitch, H.D. and E. J. Keeps. 1992. **Handbook of Human Performance Technology: a Comprehensive Guide for Analyzing and Solving Performance Problem in Organizations.** Jossey-Bass Publishers, Sanfrancisco.

Stone, H. and Sidel J.L. 1993. **Sensory Evaluation Practices.** 2 rd ed. Academic Press, San Diego.

Strait, M. J. 1997. **The Effect of Liquid or Dry Honey as a Partial Replacement for Sugar on the Baking and Keeping Qualities of Fat Reduced Muffins.** M.S. Thesis. Virginia Polytechnic Institute and State University.

Sugano, M and E. Tsuji. 1997. Rice bran oil and cholesterol metabolism **J. Nutrition**. 127(3): 521S-524S.

Suwansri, S. and J.F. Meullenet. 2004. Physicochemical characterization and consumer acceptance by Asia consumer of aromatic Jasmine rice. **J. Food Sci.** 69(1): 30-37.

Swain, M. J., A. Spinassou and M.V.L. Swain. 2007. A test procedure to characterise the heating performance of domestic microwave ovens. **International Journal of Food Science and Technology.**

Takano, K. 1989. Studies on the mechanism of lipid-hydrolysing in rice bran. **J. Japanese Soc. Food Sci. Tech.** 36: 519-524.

Tamaki, M., T. Tashiro., M. Ishiwawa and M. Ebata. 1993. Physicological studied on quality formation of rice kernel. IV effect of storage on eating quality of rice. **Japanese J. Crop Sci.** 62: 540-546.

Tanaka, Y., A.P. Resurreccion., B.O. Juliano and D.B. Bechtel. 1978. Properties of whole and undigested fraction of protein bodies of milled rice. **Agricultural and biological Chem.** 42: 2015-2023.

Tang, H., H. Ando., K. Watanabe., Y. Takeda and T. Issunaga. 2000. Some physicochemical properties of small-,medium-, and large-granule starches in fractions of waxy barley grain. **Cereal Chem.** 77: 22-31.

Teo, C.H., A.b.d. Karim., P.B. Cheah., M.H. Norziah and C.C. Seow. 2000. The role of protein and starch in the aging of non-waxy rice flour. **J. Food Chem.** 69: 229-236.

Tester, R.F. and W.R. Morrison. 1990. Swelling and gelatinization of cereal starches I. effects of amylopectin, amylose and lipids. **Cereal Chem.** 67: 551-557.

Thacker, D. 1997. Chemical aeration, pp 100-106. *In* Bent, A. ed. **The Technology of Cake Making.** Blackie Academic and Professional, London.

Thai Industrial Standard. 1987. **Standard for Rice Flour.** Ministry of Industrial, Bangkok.

Thairicefoundation. 2007. **Rice Consumption.** Available Source: http://www.thairice.org/eng/aboutRice/rice_consumption.htm, October 12, 2006.

Thomas, D.I. and W.A. Atwell. 1999. **Starches: Practical Guide for the Food Industry.** Eagon Press, Minnesota.

Tipkanon, S. 2001. **Development of Mantou Product from Composite Wheat Flour and Rice Flour.** M.S. Thesis, Kasetsart University.

Tipkanon, S., P. Chompreeda and V. Haruthaithanasan. 2001. Development of Montou product from **composite wheat flour and rice flour**, pp.429-436. *In* **The Proceedings of 40 th Kasetsart University Annual Conference.** Kasetsart University, Bangkok.

Tobias, R.D. 1997. **An Introduction to Partial Least Squares Regression.** SAS Institute, Cary, NC.

Toonsakool, K. 2006. **Development of Nutrinious Muffin Product for Breakfast from Brown Rice Flour.** M.S. Thesis, Kasetsart University.

Townsand, G.M. 2000. Cookie, cakes, and other flour confectionery, pp 428-429. *In* A. David., V. Dendy and J.D. Bogdan, eds. **Cereal and Cereal Products.** AN ASPEN Publication, USA.

Tran, T. U., K. Suzuki., H. Okdome., H. Ikezaki., S. Homma and K. Ohtsubo. 2005. Detection of changes in taste of japonica and indica brown and milled rice (*Oryza Sativa* L.) during storage using physicochemical analyses and taste sensing system. **J. Agric. Food Chem.** 53(4): 1108-1118.

Tsai, M.L., C.F. Li and C.Y. Lii. 1997. Effect of granular structures on the pasting behaviors of starch. **Cereal Chem.** 74: 750-757.

Tsugita, K.T., T. Ohta and H. Kato. 1983. Cooking flavor and texture of rice stored under different condition. **Agric. Biol. Chem.** 47: 543-549.

Uraiwan, T. and Thomas, C.Y. 1991. An Improved method for Quantification of 2-Acetyl-1-Pyrroline in Aromatic Rice by High-Resolution Gas Chromatography/mass Spectrometry/Selection Iron Monitoring. **J. Agric. Food Chem.** 39: 944-947.

Vidal, A.J. and B.O Juliano. 1967. Comparative composition of waxy and nonwaxy rice. **Cereal Chem.** 44: 86-91.

Villareal, R.M., A.P. Resurreccion., L.B. Suzuki and B.O. Juliano. 1976. Changes in physicochemical properties of rice during storage. **Starch/Starke.** 28: 88-94.

Wang, C.R. and H.C. Yung. 1997. Effect of particle size and thermal characteristic of rice flour on physical properties. **J. Food Sci. Taiwan.** 24(3): 319-330.

Wang, L. and R. A. Flores. 2000. Effect of flour particle size on the textural properties of flour tortillas. **J. Cereal Sci.** 31: 263-272.

Wang, S.S., W.C. Chiang., B.L. Zhao. X.Z. Zheng and I.H. Kim. 1991. Experimental and analysis and computer simulation of starch-water interaction during phase transition. **J. Food Sci.** 56(1): 121-124.

Wiset, L., S. Potchamachai. and J. Kongkiattikajorn. 2005. Physical and pasting properties of brow rice starch during storage, pp 235-238. *In* **The 3 rd Conference on Starch Technology.** Bangkok.

Xu, Z. and J.S. Godber. 1999. Purification and identification of components of γ-oryzanol in rice bran oil. **J. Agric. Food Chem.** 47: 521S-524S.

Yackinous, C., C. Wee and J.X. Gusinard. 1999. Internal preference mapping of hedonic ratings for the Ranch salad dressing varying in fat and garlic flavor. **Food Qual. Preference.** 10: 401-409.

Yamasaki, W.T. and Donsion. 1972. The relationship between flour particle size and cake volume potential among eastern soft wheat. **Cereal Chem.** 49: 649.

Yang, C.C, H.M. Lai and C.Y. Lii. 1984. The modified alkaline steeping method for the isolate of rice starch. **J. Food Sci.** 11 : 158-162.

Yang, X. and T. Peppard. 1994. Solid phase microextraction for flavor analysis. **J. Agric. Food Chem.** 42: 1925-1930.

Yoenyongbudhagal, S. and A. Noomhorm. 2002. Effect of raw material preparation on rice vermicelli quality. **Starch/Starke.** 54: 534-539.

Yodkansri, C. 2007. **Development of Reduced Cholesterol and Sugar of Chiffon Cake from Fragrance Rice Flour.** M.S. Thesis, Kasetsart University.

Yoshihashi, T. 2002. Quantitative analysis of 2-Acetyl-1-Pyrroline of an aromatic rice by stable isotope dilution method and model studies on its formation during cooking. **J. Food Sci.** 67: 619-622.

Yoshihashi, T., T.T.H. Nguyen and N, Kabaki. 2004**. Area dependency of 2-Acethyl-1-pyrroline content in an aromatic rice variety, Khao Dawk Mali 105.** Available Source: http//www. Jircas.affrc.go.jp, October 12, 2006.

Zhou, S.Q. and S.Y. Guo. 1995. Aging mechanism of rice and their manipulation. **Grain Storage.** 24(2): 18-31.

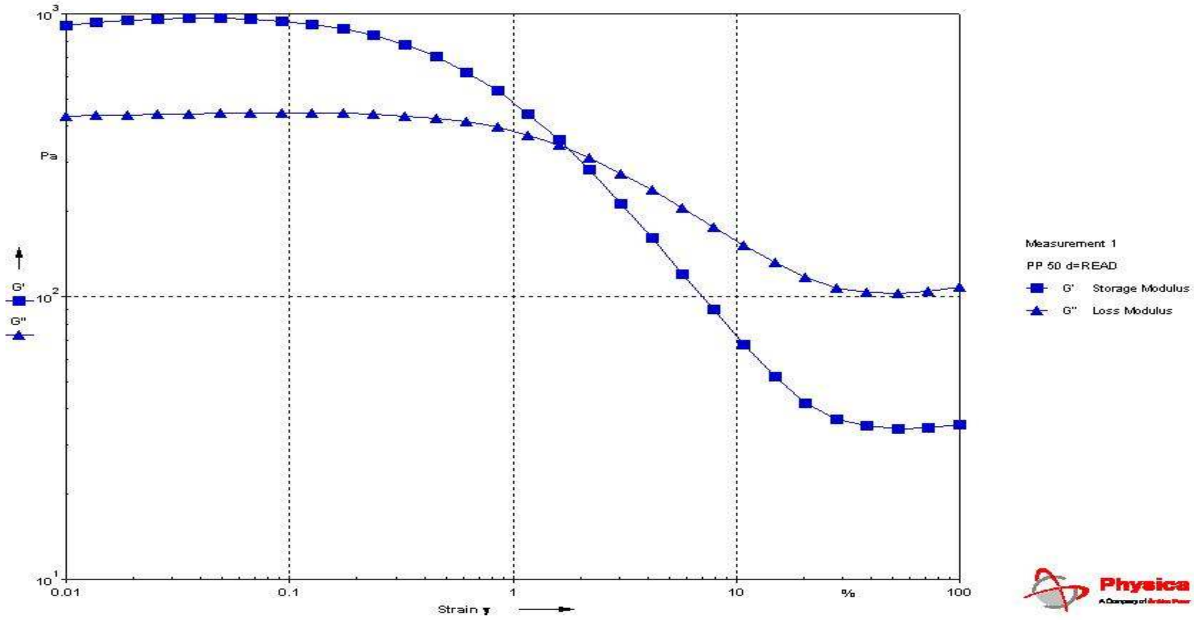
Zhou, Z., K. Robards., S. Helliwell. and C. Blanchard. 2002. Aging of storage rice : changes in chemical and physical attributes. **J. Cereal Sci.** 35: 65-78.

Zobel, H.F. 1964. X-ray analysis of starch granules, pp 109-113. *In* R.L. Whistler, ed. **Method in Carbohydrate Chemistry.** Academic Press, New York.

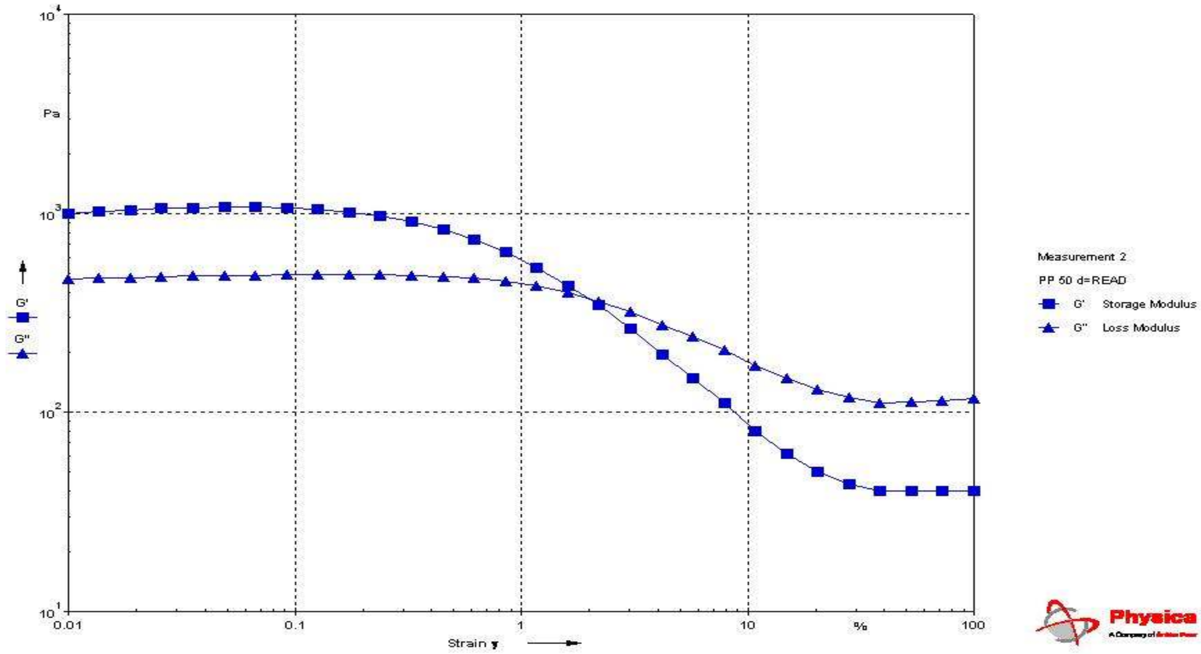
APPENDICES

Appendix A

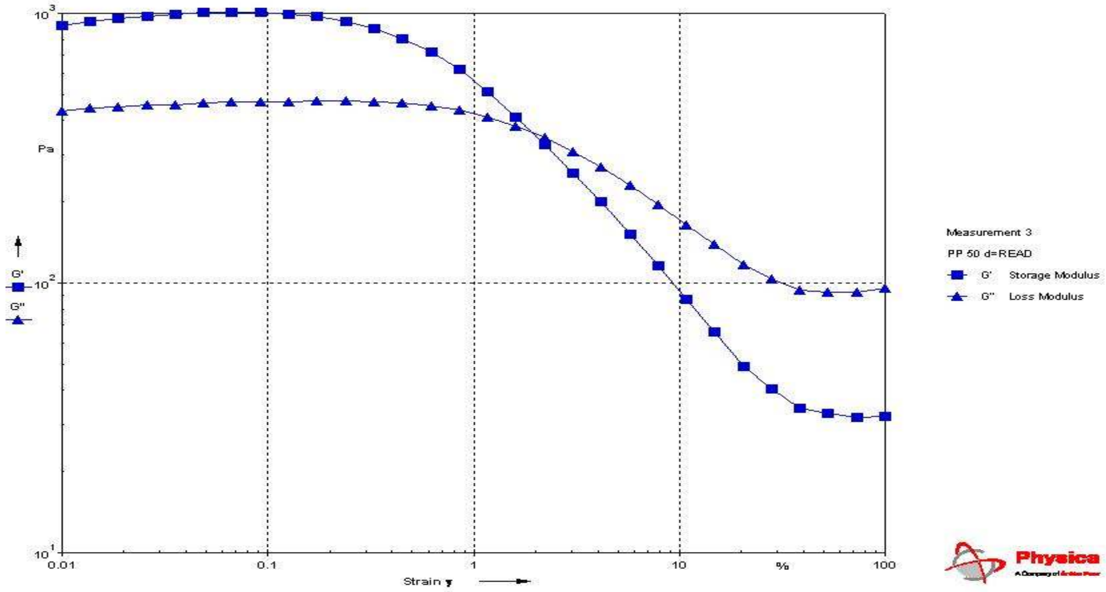
Amplitude sweep test and frequency sweep test



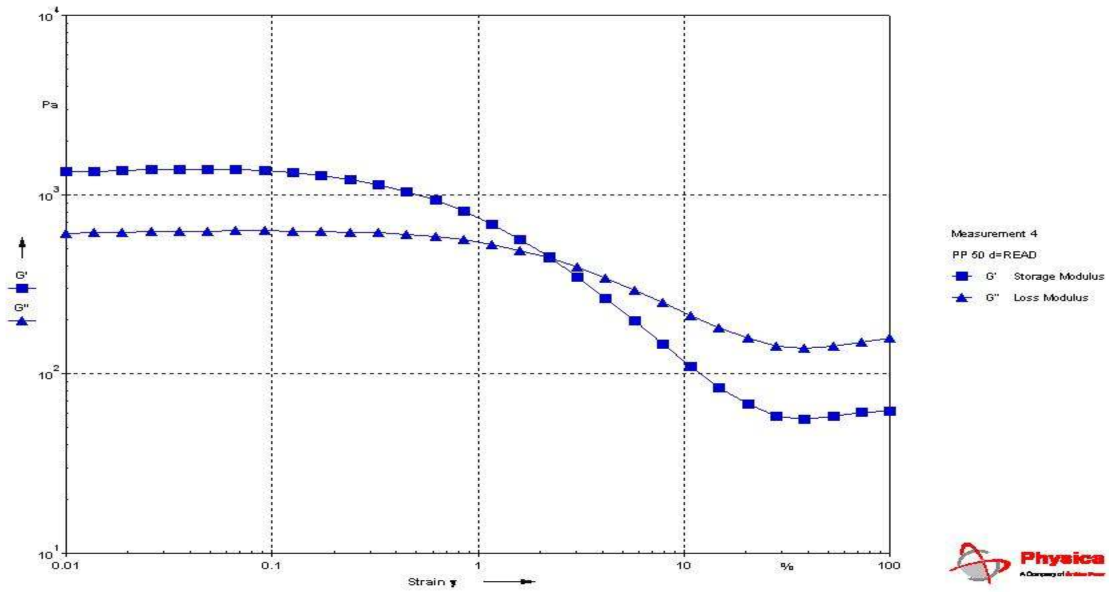
Appendix Figure A1 Amplitude sweep test of rice batter cake from rice flour with <80 mesh (Frequency at 10 rad/s, Strain 0.01 – 100 %)



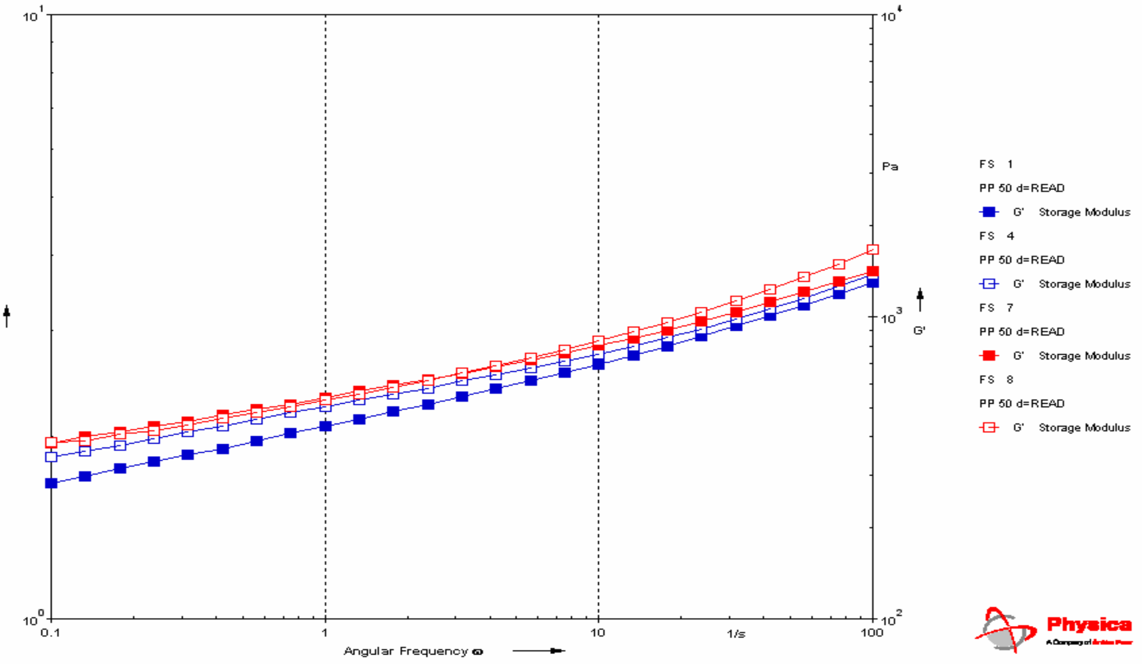
Appendix Figure A2 Amplitude sweep test of rice batter cake from rice flour with <100 mesh (Frequency at 10 rad/s, Strain 0.01 – 100 %)



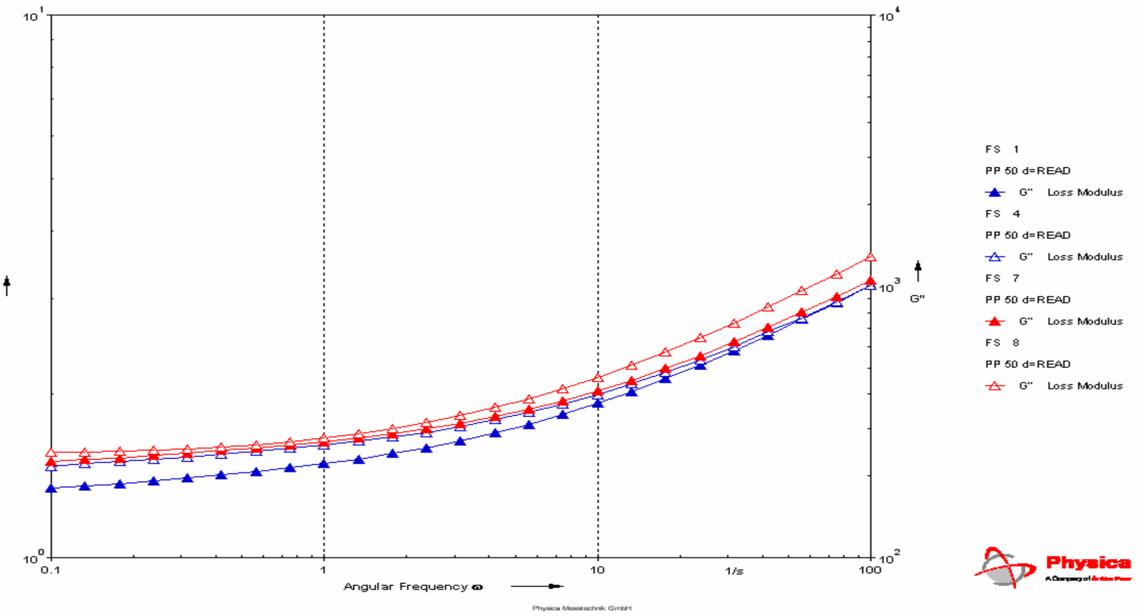
Appendix Figure A3 Amplitude sweep test of rice batter cake from rice flour with <120 mesh (Frequency at 10 rad/s, Strain 0.01 – 100 %)



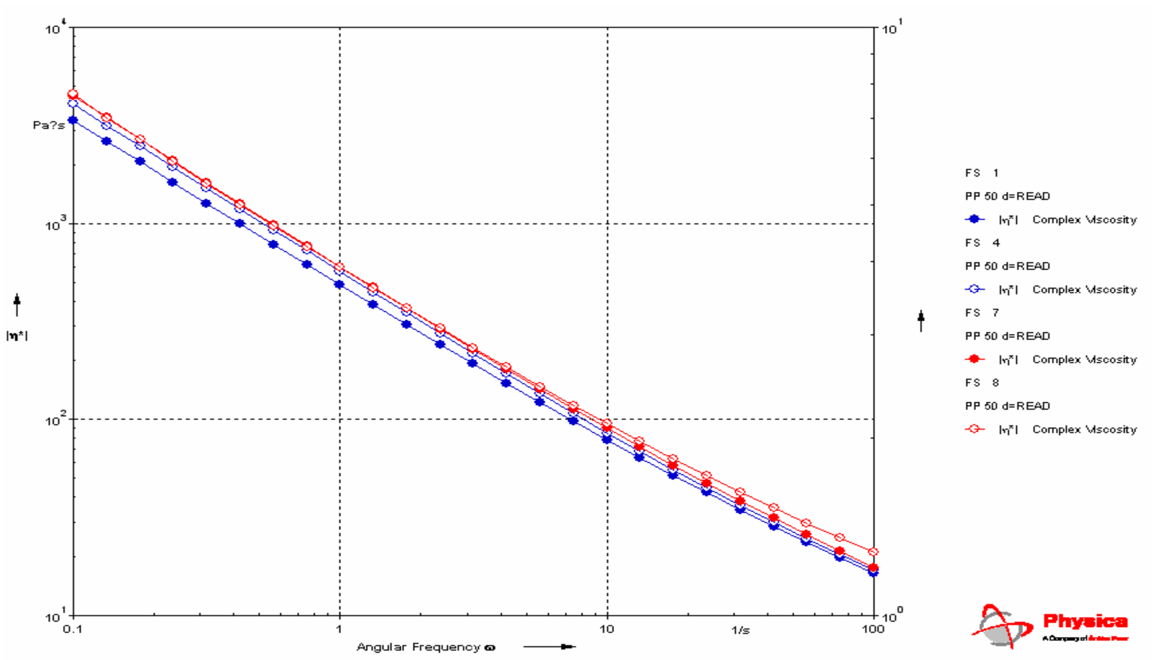
Appendix Figure A4 Amplitude sweep test of rice batter cake from rice flour with <150 mesh (Frequency at 10 rad/s, Strain 0.01 – 100 %)



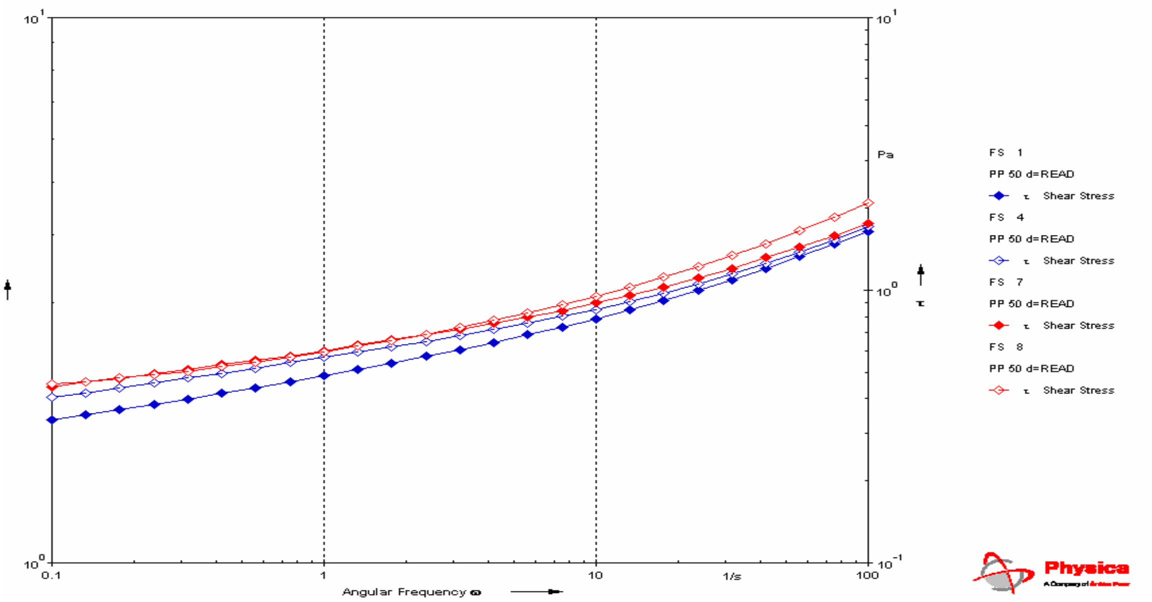
Appendix Figure A5 Frequency sweep test (Storage Modulus G′) of cake batter for all flour particle sizes



Appendix Figure A6 Frequency sweep test (Loss Modulus G″) of cake batter for all flour particle sizes



Appendix Figure A7 Frequency sweep test (Complex Viscosity) of cake batter for all flour particle sizes



Appendix Figure A8 Frequency sweep test (Shear Stress) of cake batter for all flour particle sizes

Appendix B

Questionnaires

Questionnaire for Thai consumer (flour particle size)

Questionnaire

Consumer acceptance on rice butter cake

1. Gender ( ) Male 2. Age ( ) 17-21 year ( ) 22-26 years

( ) Female ( ) 27-31 years ( ) over 31 years

3. Please evaluate sample by rating on each product attribute and evaluating the product acceptance and purchase intent on rice butter cake (9-points hedonic scale : score 1-9)

1 = Dislike extremely 2 = Dislike very much 3 = Dislike moderately
4 = Dislike slightly 5 = Neither like nor dislike 6 = Like slightly
7 = Like moderately 8 = Like very much 9 = Like extremely

3.1 Attributes	Score			
	Sample A	Sample B	Sample C	Sample D
1) Overall appearance				
2) Crumb color				
3) Overall cake aroma				
4) Butter aroma				
5) Softness				
6) Taste				
7) Overall liking				
3.2.Product acceptance	( ) Yes ( ) No	( ) Yes ( ) No	( ) Yes ( ) No	( ) Yes ( ) No
3.3 Purchase intent	( ) Yes ( ) No	( ) Yes ( ) No	( ) Yes ( ) No	( ) Yes ( ) No

Questionnaire for Thai consumer (flour particle size and storage time)

Questionnaire

Consumer acceptance on rice butter cake

1. Gender ( ) Male 2. Age ( ) 17-21 year ( ) 22-26 years

( ) Female ( ) 27-31 years ( ) over 31 years

3. Please evaluate sample by rating on each product attribute and evaluating the product acceptance and purchase intent on rice butter cake (9-points hedonic scale : score 1-9)

1 = Dislike extremely 2 = Dislike very much 3 = Dislike moderately
4 = Dislike slightly 5 = Neither like nor dislike 6 = Like slightly
7 = Like moderately 8 = Like very much 9 = Like extremely

3.1 Attributes	Score			
	Sample A	Sample B	Sample C	Sample D
1) Overall cake aroma				
2) Softness				
3) Taste				
4) Overall liking				
3.2.Product acceptance	( ) Yes ( ) No	( ) Yes ( ) No	( ) Yes ( ) No	( ) Yes ( ) No

Questionnaire for US consumers

Research Consent Form

I, ______________________, agree to participate in the research entitled "Consumer Acceptance of Rice Butter Cake" which is being conducted by Dr. Witoon Prinyawiwatkul of the Department of Food Science at Louisiana State University, phone number (225)578-5188.

I understand that participation is entirely voluntary and whether or not I participate will not affect how I am treated on my job. I can withdraw my consent at any time without penalty or loss of benefits to which I am otherwise entitled and have the results of the participation returned to me, removed from the experimental records, or destroyed. Four hundred consumers will participate in this research. For this particular research, about 20 minute participation will be required for each consumer.

The following points have been explained to me:

1. In any case, it is my responsibility to report prior participation to the investigator any allergies I may have.
2. The reason for the research is to gather information on consumer sensory acceptability of rice butter cake. The benefit that I may expect from it is a satisfaction that I have contributed to improving the quality of rice-base cake.
3. The procedures are as follows: Four coded samples will be placed in front of me, and I will evaluate them by normal standard methods and indicate my evaluation on score sheets. All procedures are standard methods as published by the American Society for Testing and Materials and the Sensory Evaluation Division of the Institute of Food Technologists.
4. Participation entails minimal to no risk: The only risk which can be envisioned is that of an allergic reaction to rice flour, maltrodextrin, sugar, magarine, eggs, milk and commonly used ingredients. However, because it is known to me beforehand that the food to be tested contains common food ingredients, the situation can normally be avoided.
5. The results of this study will not be released in any individual identifiable form without my prior consent unless required by law.
6. The investigator will answer any further questions about the research, either now or during the course of the project.

The study has been discussed with me, and all of my questions have been answered. I understand that additional questions regarding the study should be directed to the investigator listed above. In addition, I understand the research at Louisiana State University AgCenter that involves human participation is carried out under the oversight of the Institutional Review Board. Questions or problems regarding these activities should be addressed to Dr. David Morrison, Associate Vice Chancellor of LSU AgCenter at 578-8236.

_____________________________   _______________________

Signature of Investigator   Signature of Participant

Witness: ____________________   Date: ______________________________

Sample______

1. Gender: **( ) Male ( ) Female**

2. How would you rate the **OVERALL APPEARANCE** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

3. How would you rate the **VISUAL PUFFINESS** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

4. How would you rate the **CRUMB COLOR** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

5. How would you rate the **ODOR or AROMA** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

6. Do you detect any **' RICE AROMA'** of this product? **( ) Yes ( ) No**

7. How would you rate the **SOFTNESS** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

8. Please rate the **SOFTNESS** of this product base on your preference?

( ) Not soft enough ( ) Just about right ( ) Too soft

9. How would you rate the **MOISTNESS** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

10. Please rate the **MOISTNESS** of this product base on your preference?

( ) Not moist enough ( ) Just about right ( ) Too moist

11. How would you rate the **OVERALL TEXTURE/MOUTHFELL** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

12. How would you rate the **TASTE** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

13. Is the texture of this product "**SANDY"**?

( ) **NO ( ) YES → IF YES:** ( ) **ACCEPTABLE** ( ) **NOT ACCEPTABLE**

14. How would you rate **OVERALL LIKING** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

15. Is this product **ACCEPTABLE**?

( ) YES ( ) NO

16. Would you **BUY** this product if it were commercially available?

( )YES ( ) NO

Questionnaire for US consumers (cake mixed storage)

Research Consent Form

I, ____________________, agree to participate in the research entitled "Consumer Acceptance of Rice Butter Cake" which is being conducted by Dr. Witoon Prinyawiwatkul of the Department of Food Science at Louisiana State University, phone number (225)578-5188.

I understand that participation is entirely voluntary and whether or not I participate will not affect how I am treated on my job. I can withdraw my consent at any time without penalty or loss of benefits to which I am otherwise entitled and have the results of the participation returned to me, removed from the experimental records, or destroyed. Four hundred consumers will participate in this research. For this particular research, about 10 minute participation will be required for each consumer.
The following points have been explained to me:
1. In any case, it is my responsibility to report prior participation to the investigator any allergies I may have.
2. The reason for the research is to gather information on consumer sensory acceptability of rice butter cake. The benefit that I may expect from it is a satisfaction that I have contributed to improving the quality of rice-base cake.
3. The procedures are as follows: Two coded samples will be placed in front of me, and I will evaluate them by normal standard methods and indicate my evaluation on score sheets. All procedures are standard methods as published by the American Society for Testing and Materials and the Sensory Evaluation Division of the Institute of Food Technologists.
4. Participation entails minimal to no risk: The only risk which can be envisioned is that of an allergic reaction to rice flour, maltrodextrin, sugar, magarine, eggs, milk and commonly used ingredients. However, because it is known to me beforehand that the food to be tested contains common food ingredients, the situation can normally be avoided.
5. The results of this study will not be released in any individual identifiable form without my prior consent unless required by law.
6. The investigator will answer any further questions about the research, either now or during the course of the project.

The study has been discussed with me, and all of my questions have been answered. I understand that additional questions regarding the study should be directed to the investigator listed above. In addition, I understand the research at Louisiana State University AgCenter that involves human participation is carried out under the oversight of the Institutional Review Board. Questions or problems regarding these activities should be addressed to Dr. David Morrison, Associate Vice Chancellor of LSU AgCenter at 578-8236.

___________________________ ___________________________
Signature of Participant Signature of Investigator

Witness: __________________ Date: ___________________________

Sample______

1. Gender: **( ) Male** **( ) Female**

2. How would you rate the **OVERALL APPEARANCE** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

3. How would you rate the **VISUAL PUFFINESS** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

4. How would you rate the **CRUMB COLOR** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

5. How would you rate the **ODOR or AROMA** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

6. Do you detect any **' RICE AROMA'** of this product?

( ) Yes **( ) No**

7. How would you rate the **SOFTNESS** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

8. Do you detect any **' UNDESIRABLE OR OFF FLAVOR '** of this product?

( ) Yes **( ) No**

9. How would you rate the **MOISTNESS** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

10. How would you rate the **OVERALL TEXTURE/MOUTHFELL** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

11. How would you rate the **TASTE** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

12. How would you rate **OVERALL LIKING** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

13. Is this product **ACCEPTABLE**?

( ) YES ( ) NO

14. Would you **BUY** this product if it were commercially available?

( ) YES ( ) NO

Questionnaire for Thai consumers (rice bran oil formula)

Sample______

1. Gender: **( ) Male** **( ) Female**

2. How would you rate the **BUTTER ODOR** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

3. How would you rate the **SWEETNESS** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

4. How would you rate the **SOFTNESS** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

5. How would you rate the **MOISTNESS** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

6. How would you rate the **OVERALL LIKING** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

Questionnaire for Thai consumer (selecting formula)

Sample A

1. How would you rate the **SOFTNESS** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

2. How would you rate the **FLAVOR** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

3. How would you rate **OVERALL LIKING** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

Sample B

1. How would you rate the **SOFTNESS** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

2. How would you rate the **FLAVOR** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

3. How would you rate **OVERALL LIKING** of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

Questionnaire for performance test

Section I : Demographic information

1.Gender

( ) Male ( ) Female

2. Age

( ) 15-25 yr ( ) 26-35 yr ( ) 36-45 yr

( ) 46-55 yr ( ) more than 55 yr

3. Status

( ) Single ( ) Married

4. Occupy

( ) Employed ( ) Own business

( ) Unemployed ( ) Student

5. Education

( ) High school ( ) Diploma

( ) Bachelor's degree ( ) Higher bachelor's degree

6. Income

( ) <5,000 baht ( ) 5,001-10,000 baht

( ) 10,001-15,000 baht ( ) 15,001-20,000 baht

( ) 20,001-25,000 baht ( ) > 25,000 baht

7. Total of member in family

( ) 2 ( ) 4

( ) 5 ( ) Other (please specify)

Section 2: Product acceptability test

8. Did cake mixed easy to cooking instruction?

( ) Yes, because …………………………………………………………..

( ) No, because …………………………………………………………..

9. Do cake mixed convenience at your home?

( ) Yes, because …………………………………………………………..

( ) No, because …………………………………………………………..

10. Do you can find the additional ingredients for cooking cake prepared from cake mixed?

( ) Yes, because ………………………………………………………..

( ) No, because ………………………………………………………..

11. How would you rate **OVERALL LIKING** of cake mixed?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

12. How would you rate **OVERALL LIKING** of cake prepared from cake mixed?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

13. Is this product **ACCEPTABLE**? ( )YES ( ) NO

14. Would you **BUY** this product if it were commercially available?

( ) YES, because………………………………… Price………………….baht

( ) NO, because………………………………………………………..

Section. III : Family's member information

15. Gender:

( ) Male ( ) Female

16. Age

( ) 15-25 yr ( ) 26-35 yr ( ) 36-45 yr

( ) 46-55 yr ( ) More than 55 yr

Section. III : Family's member product acceptability

17. How would you rate **OVERALL LIKING** of cake?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9

18. Is this product **ACCEPTABLE**?

( ) Yes, because ………………………………………………………..

( ) No, because ………………………………………………………..

Appendix C

Cake mixed and their composition

Appendix Figure C1 Cake mixed(butter formula) and its three individual packed ingredients

Appendix Figure C2 Cake mixed (rice bran oil formula) and its three individual ingredients packed

Appendix D

Cake making process (margarine formula

1. A mixture of powder emulsifier (PGMS/DATEM ; sack No. 3) mixed with 10 % margarine content in cake formula

2. Warmed to temperature ca. 60-70°C for complete melting.

3.The emulsifier gel was allowed to cool down at room temperature

4. Poured remained margarine in the mixer

5. Added emulsifier gel in the mixer

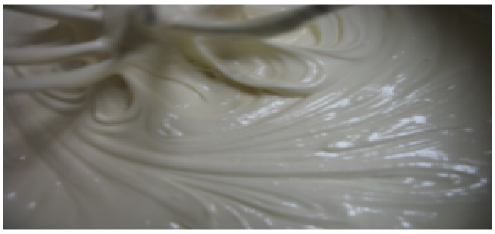
6.Mixed until light creamy for 20 min at a high speed (#8 out of 10)

7. Then mixed with powdered sugar and guar gum.(sack No. 2)

8. Whipped for additional 15 min till creamy light

9. Egg was then added and whipped for additional 1 min to attain the homogeneous creamy batter

10. Rice flour, maltodextrin, baking soda and salt (sack No. 1) added to the mixture



11. Evaporated milk and butter essence were added to the mixture from step 12 and mixed for additional 4 min

12. Batter mixture homogeneous

13.Poured in aluminum pan Previously, greased with cooking oil spray

14. Baked in the electric oven at 350°F for 60 min, and baked cakes were allowed to cool down

Appendix E

Comparison using Stuart-Maxwell and McNemar test

Appendix Table E1 Comparison of moistness and softness of product pair using Stuart Maxwell [a] of Jasmine rice cake(butter)

Product pair [b]	χ^2 value for moistness	χ^2 value for softness
A/B	33.02	48.03
A/C	28.26	23.35
A/D	125.80	156.50
B/C	0.09	3.21
B/D	82.04	79.79
C/D	76.69	100.57

[a] the critical χ^2 value = 5.99 at df = 2 and α = 0.05.
[b] Product A, B, and C, respectively, contained 0, 7.5 and 15 % w/w emulsifier gel (propylene glycol ester:diacetyl tartaric acid ester of monoglyceride, PGMS:DATEM, 8:2) based on the margarine content in the total formulation. Product D was the commercial sample.

Appendix Table E2 Comparison of consumer positive purchase intent(%) on cake mixed(rice bran oil formula) before and after influence of family's member

Before (%)	After (%)		Total
	Yes	No	
Yes	96	0	96
No	0	4	4
total	96	4	100