FORMULATION OF MODIFIED FAT BUTTER CAKE USING *Ocimum canum* MUCILAGE AS A FAT REPLACER

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Thesis
entitled

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FORMULATION OF MODIFIED FAT BUTTER CAKE USING *Ocimum Canum* MUCILAGE AS A FAT REPLACER

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ABSTRACT

The objective of this experiment is to develop a butter cake formula with a lower fat content using hairy basil (*Ocimum canum*) mucilage as a fat replacement that can be prepared in a household or at on institutional level. The hairy basil mucilage was prepared by extracting the mucilage from of the seeds using a household blender. The mucilage was dehydrated in a hot-air oven and ground into a powder form. The dried mucilage powder was used to prepare a butter cake with a lower fat content by reducing 25, 50, 75 or 100% of the butter called for in the control formula and the mucilage applied was 0, 5 or 10% by weight of butter at each reduced level. Sensory evaluation of the cakes was carried out using nine-point hedonic scale to determine the appearance, color, odor, and taste as well as overall acceptability. The scales ranged from 9=like extremely, 5=neither like nor dislike to 1=dislike extremely. The resulting cakes were also evaluated for their physical qualities namely volume, firmness and springiness, color, and water activity. The products were then stored at room temperature for 5 days. The texture and water activity of the stored cakes were determined at day 3 and 5. All determinations were carried out at least 3 times.

The results of the sensory evaluation showed that all the modified fat cakes were well accepted by the test panelists with the overall acceptability scores being in the range of 6-7 (like slightly to like moderately). The cake with 50% reduction of butter and containing 10% mucilage is the formula that gave the lowest fat level while its overall acceptability score showed no significant difference from the control. Decreasing the amount of butter yielded cakes with similar volume to the control, except 0% butter cake. The firmness of the modified fat cake was higher than the control while the springiness was lower. Moreover, the lightness (L*) value increased while the yellowness (b*) value decreased. Addition of mucilage seemed to improve the quality in cakes made with a limited amount of butter (25 and 0%). There was no difference in the water activity among the cakes. Storing the modified fat cakes for 5 days resulted in a slight increase in the water activity value with some samples becoming mouldy. In contrast the firmness and springiness values of the cakes remained similar to the values at day 1. Therefore, the modified fat cakes could be stored at room temperature for 3 days without the addition of any preservatives. In conclusion, the modified fat butter cakes could be consumed as an alternative to the full fat product by consumers who are health conscious. They can also be applied in institutional food services for patients who required a fat controlled diet.

KEY WORDS: *Ocimum canum* / FAT REPLACER / CAKE

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การพัฒนาสูตรเค้กเนยดัดแปลงไขมันโดยใช้สารสกัดจาก *Ocimum canum* (แมงลัก) เป็นสารทดแทนไขมัน

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บทคัดย่อ

การศึกษานี้เป็นการลดปริมาณไขมัน (เนย) ในเค้กเนย โดยการใช้สารสกัดจากเมล็ดแมงลักมาทดแทน โดยลดปริมาณเนยลงเป็น 4 ระดับคือ 75, 50, 25 และ 0% ของน้ำหนักเนยในสูตรมาตรฐาน และแต่ละระดับ จะมีการเติมสารสกัดจากแมงลัก 0, 5 และ 10% โดยน้ำหนักของเนยในสูตรมาตรฐาน เค้กเนยแต่ละสูตรนำมาทดสอบทางประสาทสัมผัส โดยใช้ 9-point hedonic scale ซึ่งคะแนน 9=ชอบมากที่สุด, 5=เฉย ๆ และ 1=ไม่ชอบมากที่สุด ทดสอบเนื้อสัมผัสของเค้กเนยโดยเครื่องวัดเนื้อสัมผัส TA-XTPlus วัดค่าความแน่นเนื้อ (Firmness) และการคืนตัว (Springiness) วัดค่าสีในระบบ L*a*b* และวัดปริมาณน้ำอิสระ (Water Activity) และมีการเก็บผลิตภัณฑ์ไว้ 5 วัน ที่อุณหภูมิห้องเพื่อทดสอบการเก็บรักษา โดยวัดเนื้อสัมผัส และปริมาณน้ำอิสระที่วันที่ 3 และ 5 ผลการทดสอบทางประสาทสัมผัสพบว่า การลดปริมาณเนยลงเหลือ 75 และ 50% ของน้ำหนักเนย ในทุกระดับการทดแทนด้วยสารสกัดจากแมงลัก ได้รับการยอมรับจากผู้ชิม (คะแนนอยู่ระหว่าง 6.80 ถึง 7.14) ในระดับที่ไม่มีความแตกต่างอย่างมีนัยยะสำคัญทางสถิติจากสูตรมาตรฐาน (7.30) สำหรับการวัดเนื้อสัมผัส ค่าความแน่นเนื้อมีแนวโน้มที่จะลดลง เมื่อมีการลดปริมาณเนย ในขณะที่ค่าการคืนตัว มีแนวโน้มที่จะเพิ่มสูงขึ้น การเพิ่มปริมาณของสารสกัดจากแมงลักไม่แสดงให้เห็นการเปลี่ยนแปลงอย่างชัดเจนนัก ผลการวัดค่าสีพบว่า ค่าความสว่าง (L*) เพิ่มขึ้นเป็นลำดับเมื่อลดปริมาณเนยลง ในขณะที่ค่าสีเหลือง (b*) มีแนวโน้มที่จะลดลงเล็กน้อยเมื่อมีการลดปริมาณเนย การเพิ่มสารสกัดจากเมล็ดแมงลักไม่ทำให้เกิดความแตกต่างด้านสี ในส่วนของค่าของปริมาณน้ำอิสระ ไม่พบความแตกต่างในทุกสูตร การเก็บรักษาเมื่อถึงวันที่ 5 พบว่าค่าปริมาณน้ำอิสระเพิ่มขึ้นเล็กน้อย บางสูตรมีราขึ้นที่ผิวหน้าอย่างเห็นได้ชัด ทำให้ไม่สามารถทดสอบคุณภาพได้ สูตรที่เหลือในวันที่ 5 มีค่าความแน่นเนื้อและค่าการคืนตัวใกล้เคียงกับค่าเริ่มต้น ดังนั้นเค้กเนยดัดแปลงไขมันที่พัฒนาขึ้นสามารถเก็บไว้ที่อุณหภูมิห้องประมาณ 3 วันโดยไม่ใช้วัตถุกันเสีย เค้กเนยเหล่านี้จึงเป็นทางเลือกสำหรับผู้บริโภคที่ใส่ใจต่อสุขภาพและผู้ป่วยที่จำกัดการบริโภคไขมัน

87 หน้า

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CHAPTER I
INTRODUCTION

At present there is evidence that dietary factors influence the risk of several chronic diseases such as coronary heart disease and cancer, both favorably and unfavorably. A large intake of fats which are high in saturated fat and cholesterol increase risk of heart disease and certain types of cancer. Eating high fat foods also results in weight gain which increases the risk of type 2 diabetes and related diseases. Diet and life style modification can prevent or lower the risk associated with excess body weight (1-6). Diets that promote health are high in dietary fiber, relatively high in omega-3 fatty acids and low in saturated fat, trans fat and dietary cholesterol (1, 3, 4). For good health, energy from fat intake should be around 20 – 35% of total energy (7). Furthermore, it was found that a modified fat diet in conjunction with increased viscous fiber intake could reduce cholesterol more than modified fat diet alone (4, 8).

In general, fat contributes to the appearance, texture, flavor, and mouthfeel in foods. These sensory properties tend to suffer with the replacement of fats in processed foods. Appropriate fat replacers are difficult to find because they must provide, at least partially, many of the properties that contribute to the overall acceptability of a food product. Plant polysaccharides such as fibers and starches have been used as carbohydrate-based fat replacers due to the ability to retain moisture and provide textural qualities that usually are provided by fat. Research in this area indicates that carbohydrates or a mix of carbohydrates and emulsifiers may act as fat replacers and produce acceptable food products (9). The common fat replacers include modified starches, maltodextrin, polydextrose, different types of gum alone or in combination as well as their mixture with emulsifiers. These fat replacers, however, are widely available as food ingredients for the manufacturing industry with very limited sales for use at a household level. *Ocimum canum* seed, a popular food material used in drinks, desserts and supplements in Thailand, is a good source of viscous fiber (10). Its mucilage-type, water soluble fiber shows certain characteristics

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that may be used to mimic high fat ingredients in foods. The fiber can easily be prepared in the household. Therefore, it is interesting to investigate the preparation and application of the mucilage from *Ocimum canum* seed as a fat replacer in a bakery product namely butter cake under a home-based condition. Bakery products are chosen due to their fat-rich characteristics and popularity. Hence, the developed formula could offer the consumers more alternatives for a healthy diet.

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CHAPTER II
OBJECTIVE

2.1 General objective

To investigate the possibility of using *Ocimum canum* mucilage as a fat replacer in butter cake at a household level.

2.2 Specific objectives

1. To develop a modified fat butter cake that contains *Ocimum canum* mucilage as a fat replacer.
2. To evaluate the sensory acceptability of the modified fat butter cake.
3. To determine the physical and nutritional qualities of the modified fat butter cake.
4. To perform a storage test on the modified fat butter cake.

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CHAPTER III
LITERATURE REVIEW

3.1 Fats

Fat is one of the principal and essential components of a regular diet. Dietary fats are a source of fatty acids, including essential fatty acids. Linoleic acid (omega-6) and alpha-linolenic acid (omega-3) are considered essential fatty acids which are necessary to maintain good health and normal body functions. They must be obtained from dietary sources because the body cannot make them in amounts sufficient to meet physiological needs. In contrast, populations that have high intakes of fat from meats and dairy products, which are high in saturated fat and cholesterol, tend to have a higher incidence of heart disease and certain types of cancer, such as breast, colon and prostate cancer (11). In case of breast cancer, fat may act as a tumor promoter, increasing the rate of tumor growth while in colon cancer dietary fat in the colon may act as tumor initiator (11, 12). Furthermore, eating high fat foods can result in weight gain because fat contains 9 kcal per g. Excess body fat is also associated with an increased risk of diabetes, cardiovascular disease, and high blood pressure (13). The American heart association (AHA) recommends limiting total fat intake to ≤30% of calories and saturated fat to <10% of total energy intake (1). Reducing fat intake is one effective strategy for reducing total energy consumption. Furthermore, due to the increasing rates of obesity at an earlier age, dietary fat reduction may be an effective part of an overall strategy to balance energy consumption with energy needs

The typical fat molecule consists of glycerol combined with three fatty acids (triglycerides). Fatty acids are separated by their structure as either saturated, monounsaturated or polyunsaturated. These fatty acids determine the physical properties and health effects of the triglycerides consumed. The difference in structures of these lipids affects their functions in the body and the properties they give to food. The carbon chains of fatty acids vary in length from a few to 20 or more

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carbons. Most fatty acids in plants and animals, including humans, contain between 14 and 22 carbons. (14).

3.1.1 Saturated Fatty Acids

Each carbon atom forms four bounds to link it to four other atoms. If a carbon is not bound to four other atoms, double bonds are formed. A fatty acid in which each carbon in the chain is bound to two hydrogens is saturated with hydrogens and is therefore called a saturated fatty acid. The most common saturated fatty acids are palmitic acid, which has 16 carbons and stearic acid, which has 18 carbons. These are found most often in animal foods such as meat and dairy products. Butyric acid which has 4 carbons is a common fatty acid found in butter. Vegetable sources of saturated fatty acids include palm oil, palm kernel oil and coconut oil. They are often called tropical oils because they are found in plants common in tropical climates.

3.1.2Unsaturated Fatty Acids

Unsaturated fatty acids contain some carbons that are not saturated with hydrogens. The carbons within the chain that are bound to only one hydrogen atom form carbon-carbon double bonds. A fatty acid containing one double bond in its carbon chain is called a monounsaturated fatty acid. In our diets, the most common monounsaturated fatty acid is oleic acid, which is prevalent in olive and canola oils. A fatty acid with more than one double bond in its carbon chain is named a polyunsaturated fatty acid. The most common polyunsaturated fatty acid is linoleic acid, found in corn, safflower, and soybean oils. Unsaturated fatty acids melt at cooler temperatures than saturated fatty acids of the same chain length. Therefore, the more unsaturated bonds a fatty acid contains, the more likely it is to be liquid at room temperature (6, 15).

3.2 Digestion and Absorption of Fats

In healthy adults most of the digestion of dietary fat takes place in the small intestine due to the action of lipid-digesting enzymes called lipases. Some lipid digestion also occurs in the stomach due to the action of lipases produced in the mouth

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and stomach. The enzymes work best on triglycerides containing short and medium-chain fatty acids such as those in milk, and so are particularly important in infants (14).

In the small intestine, bile from the gallbladder helps break fats into small globules. The triglycerides in these globules are digested by lipases from pancreas, which breaks them down into fatty acids and monoglycerides. These products of triglyceride digestion, cholesterol, and other fat-soluble substances including fat-soluble vitamins mix with bile to form smaller droplets called micelles. Micelles have a fat-soluble center surrounded by a coating of bile acids. They facilitate the absorption of lipids into the mucosal cells of the small intestine by allowing these substances to get close enough to the brush border to diffuse across into the mucosal cells. Most of the bile acids in micelles are also absorbed and returned to the liver to be reused. Because fat-soluble vitamins and other fat-soluble molecules present in foods must be incorporated into micelles to be absorbed, their absorption depends on the presence of dietary fat. Once inside the mucosal cell, long-chain fatty acids, cholesterol, and other fat-soluble substances require further processing before they can be transported in the blood (6).

3.2.1 Lipid Transport in the Body

Just as water-insoluble lipids require special mechanisms to be absorbed into the body, they require special transport particles to travel throughout the body in the blood. These transport particles, called lipoproteins, are created by combining water-insoluble lipids with phospholipids and proteins. The resulting particle consists of a fat-soluble core surrounded by a water-soluble envelope. Lipoproteins helps transport dietary triglycerides, cholesterol, and fat-soluble vitamins from the small intestine and stored or newly synthesized lipids from the liver (6).

3.2.2 Transport from the Small Intestine

Lipids are transported from the small intestine depending on their solubility in water. Short- and medium-chain fatty acids, which are partially water-soluble, can be transported from the small intestine in the blood and delivered to cells throughout the body. Lipids that are not soluble in water, such as long-chain fatty acids and

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cholesterol, cannot enter the bloodstream directly so they must be incorporated into lipoproteins. For this to occur, long-chain fatty acids and monoglycerieds are first assembled into triglycerides by the mucosal cell. These triglycerides are then combined with cholesterol, phospholipids, and a small amount of protein to form lipoprotein call chylomicrons. Chylomicrons are transferred into the lymphatic system and then enter the bloodstream without first passing through the liver.

Chylomicrons circulate in the blood. The enzyme lipoprotein lipase, present on the surface of the cells lining the blood vessels, breaks the triglycerides down into fatty acids and glycerol, which enter the surrounding cells. The fatty acids can be either used as fuel or re-synthesized into triglycerides for storage. What remains of the chylomicron is a chylomicron remnant composed mostly of cholesterol and protein. This goes to the liver and be disassembled (6).

3.2.3 Transport from the Liver

The liver is the major lipid-producing organ in the body. There, excess protein, carbohydrate or alcohol can be broken down and used to make triglycerides or cholesterol. Triglycerides made in the liver are incorporated into lipoprotein particles called very-low-density lipoprotein (VLDLs). Cholesterol synthesized in the liver or delivered in chylomicron remnants can also be incorporated into VLDLs or can be used to make bile. VLDLs transport lipids out of the liver and deliver triglycerides to body cells. As with chylomicrons, the enzymes lipoprotein lipase breaks down the triglycerides in VLDLs so that the fatty acids can be taken up by surrounding cells. Once the triglycerides are removed from the VLDLs, denser, smaller, intermediate-density lipoprotein (IDL) remains. About two-thirds of the IDLs are returned to the liver and the rest are transformed in the blood into low-density lipoprotein (LDLs). LDLs contain less triglycerides and therefore proportionally more cholesterol than VLDLs and are the primary cholesterol delivery system for cells (6).

3.2.4 Cholesterol Delivery

For LDLs to be taken up by cells, a protein on the surface of the LDL particles called apoprotein B (apo B) must bind to a receptor protein on the cell membrane, called an LDL receptor. This binding allows LDLs to be removed from the

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blood circulation and enter cells where their cholesterol and other components can be used. If the amount of LDL cholesterol in the blood exceeds the amount that can be taken up by cells- due to either too much LDL cholesterol or too few LDL receptors- the result is a high level of LDL cholesterol. High levels of LDL particles in the blood have been associated with an increased risk for heart disease (6).

3.2.5 Reverse Cholesterol Transport

Because most body cells have no system for breaking down cholesterol, cholesterol must be returned to the liver to be eliminated from the body. This reverse cholesterol transport is accomplished by the densest of lipoprotein particles, called high-density lipoproteins (HDLs). These particles originate from the intestinal tract and liver and circulate in the blood, picking up cholesterol from other lipoproteins and body cells. They function as a temporary storage site for lipid. Some of the cholesterol in HDLs is taken directly to the liver for disposal, and some is transferred to organs that have a high requirement for cholesterol, such as those involved in steroid hormone synthesis. High level of HDL in the blood helps prevent cholesterol from depositing in the artery walls and are associated with a reduction in heart disease risk (6).

3.3 Lipids and Health

Adequate amounts of essential fatty acids must be consumed in the diet to maintain normal body function and health. However, diets high in fat, particularly certain types of fat, are associated with an increased risk for many chronic diseases. The development of cardiovascular disease has been linked to diet high in cholesterol, saturated fat, and *trans* fat. The risk of certain types of cancer, including that of the breast, colon and prostate, has been associated with a high-fat intake. Obesity is also associated with diets high in fat because these diets are usually high in energy and promote storage of body fat. Excess body fat in turn is associated with an increased risk of diabetes, cardiovascular disease, and high blood pressure (6).

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3.3.1 Cardiovascular Disease

An increased LDL level in blood increases the risk of atherosclerosis. Lipoprotein production decreases and the number of LDL receptors increase when the diet is low in saturated fats. This allows more cholesterol to be removed from the bloodstream (6, 16). The relationship between lipid levels and coronary heart disease rates in Asian countries is grossly similar to that of European countries. The higher the total cholesterol level, the higher the coronary heart disease rate. Lewis and his colleagues (17) showed that there was a higher total cholesterol level among the population in Northern Europe (Uppsala and London) as compared with that in Southern Europe (Geneva and Naples). Keys (18) in the Seven Countries Study showed similar findings. Northern Europe (Finland, The Netherlands) had a higher total cholesterol level in blood as compared with Southern Europe (Greece, Italy and Yugoslavia). Simons (19) reported variations in the total cholesterol level, which correlated positively with coronary heart disease incidence in the 19 countries studied. When the non-European countries (US, Australia, UK and Japan) were excluded, this became even more apparent with the highest total cholesterol levels associated with the highest coronary heart disease rates. According to the SEAMIC Health Statistics (20), death rate of Thai people due to coronary heart disease has increased more than three times, i.e. from 19.0 per 100 000 (ranked fifth) in 1960 to 15.3 per 100 000 in 1970, to 31.4 per 100 000 (ranked second) in 1980, to 56.0 per 100 000 in 1992 (ranked first) and to 71.2 per 100 000 (ranked first) in 1997. In addition, Thantrarorongroj and Nelson (21) reported a 6-fold increase in the coronary heart disease incidence of hospital admissions to the Bangkok Adventist Hospital during a span of 28 years from 1958 to 1985. Male coronary heart disease patients predominate. Literature values related to total cholesterol levels in healthy Thai subjects ranged from a value of 4.2 mmol/l in the rural population to a value of 5.6 mmol/l in the urban population (22-25). Mean total cholesterol levels increase with age and a slightly higher total cholesterol value in females was noted. The coronary heart disease patients were also shown to have a higher mean total cholesterol value of 6.0 mmol/l (25).

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3.3.2 Dietary Fat and Cancer

Epidemiologic data suggest a direct relationship between total fat intake or consumption of animal fat and increased cancer risk at several sites, including the postmenopausal breast, the colon/rectum and the prostate (26-30). Migrant studies showed that changes toward a high-fat, low-fiber "Western" diet resulted in a rise in breast cancer incidence. Data for Asian-American women born in the West indicated a breast cancer risk 1.6 times higher than that for Asian-American women born in the East (31). Case-control and cohort studies, however, have not found a clearly significant association between fat intake and breast cancer incidence. A meta-analysis of 23 studies by Boyd and colleagues (32) reported a summary relative risk (RR) of 1.21 for case-control studies and 1.01 for cohort studies, similar to a recent meta-analysis of cohort studies (33) that found a summary RR of 1.05.

Several factors could contribute to the lack of conclusive epidemiologic evidence between total fat intake and breast cancer risk, including importance of diet before adulthood, differences in methodology, inaccuracy in dietary assessment, insufficient variation in fat intake within a population, effects of correlated variables, variations in genetic susceptibility and breast tumor heterogeneity within the populations studied. International correlation studies showed strong associations between colorectal cancer incidence and intake of red meat or animal fats (26, 29, 30). Furthermore, data from case-control and cohort studies, including studies that used adenomatous polyps as markers of risk, generally support the associations with red meat, but data for fat intake are less consistent (34-37). For example, data from a cohort of more than 47,000 American male health professionals found no significant risk association with any types of fat but showed a significantly elevated risk of colon cancer associated with red meat intake (RR = 1.71). This association was not confounded by other dietary factors, physical activity, body mass, alcohol intake, cigarette smoking, or aspirin use (36).

Cross-cultural and migrant studies support the suggestion that a "Western" diet is associated with increased disease risk for prostate cancer as well as for breast and colorectal cancers (26, 29). A review of epidemiologic studies found that numerous case-control and cohort studies indicated a consistent relationship between prostate cancer and consumption of either fat or high-fat foods, especially red meat

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(38). A study of the relationship of prostate cancer with diet in blacks, whites, and Asians in the United States and Canada (39) reported a significant direct association with saturated fat, with highest risks for Asian-Americans. However, estimates suggest differences in saturated fat intake accounted for only approximately 10% of black/white differences and approximately 15% of Asian-American/white differences in prostate cancer incidence, thus supporting a hypothesized etiologic role for other environmental factors or genetically determined variations (39).

The type of fat appears to be important in cancer development. For example, data from international correlation and case control studies linked animal fat and red meat to colon cancer risk but do not support an association between colon cancer and vegetable fat (26, 29, 30, 34). For prostate cancer, some data suggest that alinolenic acid appeared to increase disease risk (RR=3.43), whereas saturated fat (RR=0.95), monounsaturated fat (RR= 1.58), and linoleic acid (RR=0.64) showed no significant associations (40). The relationship between breast cancer and type of fat is unclear. Based on international food disappearance data, consumption of both saturated fat and omega-6 polyunsaturated fat has been correlated with increased breast cancer risk (30). In a recent study, (41) however, saturated fat showed no association (RR=0.95), whereas total polyunsaturated fatty acids (RR=0.70) and oleic acid (RR=0.81), a monounsaturated fatty acid, showed inverse associations with breast cancer risk. Moreover, consumption of olive oil, in which oleic acid is a major component, appeared to reduce breast cancer risk (RR=0.87) (42). In international correlation studies, highly unsaturated omega-3 fatty acids -- found primarily in fish oils -- were not associated with increased breast cancer risk and have been hypothesized to be protective (30, 43).

3.3.3 Dietary Fat and Obesity

A weighted regression analysis shows a significant positive association between fat consumption and the proportion of the population who are overweight (44). This suggests that halting the increase in dietary fat in many countries where the diet is traditionally low in fat may be an effective strategy to prevent an increase in obesity. Migration studies provide additional evidence. Reanalysis of the Ni-Hon-San migration study (45), where 8006 Japanese men living in Honolulu were compared

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with 2183 men living in Hiroshima and Nagasaki, shows that while the total energy intake was only slightly higher in Honolulu than Hiroshima and Nagasaki, the percentage of energy from fat was two times greater in Honolulu. The mean body mass index (BMI) and subscapular skinfold thickness were also greater in men living in Honolulu and more of these men were obese. The Leeds Fat Study (46) shows that when the frequency distribution of BMI among individuals who consumed a higher-fat diet (>45% of energy) was plotted, the tail was skewed to the right as compared to those who consumed a lower-fat diet (<35% of energy), and the proportion of obese individuals was about 19 times higher among those who consumed higher-fat diets than those who consumed lower fat diets. However, there were also a number of individuals who consumed a higher fat diet but whose BMI was normal, suggesting that other factors, including genetic susceptibility, must play a role. Another ecologic study used the time-trend analysis to examine obese individuals and their past diet (47). Among 377,200 Danish military recruits from the years 1943–1974, there was a marked parallel between the percentage of energy from fat and the subsequent development of obesity. Studies conducted among the Pima Indians in the United States (48) produce similar results.

Obviously, the association between high-fat intake and subsequent obesity is compounded by other factors, most notably the declining trend in physical activity. A longitudinal survey in China also suggests that the increase in fat intake led to an increase in body weight (49, 50). The potential confounders in the relation of diet to BMI (e.g., age, sex, physical activity, and smoking) were taken into account. To test the hypothesis that fat has an independent effect on body weight, the effect of change in absolute amount of energy from fat was examined while controlling for the effect of change in energy from the nonfat sources (i.e., protein and carbohydrate). Similarly, the effect of change in the percentage of energy from fat was examined while controlling for total energy intake. In both cases, a significant effect of fat intake on BMI was found. A 100 kcal increase in fat intake was associated with about 0.05 and 0.01 unit increase in BMI in adolescents and adults, respectively. In contrast, a 100 kcal increase in protein and carbohydrate intake combined was associated with an increase of only 0.01 and 0.0007 BMI unit in adolescents and adults, respectively. Similar results were seen when fat intake was expressed as the percentage of total

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energy intake. These findings suggest that the energy from fat may have a greater effect on body weight than energy from non-fat sources. They are consistent with the view that the increase in fat intake may put a significant fraction of the population at risk of obesity, especially those who are genetically predisposed to the condition (47, 51-54).

3.4 Function of Fats in Food

Fats impart many unique properties to foods. The chemical configuration of fat molecule (specifically the length and saturation of the three fatty acids on the glycerol molecule of a triglyceride) contributes to the uses of fat in foods. It contributes to the functions of fat including heat transfer, shortening power and emulsions as well as influences the fat's melting point, plasticity, solubility, flavor, texture, appearance, satiety and nutrient content (55) (**Table 3.1**).

Table 3.1 Functions of Fats in Foods (55)

Function	**Examples**
Heat transfer	Sautéing, pan-frying, deep-flying
Shortening power	Biscuits, pastries, cakes, cookies
Emulsions	Mayonnaise, salad dressing, sauces, gravies, puddings, cream soups
Varying melting point	Candies
Plasticity	Confections, icings, pastries, other baked goods
Solubility	Fat do not dissolve in water, yielding unique food flavors/texture and foods such as salad dressings
Flavor/mouth feel	Flavor (butter, bacon, fried foods), lubricity, thickness, cooling
Texture	Creaminess, flakiness, tenderness, elasticity, curability, viscosity
Appearance	Sheen, oiliness, color
Satiety	Fat contribute to "feeling full"
Nutrients	9 kcal/g

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3.4.1 Heating Medium

A major function of fats is their ability to act as a medium for heat transfer. Numerous meals use fat to transfer heat to foods without burning them- butter in the frying pan, palm oil or shortening in the deep-fryer and vegetable oil in the wok. The amount of fat used can range from the minimal quantities used in sautéing, to the moderate levels use in pan-frying, to enough to completely submerge a food, as in deep frying (56).

3.4.2 Shortening Power

The shortening power of certain fats makes them essential in the preparation of pastries, pie crusts, biscuits, and cakes. The more highly saturated fat tends to have a greater shortening power. Mixed into a flour mixture, fat separates the flour's starch and protein and, when heated, melts into the dough. This creates air spaces that give the finished baked product its characteristic delicate texture. A fine grain is created from certain cake and cookie batters with the use of shortenings that gently encase the numerous air bubbles, serving as a starting point for the air to expand and increase the overall volume. Baked goods become more tender, up to a point, as fat concentration increases (55).

3.4.3 Emulsifiers

There are three parts of an emulsion, the oil base, the water base and emulsifier to stabilizing other 2 parts.

The two phases of emulsions are kept apart by surface tension, and the boundary between them is called the interface. The emulsifier migrates to this interface and acts as a surfactant, lowering the surface tension between the dispersed and continuous phase so that the two phases mix more readily.

Emulsifying agents act as a bridge between oil and water by being a two part molecule, one portion being hydrophilic, where the other is hydrophobic. It has been suggested that this balance of hydrophilic and hydrophobic portions allows emulsifiers to act like a "zipper" in drawing the water and oil phase together (55).

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Mono- and diglycerides are the most frequently used emulsifiers in the food industry. They are added to foods for this ability to increase or improve emulsion stability, dough strength volume, texture and tolerance of ingredients to processing.

Other emulsifiers are phospholipids (e.g. lecithin from egg yolks), milk proteins, soy protein, gelatin, gluten, vegetable gums such as carrageenan and starches. Ground paprika, dried mustard and other finely ground herbs or spices, which are often included in salad dressings, also act as emulsifiers. Emulsifiers synthesized by the food industry include compounds such as polysorbate 60 and propylene glycol monoesters.

3.4.4 Melting Point

Not all fats melt at the same temperature. Each food fat has a unique melting temperature range because their triglycerides contain different fatty acid. These fatty acids are single molecules that each has a distinct melting point. Ultimately, a fat's melting point is determined by the following four characteristics of the fatty acid (56).

- Degree of saturation
- Length
- *Cis-trans* configuration
- Crystalline structure

Degree of Saturation

Most plant oils contain more polyunsaturated fatty acids than saturated, which cause them to be liquid at room temperature. Animal fat tends to have more saturated fatty acids, causing them to be solid at room temperature (55, 56).

Length of Fatty Acid

The length of the fatty acids can alter these general rules, as even saturated fats with shorter carbon chains can have lower melting points than those with longer ones (55, 56). Butyric acid and stearic acid are saturated fatty acids found in butter. However, butyric acid has only 4 carbons and thus melts at room temperature. Coconut oil is saturated oil containing short fatty acids, which causes it to

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remain solid at room temperature. Nevertheless, it will quickly liquefy if the bottle is held in a person's warm hand.

Cis-trans Configuration

Another significant structural difference that affects melting point is whether the fatty acid has more *cis* or *trans* double bonds. A fatty acid with a trans configuration has a higher melting point than an identical fatty acid with a *cis* form (55, 56). For example, oleic acid, an 18 carbon fatty acid with one double bond in the *cis* form has a melting point of 14 ^{o}C, whereas the same fatty acid with a *trans* double bond has a melting point of 44 ^{o}C. Hydrogenation, a commercial process that adds hydrogen to the double bonds of the unsaturated fatty acids, change a *cis* form to a *trans* form.

Crystalline Structure

The fourth influence on the melting point of fats is its crystalline structure, the arrangement of the fatty acids on the triglyceride molecule. How they are packed, or crystallized, in the solid phase of the fat determines at what point the fat will melt. This principle is very important to chocolate manufacturers. The larger the fat crystals, the higher its melting point will be (55, 56). This allows chocolate to be held in the hand without melting.

3.4.5 Plasticity

The plasticity of fat is its ability to hold its shape but still be molded or shaped under light pressure. Plasticity determines a fat's spread ability. It is an important characteristic in the preparation of confections, icing, pastries and other baked products. Although most fat looks solid at room temperature, they are actually composed of liquid oil with a network of solid fat crystals holding it in place. This combination allows the fat to be molded into various shapes (55). Chilled butter has very little plasticity as compared to hydrogenated vegetable oil, or shortening. The more unsaturated a fat there is, the more plastic it will be. Temperature also influences plasticity. For example, hard fats such as butter become soft and more spreadable when warmed.

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3.4.6 Solubility

Fats are generally insoluble in water. That is why oil separates from the vinegar in salad dressing. Fats dissolve in organic compounds such as benzene, chloroform and ether (56).

3.4.7 Flavor

One of the most obvious contributions to flavor in foods from fat is found in fried foods such as breaded poultry or fish, French fries, potato chips and doughnuts. The flavor developed in certain foods by fat is very difficult to duplicate (55, 56). For example, fats give butter, bacon and olive oil their own distinctive tastes. Fats not only contribute their own flavor to foods, but also absorb fat-soluble flavor compounds from other foods. Sautéing garlic, onions and herbs in oil releases their flavorful and aromatic compounds, while also lending them a smooth, rich mouthfeel.

3.4.8 Texture

Fat also contribute texture to foods (55). Fat gives textures to flaky pastries, smooth chocolates, halt-melted ice cream, whipped cream topping, and crispy fried foods. The characteristic texture of baked products is based upon fat's positive influence on tenderness, volume, structure, and freshness.

The higher the fat content in ice cream, the smoother and creamier is the mouthfeel. The tenderizing effect of fats makes foods easier to chew and causes foods to feel moister in the mouth (57). The lubricating action of fat moistens certain foods such as crackers and chips in which saliva would not be enough

3.4.9 Appearance

Foods are made more appealing by pigments located in a food's natural fats (55). Milk would be chalky white or bluish if not for its natural fat-based pigments giving it a more appealing color. The soft yellow hue of butter was so important to consumer that attempts were made to duplicate it in margarine. Fat also coats food with a sheen of delicate oil that improve the appeal of chicken, pastries, chocolate, and many other foods.

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3.4.10 Satiety

Besides their contribution to the physical and sensory characteristics of foods as discussed above, fats also induce a sense of fullness, or satiety (55). Foods and beverages containing fat help to delay the onset of hunger pangs which signal the desire to eat by two methods. Firstly fats take longer to digest than carbohydrates and proteins and secondly fats delay the emptying of the stomach contents making a person feel full longer.

3.5 Shortened Cake

Shortened cakes, also called butter or conventional cakes contain largh amount of fats. Both the batter and the baked cake are foams, the former a mobile and the latter a rigid one. Shortened cake is usually leavened with baking powder or baking soda. Steam generated from the liquid ingredients and air incorporated during the mixing process also contributes to leavening (58). The quality of the finished product is influenced by the kind and proportions of ingredients, how the ingredients are manipulated and also how the cake is baked. High-quality shortened cake has a flat or slightly rounded top. The crust should be fine grained with a uniform golden brown color. The grain (cells) should be small and uniform in size, the cell walls thin and the crumb resilient, soft and velvety. The cake should be light, tender and slightly moist. It should taste acceptably sweet and otherwise have a good flavor (59).

Cake consists of a flour mixture with extra sugar and sometimes fat. It can be high in carbohydrates and fat contributing to a general figure of about 200 kcal and 8 grams of fat per slice. Any nutrient modification of cake mixture usually focuses on the fat content. Fat is not always easy to replace. The flavor lost by the removal of the fat can be replaced, in part, by adding more vanilla or another flavor extract. The thicker, richer consistency provided by fat can be partially replaced by using a fat replacer (58).

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Ingredients in Shortened Cake

Shortened cakes have many ingredients such as flour, sugar, egg, etc. (58, 59). They all contribute to the quality and acceptability of the final products. The main ingredients and their functions are described below.

Flour

Cake flour provides structure to cakes when its starch gelatinizes and its proteins form gluten. The structural strengthening effect of cake flour and egg is balanced by the tenderizing effect of the sugar and fat ingredients.

Sugar

Sugar's tenderizing effect is thought to be the result of its dilution of the flour proteins and delaying of starch gelatinization. The extra sugar results in cakes with greater moisture content, which improves their shelf life. Sugar also functions to sweeten, to increase volume and to brown the crust.

Fat

Fats such as butter and shortening contribute to tenderness, volume, moistness and flavor. These attributes are best achieved by fat other than vegetable oil which does not entrap air during creaming. A unique function of fat in shortened cakes is that it serves as a means of incorporating air into the batter. .

Egg

Eggs are added to help strengthen the structure, as well as to increase leavening, to act as emulsifiers, and to add color and flavor. Eggs serve as a means of incorporating air into cake batter, especially if the eggs are separated and the beaten whites are folded into the batter after it is mixed. Eggs also supply liquid to batters and dough. In addition, egg yolk is a rich source of emulsifying agents.

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Leavening Agent

Cakes are leavened with gas produced by baking soda, baking powder, air and/or steam. The amount of chemical leavening agent used is dependent on how much flour is used. In general for high-ratio cakes, 1 teaspoon of baking powder or ¼ teaspoon of baking soda is used per every cup of flour (58, 59).

3.6 Fat Replacer

Fat contributes key sensory and physiological benefits to foods. It contributes to the combined perception of mouthfeel, taste and aroma/odor. Fat also contributes to creaminess, appearance, palatability, texture, lubrication properties of foods and increases the feeling of satiety during meals. It can carry lipophilic flavor compounds, can act as a precursor for flavor development and stabilize flavor. Hence, to replace fat in food formulation, a substance which can contribute to as many as possible of those properties is required.

Fat replacers are structurally different from fat and do not provide readily absorbable nutrients. The simplest technique for replacing fat is to add air or water. To meet the challenge of stabilizing the air or binding the water, other ingredients are frequently added. Advanced technologies apply a careful balance of ingredients and proper processing to produce a reduced-fat product with the organoleptic characteristics of the traditional product. Current ingredients used as fat replacers cover the spectrum of macronutrients from dietary fiber to lipids (60).

Fat replacers are generally categorized into two groups

1. Fat substitutes are macromolecules that physically and chemically resemble triglycerides (conventional fat and oils) and which can theoretically replace the fat in foods on an almost one-to one, g-for-g basis. They are often referred to as lipid- or fat-based fat replacers. Fat substitutes are either chemically synthesized or derived from conventional fats and oils by enzymatic modification. Many fat substitutes are stable at cooking and frying temperatures.

2. Fat mimetics are substances that imitate organoleptic or physical properties of triglycerides but cannot replace fat on a one-to-one, g-for-g basis. Fat mimetics, often called protein- or carbohydrate- based fat replacers, are common food constituents, e.g. starch and cellulose, but may be chemically or

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physically modified to mimic the function(s) of fat. The caloric value of fat mimetics ranges from 0-4 kcal/g. Fat mimetics are not suitable for frying because they bind excessive water and denature or caramelize at high temperatures. Fat mimetics are generally less flavorful than the fats that the mimetics are intended to replace. They carry water-soluble flavors but not lipid-soluble flavor compounds. Successful incorporation of lipophilic flavors into foods that are formulated with fat mimetics may require emulsifiers.

3.6.1 Carbohydrate-based Fat Replacers

Carbohydrate-based fat replacers include dietary fiber, modified starches, polydextrose, gums and gels, and pectin. Many of these products are the same ingredients food manufacturers have been using for years with their functionality now redefined and recognized for their ability to mimic attributes of fat in food systems. Some, such as cellulose gel (microcrystalline cellulose), specialty pectins (citrus peel extract), and dextrins (tapioca. corn, potato, and rice derivatives) are traditional ingredients that are modified to provide enhanced functionality in reduced-fat systems. The degree of digestibility defines the energy value of carbohydrate-based fat replacers. As would be expected, fibers, gums, gels, and pectins contribute none or few calories. Modified starches, dextrins, and maltodextrins are fully digestible carbohydrates with 3-4 kcal/g. Because of the presence of fiber, fruit pastes (e.g. prune and fig pastes) with sweeteners average 3 kcal/g and fruit paste blends range between 0.7-3.8 kcal/g. Polydextrose is a polymer of dextrose with some bound sorbital and citric acid and is only partially absorbed. It provides only 1 kcal/g.

Functional characteristics of carbohydrate-based fat replacers relate mostly to their ability to bind water. They add bulk, viscosity, structure, slip and texture to products. If they could totally replace fat in products, the energy savings would be considerable. Not only are their energy values inherently lower than fat but their energy contribution becomes diluted because only a small amount is needed to bind water and fill the void left by the fat removed. Unfortunately, there are only a few categories of food in which these ingredients can be used as the sole replacement for fat.

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Protein-based Fat Replacers

The simplest protein-based fat replacement strategy is to add milk protein and milk solids to reduced-fat products, such as skim or modified fat milk. Other ingredients used to increase milk solids are whey protein concentrate and whey protein isolates. Microparticulated protein is usually based on whey protein concentrate, but can be prepared from other sources of protein as well. Other protein-based fat replacers include gelatin, isolated soy protein, and protein blends that also contain gums and modified starches. Most of these ingredients contain small quantities of carbohydrate, fat, and ash. However, their energy values approximate that of protein and range from 3.1-4.1 kcal/g. The actual energy contribution of these ingredients in a food is less than would be expected by comparing their energy values with that of fat. The small amounts of these replacers used in formulas and their hydration in food systems combine to lessen their contribution to energy values of products.

Besides providing many of the same characteristics as carbohydrate-based replacers, protein-based fat replacers provide added functionality to food system including opacity and emulsification. Microparticulated protein has a clean flavor base and good flavor-release qualities (60).

3.6.3Fat-based Fat Replacers and Other Fat Replacers

Mono- and diacylglycerol, propylene glycol mono- and di-esters, and sodium or calcium stearoyl lactylate are common fat-based emulsifiers used to manipulate the structure of fat in traditional products and to extend the functionality of fat in reduced fat systems. Mono- and diacylglycenol are subject to the same hydrolysis process as triacylglycenol and, therefore, yield 8.1-9.1 kcal/g. The energy content of the other emulsifiers is related to the number of fatty acids and the nature of their backbone.

Fat-based replacers vary in their ability to replace the functionality of fat. At a minimum they provide structure and mouthfeel. At best, the synthetic oils (e.g. sucrose polyester) will be able to fully function as a fat (60).

Fat replacers represent a variety of chemical types with diverse functional and sensory properties and physiological effects. **Table 3.2** lists the general functions of fat replacers in selected applications and food product categories (61).

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Table 3.2 Selected functions and applications of fat replacers (61)

Application	Fat replacer	General functions
Baked foods	Fat- based	Emulsify, provide cohesiveness, tenderize, carry flavor, replace shortening, prevent staling, prevent starch retrogradation, condition dough
	Carbohydrate-based	Retain moisture, retard staling
Frying	Fat- based	Emulsify, provide flavor and crispiness, conduct heat
Salad dressing	Fat- based	Emulsify, provide mouthfeel, hold flavorants
	Carbohydrate-based	Increase viscosity, provide mouthfeel, texturize
	Protein-based	Texturize, provide mouthfeel
Frozen desserts	Fat- based	Emulsify, texturize
	Carbohydrate-based	Increase viscosity, texturize, thicken
	Protein-based	Texturize, stabilize
Margarine, shortening, spreads, butter	Fat- based	Provide spread ability, emulsify, provide flavor and plasticity
	Carbohydrate-based	Provide mouthfeel
	Protein-based	Texturize
Confectionery	Fat- based	Emulsify, texturize
	Carbohydrate-based	Provide mouthfeel, texturize
	Protein-based	Provide mouthfeel, texturize
Processed meat products	Fat- based	Emulsify, texturize, provide mouthfeel
	Carbohydrate-based	Increase water holding capacity, texturize, provide mouthfeel
	Protein-based	Texturize, provide mouthfeel, water holding
Dairy product	Fat- based	Provide flavor, body, mouthfeel, and texture; stabilize, increase overrun
	Carbohydrate-based	Increase viscosity, thicken, aid gelling, stabilize
	Protein-based	Stabilize, emulsify
Soups, sauces, gravies	Fat- based	Provide mouthfeel and lubricity
	Carbohydrate-based	Thicken, provide mouthfeel, texturize
	Protein-based	Texturize
Snack products	Fat- based	Emulsify, provide flavor
	Carbohydrate-based	Texturize, aid formulation
	Protein-based	Texturize

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The largest group of fat replacers is derived from plant polysaccharides such as gums, cellulose, dextrin, fiber, maltodextrins, starches and polydextrose (62). Fat-based fat substitutes physically and chemically resemble fats and oils. They are also stable at cooking and frying temperatures. Carbohydrate-based fat mimetic, on the other hand, differ strongly from fats and oils. Generally they adsorb a substantial amount of water and are therefore not suitable for frying. However, many of them are suitable for baking and retorting. Lowering the fat content of a food by replacing fat with fat replacers is based on their ability to increase viscosity, to form gels, provide mouth feel and texture, and to increase water-holding capacity (63).

Since the mid-1980s, gums have been used as a tool to reduce calories in a wide variety of food formulations. The gums provide viscosity and body and in some cases form gels. The application of gums is based on their ability to control the rheological characteristics of aqueous systems. In particular, gums can affect the stabilization of emulsions, help to suspend particles, control crystallization and inhibit syneresis. Guar and xanthan gums are among the group of gums frequently included in reduced fat formulations.

Zambrano *et al.* (60) developed modified fat cakes by substituting fat with either guar or xanthan gums and compared with the commercial fat substitute, N-Flate® (National Starch, Sao Paulo, Brazil). The modified fat cakes contained guar gum, xanthangum or N-Flate as fat replacers at the level of 25, 50, 75 and 100%. The moisture content and dough specific density of the cakes in which the fat was replaced showed no significant differences from the control. For internal characteristics, only the cakes with 25% fat replacer were statistically equivalent to the control. The score for internal characteristics decreased with an increase in fat replacing level, resulting in the formation of tunnels with unequal cells, rough grains and a dried out crumb. The cakes with 100% replacement produced a highly compact cake, no tunnels and completely closed cells. Furthermore, replacing fat with guar or xanthan gums more than 75% reduced the softness of the cake. After 5, 10 and 15 days storage at 25 ^{o}C, the cake with 50% replacement with guar or xanthan gum showed no significant differences with respect to firmness and elasticity. This could be related to the capacity of the gums to retain water and avoid its migration which make the gums useful in the replacing of fat in bakery products. However, they found that the cake

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made with xanthan gum was considered better with respect to overall appreciation and texture in the acceptability.

In Khalil study, fat in Madeira cake was partially replaced with different levels (0, 25, 50 and 75% of fat weight) of commercial carbohydrate-based fat replacers alone and in combination with an emulsifier (mono- and di- glycerides; 0 and 3% of flour weight). The cake prepared with fat replacers at the 25 and 50% levels had higher volume, specific volume and standing height than those of the control. It also received higher mean scores for flavor, softness and eating quality than the control in the sensory evaluation. Incorporating emulsifiers with fat replacers did not affect the crust color, crumb color and flavor, but significantly improved softness and eating quality (64).

Chia seeds were an important staple food for Mesoamericans in pre-Columbian times. They are small with three unequal semiaxes and are made into a popular drink in Mexico by mixing the seeds with water or lemon juice. The gel is extracted from soaked seeds and used as a fat replacer. Borneo *et al*. (9) replaced eggs or oil in cake formula with chia gel extracted from the seed of *Salvia hispanica* L., commonly known as chia seed at the levels of 25, 50 and 75%. They found that chia gel could replace as much as 25% of oil or egg in cakes. The substitution of chia gel at 25% for oil in cake did not produce significant differences in terms of color, taste, texture and overall acceptability from those of the control. However, cake volume of the substituted sample was lowered as the percentage of chia gel increased.

Akesowan (65) incorporated konjac flour (0.5 and 1%) with soy protein isolate (5 and 10%) in reduced-fat chiffon cakes prepared with 50% vegetable oil replacement with water. He found that the addition of konjac flour and soy protein insolate produced reduced-fat cakes with significantly lower specific volume, but higher weight loss and water activity. All reduced-fat formulations were significantly darker than the control. The high concentration of soy protein insolate produced the cakes with higher L* (lightness) but lower a* (redness) and b* (yellowness) value. The addition of konjac flour incorporated with soy protein isolate significantly decreased hardness, cohesiveness and springiness of reduced-fat cakes. Sensory evaluation results indicated that the cakes with konjac flour and soy protein isolate tended to be darker, juicy, sweet and flavor but softer than the control. Moreover, the cake with

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0.5% konjac flour and 10% soy protein isolate was rated as tender as the control. The reduction of fat and total caloric value of this cake was about 37.9 and 14.6%, respectively, whereas the increment of protein was 24.5% in relation to 100 g of the control cake.

In chocolate muffin, soluble cocoa fiber was used to replace part of the oil ingredient (25, 50 and 75%) to make modified fat chocolate muffins. The height of the baked product fell as the fat replacement percentage rose, but no weight loss differences were observed after 1hour cooling. The texture of the modified fat muffins showed lower values for hardness, chewiness and resilience than those of the control sample and retained greater moisture. The chocolate color of samples with the highest level of fat replacement was scored similar to the full-fat control formulation indicating a good color development without an additional amount of cocoa powder. The sponginess and springiness of the samples with the lowest fat replacement were scored similar to the full-fat control formulation. In general, muffins containing cocoa fiber were increasingly more cohesive and more difficult to chew and swallow when higher level of cocoa fiber was added (66).

Cookies are considered one of the high-fat food products that acquire texture and flavor characteristic from fat. Several studies have attempted to reduce the fat content of cookies by substituting food ingredients such as fruit purees and mungbean paste for fat. Generally, reduced-fat cookies were less acceptable than high-fat cookies, with difference in flavor and texture more pronounced as the level of fat replacement increased. Romanchik- cerpovicz *et al.* (27) showed that okra gum, derived by water extraction from immature pods of *Hibiscus escutentus* L., was an acceptable fat replacer in chocolate bar cookies. They prepared fat-free cookies by replacing margarine and egg yolk in high-fat cookies with okra gum. The moisture content of fresh okra gum (28.3±0.4%) cookies was higher than high-fat cookies (8.5±0.3%) and remained higher after 48 hours. Sensory scores for color, smell, flavor, aftertaste, moistness and overall acceptability for fresh cookies were acceptable, yet lower for flavor and aftertaste in fat-free cookies than high-fat cookies. After 48 hours, moistness ratings for fat-free cookies were acceptable and higher than high-fat cookies (67).

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3.7 *Ocimum canum*

Ocimum canum Linn. is a common food plant in Thailand. The other scientific name is *Ocumum americanum* Linn. (68). Common names include hairy basil, hoary basil, mang lak (Thai) and komko khaao (northern Thai). The plant is propagated by seeds and is commonly grown in gardens as an aromatic herb. The fragrant leaves are used for flavoring sauces, soups and salads. The plant possesses aromatic, carminative, diaphoretic and stimulant properties. A decoction of the plant is taken for coughs and that of leaves for dysentery. It is also used as a mouth wash for relieving toothache. The juice of leaves is given to children for cold, catarrh and bronchitis. A paste of leaves is used as an external application for parasitical skin affections. Fresh leaves are common in homeopathy (69). Ether extracts of leaves show *in vitro* antibacterial activity against *Micrococcus pyogenes* var. *aureus* and *Escherichia coli*. The volatile oil from the whole plant inhibits the growth of tubercular bacilli, the leaf oil shows anti-bacterial activity against *Mycobacteria*.

The leaves and seeds are used as ingredients in many Thai foods. The seed are small and oval (2.0 x 1.0 x 0.8 mm) with an average weight of 0.4- 2.0 mg/seed. Seeds are normally used in the form of raw whole seed to make desserts and can be used as bulk laxative (10). The seeds of the plant have also been used in the preparation of a cooling drink. The seed is composed of 55.7% carbohydrate, 19.6% fat, 17.9% protein and 6.9% minerals. The seed has mucilage that forms gel in water yielding a high viscosity. When steeped the seeds in water, they liberate mucilage which is semi-transparent and nearly tasteless. One g of seed in water will swell into a 45 ml volume. The mucilage isolated from seed shows high moisture content and moisture adsorption. Flow ability is poor but good in compressibility (70).

Acute toxicity test of the seeds by orally administered at a dose of 0.25-5 g/kg body weight in male and female rats, showed no toxic effects within 7 days of observation. Sub-chronic toxicity test by orally administered at a dose of 1 g/kg continuously for 10 days, exhibited no effects in rabbits, rats or cats. For chronic toxicity test, the seeds were orally administered at doses of 0.25, 0.5, 1 and 2 g in each group of rats continuously for 12 weeks. No changes in the histopathological characters of the livers, small and large intestines were observed. Being used as foods, precaution should be noted that the seeds should be prepared with sufficient water for

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completely swelling before consuming to prevent dehydration, flatulence, constipation or intestinal obstruction.

Premwatana *et al.* (71) determined the dietary fiber content in 29 commonly eaten Thai plants and found that *Ocimum canum* seeds contained the highest dietary fiber with low sugar content (80 g of dietary fiber and 0.55 g of sugar/100 g dry weight). They suggested that *Ocimum canum* seeds were a good source of viscous fiber which has physiological effects on the gastrointestinal tract and systemic effects. Previous studies reported the beneficial physiologic effects of *Ocimum canum* seeds, including cholesterol lowering, laxative and blood glucose lowering in human (72). In 1985, Muangman *et al.* (10) reported a beneficial effect of *Ocimum canum* seeds intake in reducing the incidence of constipation in 53 elderly postoperative patients. The effect of *Ocimum canum* seeds on bowel movement of healthy volunteers in comparison with a psyllium seed product, oranged-flavoured Metamucil® in order to assess its potential use as a bulk laxative was studied by Sriratanaban *et al.* (73). The stool weight of the elderly postoperative patients treated with *Ocimum canum* seed for a 3-8 day period significantly increased compared with that of the untreated period. In addition, the relationship of body weight, body mass index and lipid profile in overweight and obese subjects (BMI > 25 kg/m^2) when using hairy basil seeds in replacement of dinner was studied by Kijsirkul *et al.* (74). They found that using *Ocimum canum* Linn. seeds in replacement of dinner for 1 month decreased body weight and BMI of the subjects significantly.

The information on using the *Ocimum canum* mucilage in food is limited. Noiduang and Wilepana (75) used it as a stabilizer in dipping sauce for chicken. They found that the dipping sauce containing 0.3% (w/w) dried mucilage gave the highest sensory score in terms of viscosity and overall acceptance. The comparison of the sensory evaluation between dipping sauce containing 0.3% (w/w) dried mucilage and standard dipping sauce showed no significant differences.

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CHAPTER IV
MATERIALS AND METHODS

4.1 Preparation of Mucilage

Dry *Ocimum canum* seeds were bought from a supermarket in Bangkok Metropolitan. The seeds (20 g) were soaked in 800 ml deionized water for 1 h at room temperature to completely swell. Then, the swollen seeds were blended in a home use blender at a low speed and the mixture filtered through a clean cheese cloth to obtain mucilage. The mucilage was dried at 60^{o}C in a hot-air oven for 24 h. The dried mucilage was ground into powder and kept in a plastic bag at room temperature until use. A flow chart of mucilage preparation appears as **Appendix A**.

4.2 Preparation of Butter Cake

4.2.1 Preparation of Control Butter Cake

The formula of control butter cake used in this study was obtained from a conventional bakery cook book (76). The ingredients used in the control formula are shown in **Table 4.1**.

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Table 4.1 Ingredients of control cake

Ingredients	Quantity (g)
All purpose flour	105
Sugar	140
Butter	150
Egg	165
Vanilla extract	5
Baking powder	2
Salt	1

An oven (Mamaru Electric Oven Model MR1203) was preheated to 180^{o}C. In a large plastic bowl, all ingredients were blended using a mixer (Delonghi mixer, model Jolly Line KF352c.W) at a low speed until the mixture was homogeneous. After that it was beaten for another 3 minutes at a medium speed. The batter was poured into a stainless steel tray and baked at 180^{o}C for 55-60 minutes. A toothpick was inserted into the center of the cake and when it came out either clean or with only a few crumbs clinging to it suggesting that the cake was done. If there was uncooked batter or many damp crumbs on the toothpick, the cake was returned into the oven and continued baking. The cake was left at room temperature for 1 h for cooling. Then, it was stored in a plastic box for 24 h before further quality determination.

4.2.2 Preparation of Modified Fat Cake

For modified fat formula, all butter cake ingredients were kept constant except for the partial replacement of butter with *Ocimum canum* mucilage. Five g of mucilage were rehydrated in 500 ml distilled water and wait about 1 hour. A series of modified fat cakes were prepared by reducing the butter in the formula of the control cake to 75, 50, 25 and 0% (w/w). The rehydrated *Ocimum canum* mucilage was used at 0, 5, and 10 % (w/w) of butter weight to replace butter in the control formula. The modified fat cakes were coded as shown below in **Table 4.2.**

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Table 4.2 Code given to a series of modified fat cakes containing varying amount of *Ocimum canum* mucilage

% Butter	% *Ocimum canum* mucilage[1]		
	0	**5**	**10**
100	Control	-	-
75	F75R0	F75R5	F75R10
50	F50R0	F50R5	F50R10
25	F25R0	F25R5	F25R10
0	F0R0	F0R5	F0R10

[1] *Ocimum canum* mucilage used contained 1% of dry mucilage powder (w/w)

4.3 Quality Evaluation of the Modified Fat Cakes

4.3.1 Sensory Evaluation

Sensory evaluation of control and modified fat butter cakes was performed in a testing booth at the Sensory Science Laboratory, Food Science and Technology Section, Institute of Nutrition, Mahidol University, under daylight fluorescent bulb, air-conditioned and free from cooking odor and noise. The acceptability of all types of cake was evaluated by a panel of 50 subjects recruited from staff and graduate students of the Institute of Nutrition, Mahidol University. The samples were prepared and stored in a plastic box at room temperature one day prior to the evaluation. All samples were served on white paper plates labeled with three digit number codes selected from a random number table. Each sample was cut into a 2.5 x 2.5 cm piece. Three samples were served one at a time to each panelist during the test. The order of sample presented to each panelist was randomized. The panelists were asked to rinse their mouth with water between testing each sample. The panelists were not allowed to communicate with each other.

Each sample was evaluated for general appearance (overall appearance, color and texture) and acceptability (overall acceptability, flavor and texture). Nine-point hedonic scales were used for evaluation. The scale ranged from 1 to 9 where 1 =

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“Dislike extremely”, 5= “Neither like nor dislike” and 9 = “Like extremely”. The questionnaire for sensory evaluation is shown in **Appendix B**.

4.3.2 Baking Quality Evaluation

The baking quality of the prepared modified fat butter cakes were evaluated (77) to compare with the control cake.

Volume

The volume of each cake was determined 1 h after preparation using the sesame seed displacement method (78). The method measured the difference of the volume of low-density seeds (e.g. sesame seeds) in a container with and without cakes. The measurement was done in triplicates for each sample.

Texture

The texture of each cake was evaluated using a Texture Analyzer TA.XTPlus (Stable Micro Systems Ltd., Surrey, UK). Each sample was sliced off the bottom and top crusts plus marginal amount of the side to form a cube-like shape (2.5 x 2.5 x 2.5 cm). The texture characteristics of the sample were assessed for firmness and springiness using a 36 mm cylinder probe (P/36R). The firmness of cake was measured at the center of each piece and compressed to 25% of its original height. The maximum force of resistance to compression was recorded as cake firmness. Springiness was recorded as the forces after 60 seconds compression divided by the maximum force and then multiplied by 100%. Each batch of measurement for every cake formula consisted of ten pieces of cake. An example of the graph of texture profile analysis of butter cake is shown in **Appendix C**.

Color

The color was measured using a Juki Spectro Colorimeter Model JS555 (Color Techno System Corporation, Tokyo, Japan). Each sample was sliced off the bottom and top crusts and ground. The sample was then placed in a cuvette and the color measured by the colorimeter. The L*a*b* color scale was used, where L* expresses the lightness, a* expresses redness and b* expresses yellowness.

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Water Activity

The water activity (A_w) of each cake was measured with a Novasina water activity analyzer (Model IC-500, Switzerland). Each sample was sliced off the bottom and top crusts, ground and placed in a sample container. Water activity was measured at a control temperature of 25 ±1^{o}C in triplicates.

4.3.3 Storage Test

Each freshly prepared cake was stored in a plastic box at room temperature for 5 days. The temperature during the test period was around 24-30^{o}C. The effect of storage time on texture and water activity was measured on day 3 and day 5.

4.3.4 Calculation of Fat and Energy Content

The fat and energy content of each cake was calculated based on the food composition data in the Nutritive Values of Thai Foods (79).

4.4. Statistical Analysis

All experiments were repeated at least 3 times with duplicate measurements. Incomplete randomize block design was used. Statistical program SPSS™ software for windows version 13.0 (SPSS Inc., Illinois, USA) was used to analyze the data. Significance among mean values was assessed using One-Way ANOVA at 5% level of probability followed by LSD Multiple Range test. For the data from the storage test, due to the mold spoilage of some cake formulas at day 5, the results of water activity and texture measurements were evaluated for significant difference at 5% level of probability using Student's t-test.

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CHAPTER V
RESULTS

In this study, *Ocimum canum* mucilage was used to replace butter in the conventional recipe of butter cake. Modified fat cakes were prepared by reducing the amount of butter in the control formula to 75, 50, 25 and 0% of the original weight. At each level of fat reduction, butter was replaced with rehydrated *Ocimum canum* mucilage at 0, 5 and 10 % (w/w). The resulting cake products were subsequently determined for their sensory and baking qualities. Photographs of the control and modified fat butter cakes appear in **Appendix D**.

Quality Evaluation of the Control and Modified Fat Cakes

Sensory Evaluation

The sensory evaluation scores (general appearance and acceptability) of the control and 12 modified fat cakes are presented in **Table 5.1**. The analyses of variance for parameters in these experiments are shown in **Appendix E**. Figures that display the results for each sensory characteristic for easy comparison among formulas with the same level of fat reduction appear as **Appendix F**. The scores of general appearance (overall appearance, color and texture) and the acceptability (overall acceptability, acceptance of flavor and texture) of all cakes were higher than 6.0 (like slightly), except the acceptability of texture of F25R0 (formula containing 25% butter and 0% mucilage) and F0R5 (formula containing 0% butter and 5% mucilage). Overall results suggested that among the cakes (control cake and different modified fat cakes) there were some differences but there was no clear indication (no significant difference, $p>0.05$) on the trend of the effects of fat content or level of fat replacer. Nevertheless, at low levels of fat (25 and 0 % butter) the acceptability scores (before and after tasting were significantly lower ($p<0.05$) than those of the control and higher fat 75 and 50% butter) cakes.

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Table 5.1 Sensory evaluation scores of control and modified fat cakes containing *Ocimum canum* mucilage [1, 2, 3]

Sample code	General appearance			Acceptability		
	Overall appearance	Color	Texture	Overall acceptability	Flavor	Texture
Control	7.1 ± 0.8 [a]	7.5 ± 0.7 [a]	7.0 ± 1.0 [a,b]	7.3 ± 1.0 [a]	7.6 ± 1.2 [a]	6.8 ± 1.1 [a,b]
F75R0	7.1 ± 1.1 [a]	7.4 ± 1.2 [a,b]	6.9 ± 1.3 [a,b]	6.8 ± 1.2 [a,b,c]	7.0 ± 1.3 [a,b,c]	6.6 ± 1.3 [a,b,c]
F75R5	6.8 ± 1.2 [a,b]	7.0 ± 1.2 [b,c,d]	6.4 ± 1.4 [b,c]	6.7 ± 1.5 [a,b,c,d]	6.8 ± 1.5 [b,c,d]	6.4 ± 1.7 [b,c]
F75R10	7.0 ± 1.0 [a]	7.0 ± 1.2 [b,c,d]	7.0 ± 1.1 [a]	7.0 ± 1.0 [a,b]	7.2 ± 1.2 [a,b]	7.1 ± 1.3 [a]
F50R0	7.1 ± 1.2 [a]	7.3 ± 1.0 [a,b,c]	7.0 ± 1.0 [a]	7.1 ± 1.1 [a]	7.0 ± 1.3 [b,c,d]	6.5 ± 1.7 [a,b,c]
F50R5	6.7 ± 1.2 [a,b,c]	6.9 ± 1.1 [c,d,e]	6.6 ± 1.3 [a,b,c]	6.8 ± 1.3 [a,b,c]	7.0 ± 1.2 [b,c,d]	6.4 ± 1.6 [b,c]
F50R10	6.8 ± 1.3 [a,b]	7.0 ± 1.2 [b,c,d,e]	6.6 ± 1.5 [a,b,c]	6.7 ± 1.6 [a,b,c,d]	6.8 ± 1.6 [b,c,d]	6.5 ± 1.8 [a,b,c]
F25R0	6.7 ± 1.3 [a,b,c]	7.1 ± 1.3 [a,b,c,d]	6.6 ± 1.2 [a,b,c]	6.4 ± 1.4 [c,d]	6.7 ± 1.2 [c,d]	6.0 ± 1.7 [c,d]
F25R5	6.5 ± 1.5 [b,c]	6.8 ± 1.3 [d,e]	6.3 ± 1.4 [c]	6.6 ± 1.6 [b,c,d]	6.6 ± 1.6 [c,d]	6.1 ± 2.0 [b,c,d]
F25R10	6.7 ± 1.5 [a,b,c]	6.8 ± 1.4 [d,e]	6.3 ± 1.6 [c]	6.4 ± 1.8 [c,d]	6.5 ± 1.7 [d]	6.3 ± 1.0 [b,c,d]
F0R0	6.7 ± 1.4 [a,b,c]	7.0 ± 1.1 [b,c,d]	6.5 ± 1.3 [b,c]	6.5 ± 1.1 [b,c,d]	6.5 ± 1.2 [d]	6.2 ± 1.6 [b,c,d]
F0R5	6.2 ± 1.4 [c]	6.5 ± 1.3 [e]	6.3 ± 1.4 [c]	6.2 ± 1.3 [d]	6.5 ± 1.4 [d]	5.6 ± 1.6 [d]
F0R10	6.7 ± 1.6 [a,b,c]	6.9 ± 1.1 [b,c,d]	6.7 ± 1.4 [a,b,c]	6.9 ± 1.2 [a,b,c]	6.7 ± 1.4 [b,c,d]	6.7 ± 1.8 [a,b]

[1] Values are expressed as mean ± SD. (n=50)

[2] Values in the same column with different letters are significantly different at $p<0.05$.

[3] F=Level of butter (fat) reduction, R=Level of mucilage used. For cake identification (code), see **Table 4.2**.

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When comparing the cakes with the same amount of butter an increase in the amount of *Ocimum canum* mucilage used in the formula did not produce any significant effects ($p>0.05$) on the sensory scores of most cakes. A significant improvement in sensory scores ($p<0.05$) were observed with an increase in the amount of mucilage only in the formula without butter.

General appearance of all cakes was assessed in terms of the acceptability of the panelists on the color, texture and overall appearance. Reducing the amount of butter without adding *Ocimum canum* mucilage did not significantly change the acceptability towards color ($p>0.05$), except in the sample with no butter which received a significantly lower score ($p<0.05$) than that of the control. Addition of mucilage as a fat replacer in the modified fat cakes, however, significantly reduced the color preference ($p<0.05$). Nevertheless, this effect was not observed in the formula with no butter. Replacing butter with mucilage gave inconsistent results regarding the acceptability of the observed texture. In general the scores for modified fat cakes were in close range with that of the control. This, in turn, resulted in a similarity of the overall appearance score among all types of cake.

The control and modified fat cakes were also evaluated for the acceptability of flavor and texture after tasting as well as overall acceptability. Reduction of fat caused a marked decrease in flavor acceptability ($p<0.05$). The higher the percentage of butter replacement, the lower the score while adding mucilage as a fat replacer did not significantly help restore the flavor score at all levels ($p>0.05$). A similar trend was observed for the texture acceptability score when the amount of butter in the formula was reduced. A significant decrease in the score ($p<0.05$) was shown in the modified fat cakes with 25 and 0% butter. Interestingly, using 10% mucilage to replace butter could improve the texture score ($p<0.05$). The overall acceptability score of the modified fat cakes without mucilage and with all levels of addition of mucilage did not significantly differ from that of the control ($p>0.05$) when butter was removed up to 50%. In the modified fat cakes with 25 and 0% butter, the overall score was significantly different from the control ($p<0.05$) while no significant difference was found among these cakes with varying amount of mucilage .

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Baking Quality Evaluation

The volume and texture values (i.e. firmness and springiness) of control and modified fat cakes are shown in **Table 5.2**. The color values are presented in **Table 5.3**. The water activity is presented in **Table 5.4**. Figures that display the results for parameter for easy comparison among formulas with the same level of fat reduction appear as **Appendix F**.

Cake Volume

The volume of nearly all cakes was not significantly different ($p>0.05$) except that of the cake containing 0% fat which was significantly lower ($p<0.05$) than that of the others. Addition of *Ocimum canum* mucilage at all levels for each level of butter replacement in the cake did not significantly affect on the volume of cake.

Cake Texture

The firmness of modified fat cakes, except the cake containing 0% butter was significantly higher than that of the control cake ($p<0.05$). The value seemed to increase when the amount of *Ocimum canum* mucilage increased in the modified fat cakes with 75 and 50% butter while the values did not change much in the lower fat cakes. The springiness of the modified fat cakes with 75% butter did not differ significantly ($p>0.05$) from that of the control while the springiness of the remaining modified fat cakes tended to be higher than that of the control.

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Table 5.2 Volume and texture values of control and modified fat cakes [1, 2, 3]

Formula	Volume (ml)	Texture	
		Firmness (g)	Springiness (%)
Control	15.3±0.2 [a]	250 ±46 [g]	49.66 ±1.00 [f]
F75R0	15.4±0.2 [a]	372±45 [b,c]	53.38±0.95 [d,e]
F75R5	15.4±0.2 [a]	319±28 [d,e]	50.54±0.48 [f]
F75R10	15.3± 0.2 [a]	409±22 [a]	50.78±0.48 [f]
F50R0	15.0±0.2 [a,b]	340±28 [c,d]	52.86±0.36 [e]
F50R5	15.1±0.2 [a,b]	374±35 [b]	54.71±0.75 [b,c]
F50R10	14.8±0.1 [b]	382±40 [a,b]	54.32±0.48 [b,c,d]
F25R0	15.1±0.1 [a,b]	265±27 [g]	53.59±0.60 [c,d,e]
F25R5	15.1±0.2 [a,b]	302±27 [e,f]	55.48±0.41 [b]
F25R10	15.1±0.2 [a,b]	268±60 [f,g]	54.97±1.37 [b,c]
F0R0	13.1±0.2 [c]	162±29 [h]	57.40±2.50 [a]
F0R5	12.9±0.2 [c]	156±25 [h,i]	57.32±3.16 [a]
F0R10	13.0±0.2 [c]	132±27 [i]	58.37±1.580 [a]

[1] Values are expressed as mean ± SD. (n=30)

[2] Values in the same column with different letters are significantly different at $p<0.05$.

[3] F=Level of butter (fat) reduction, R=Level of mucilage used. For cake identification (code), see **Table 4.2**.

Color of Cake

When compared to the control, the color of modified fat cakes slightly increased in lightness ($p<0.05$). The lightness value (L*) of the cakes was altered only slightly when added with *Ocimum canum* mucilage. The redness value (a*) of all cakes was very low (-0.66 to +1.26). The yellowness value (b*) of the modified fat cakes became lower when the amount of butter in the formula was reduced. The amount of mucilage in the cakes did not significantly affect the yellowness ($p>0.05$).

Water Activity

Water activity value of the modified fat cakes was in the range of 0.87-0.92. The value was in the same range as that of the control (0.92). In general the

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water activity value of the cakes containing 10% mucilage was significantly higher ($p<0.05$) than that of the cakes with no mucilage addition.

Table 5.3 Color values of control and modified fat cakes [1, 2, 3]

Formula	Color Value		
	L*	a*	b*
Control	70.73 ±0.19.[a]	-0.62 ± 0.41 [a]	+37.09 ± 0.63 [e,f]
F75R0	72.04 ± 0.66 [b]	+0.50 ± 0.22 [f,g]	+36.56 ± 0.41 [d,e]
F75R5	72.40 ± 0.30 [b]	+0.80 ± 0.18 [g]	+38.15 ± 0.12 [g]
F75R10	72.63 ± 0.15 [b]	+0.06 ± 0.05 [d,e]	+38.44 ± 0.10 [g]
F50R0	74.49 ± 0.90 [c,d]	-0.10 ± 0.62 [b,c]	+37.82 ± 0.36 [f,g]
F50R5	74.41 ± 0.23 [c]	+0.34 ± 0.11 [e,f]	+33.43 ± 0.23 [c]
F50R10	71.76 ± 0.44 [a,b]	+1.26 ± 0.05 [h]	+35.77 ± 0.39 [d]
F25R0	77.13 ± 0.57 [f,g]	-0.66 ± 0.33 [a]	+31.57 ± 0.26 [a]
F25R5	75.80 ± 0.88 [e]	-0.04 ± 0.21 [c,d]	+31.21 ± 0.68 [a]
F25R10	76.43 ± 0.57 [e,f]	-0.42 ± 0.10 [a,b]	+32.53 ± 0.52 [b]
F0R0	75.63 ± 0.71 [d,e]	+0.44 ± 0.23 [e,f,g]	+31.24 ± 0.71 [a]
F0R5	77.68 ± 1.44 [g]	+0.03 ± 0.13 [d,e]	+32.28 ± 0.75 [b]
F0R10	75.48 ± 0.87 [c,d,e]	+0.70 ± 0.08 [f,g]	+31.99 ± 0.70 [a,b]

[1] Values are expressed as mean ± SD. (n=30)

[2] Values in the same column with different letters are significantly different at $p<0.05$.

[3] F=Level of butter (fat) reduction, R=Level of mucilage used. For cake identification (code), see **Table 4.2**.

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Table 5.4 Water activity of control and modified fat cakes [1, 2, 3]

Formula	A_w
Control	0.92 ± 0.01 [a]
F75R0	0.89 ± 0.01 [b,c,d,e]
F75R5	0.92 ± 0.01 [a,b,c]
F75R10	0.91 ± 0.01 [a,b,c,d]
F50R0	0.89 ± 0.01 [b,c,d,e]
F50R5	0.90 ± 0.00 [a,b,c,d]
F50R10	0.90 ± 0.00 [a,b,c,d,e]
F25R0	0.89 ± 0.00 [b,c,d,e]
F25R5	0.89 ± 0.00 [c,d,e]
F25R10	0.89 ± 0.00 [d,e]
F0R0	0.87 ± 0.01 [e]
F0R5	0.88 ± 0.01 [e]
F0R10	0.92 ± 0.05 [a,b]

[1] Values are expressed as mean ± SD. (n=30)

[2] Values in the same column with different letters are significantly different at $p<0.05$.

[3] F=Level of butter (fat) reduction, R=Level of mucilage used. For cake identification (code), see **Table 4.2**.

Effect of Storage

Effect of storage on the firmness, springiness and water activity of cakes are shown in **Tables 5.5, 5.6 and 5.7**, respectively. At day 5, there were molds present on some cake samples therefore these samples were discarded and the quality was not determined.

During 5 days of storage, the firmness values of the control cake and the modified fat cakes containing 75 and 50% butter decreased while those of the modified fat cakes with 25 and 0% butter increased significantly ($p<0.05$).

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Table 5.5 Effect of storage on firmness of cake [1, 2, 3]

Formula	Firmness (g)		
	Day 1	**Day 3**	**Day 5**
Control	251±46 [a]	213±27 [b]	ND [4]
F75R0	372±45 [a]	297±39 [b]	326±33 [b]
F75R5	319±28 [a]	276±27 [b]	323±36 [a]
F75R10	409±22 [a]	382±43 [a]	ND
F50R0	340±28 [a]	291±21 [b]	ND
F50R5	375±35 [a]	286±17 [b]	ND
F50R10	382±40 [a]	476±47 [b]	ND
F25R0	265±27 [c]	435±54 [b]	501±83 [a]
F25R5	302±27 [c]	355±43 [b]	408±47 [a]
F25R10	268±59 [b]	388±80 [a]	421±48 [a]
F0R0	162±29 [b]	214±48 [a]	230±40 [a]
F0R5	156±25 [c]	290±69 [b]	348±44 [a]
F0R10	132±27 [b]	283±17 [a]	290±52 [a]

[1] Values are expressed as mean ± SD. (n=30)

[2] Values in the same row with different letters are significantly different at $p<0.05$.

[3] F=Level of butter (fat) reduction, R=Level of mucilage used. For cake identification (code), see **Table 4.2**.

[4] ND = not determined.

The springiness value of the control cake and the modified fat cakes with 75% butter, regardless of the amount of mucilage, remained relatively constant. In contrast the values for the modified fat cakes containing 50, 25 and 0% butter significantly decreased over the storage time. At each level of butter replacement, varying the amount of mucilage used did not show any influence on the change in springiness.

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Table 5.6 Effect of storage on springiness of cake [1, 2, 3]

Formula	Springiness (%)		
	Day 1	**Day 3**	**Day 5**
Control	50± 1 [b]	51± 1 [a]	ND [4]
F75R0	53± 1 [a]	50± 1 [b]	49± 1 [c]
F75R5	50± 0 [b]	51± 0 [a]	50± 1 [c]
F75R10	51± 0 [b]	52± 1 [a]	ND
F50R0	53± 0 [a]	50± 0 [b]	ND
F50R5	55± 0 [a]	50± 1 [b]	ND
F50R10	54± 0 [a]	53± 0 [b]	ND
F25R0	54± 1 [a]	49± 1 [b]	49± 0 [b]
F25R5	55± 0 [a]	53± 1 [b]	52± 1 [c]
F25R10	55± 1 [a]	53± 1 [b]	52± 1 [c]
F0R0	57± 2 [a]	54± 1 [b]	53± 1 [b]
F0R5	57± 3[a]	53± 1 [b]	52± 1 [b]
F0R10	58± 2[a]	54± 1 [b]	54± 1 [b]

[1] Values are expressed as mean ± SD. (n=30)

[2] Values in the same row with different letters are significantly different at $p<0.05$.

[3] F=Level of butter (fat) reduction, R=Level of mucilage used. For cake identification (code), see **Table 4.2**.

[4] ND = not determined.

During storage for 5 days, the water activity of the control cake and the modified fat cakes containing 75% butter decreased slightly ($p<0.05$). The water activity of the remaining modified fat cakes appeared relatively constant regardless of the level of mucilage used.

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Table 5.7 Effect of storage on water activity of cake [1, 2, 3]

Formula	A_w		
	Day1	**Day 3**	**Day 5**
Control	0.92 ±0.01 [a]	0.89 ± 0.00 [b]	ND[4]
F75R0	0.89 ±0.01 [a]	0.88 ± 0.01 [b]	0.87± 0.00 [c]
F75R5	0.92 ± 0.06 [a]	0.90 ± 0.01 [b]	0.88 ± 0.01 [c]
F75R10	0.91 ± 0.01[a]	0.90 ± 0.01 [a]	ND
F50R0	0.89 ± 0.01 [a]	0.89 ± 0.01 [a]	ND
F50R5	0.90 ± 0.00 [a]	0.89 ± 0.01 [a]	ND
F50R10	0.90 ± 0.00 [a]	0.91 ± 0.00 [b]	ND
F25R0	0.89 ± 0.00 [a]	0.87 ± 0.01 [b]	0.87 ± 0.01 [b]
F25R5	0.89 ± 0.00 [a]	0.90 ± 0.00 [b]	0.89 ± 0.00 [a]
F25R10	0.89 ± 0.00 [a]	0.89 ± 0.00 [a]	0.89 ± 0.01 [a]
F0R0	0.87 ± 0.01 [a]	0.88 ± 0.01 [a]	0.89 ± 0.01 [a]
F0R5	0.88 ± 0.01 [b]	0.88 ± 0.00 [b]	0.89 ± 0.00 [a]
F0R10	0.92 ± 0.05 [a]	0.89 ± 0.00 [a]	0.89 ± 0.01 [a]

[1] Values are expressed as mean ± SD. (n=30)

[2] Values in the same row with different letters are significantly different at $p<0.05$.

[3] F=Level of butter (fat) reduction, R=Level of mucilage used. For cake identification (code), see **Table 4.2**.

[4] ND = not determined.

Estimation of Fat and Energy Content

The estimates of fat and energy content of the control and modified fat cakes are presented in **Table 5.8**. All values were derived by calculation based on the quantity of each ingredient and their respective reported nutritive values (**Appendix G**). As expected the amount of fat in 100 g cake was reduced correspondingly with the increasing replacement of butter in the cake formula using *Ocimum canum* mucilage. The fat content decreased from 28 g in the control cake to 23, 18, 12 and 5 g in the modified fat cake with 75, 50, 25 and 0% butter, respectively. As a result the

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total energy content was lower in the modified fat cakes. The energy content of the control cake was 444 kcal and that of the modified fat cakes was in the range of 314 – 420 kcal.

Table 5.8 The calculated energy, fat and % reduction per 100 g of butter cake[1]

Formula	Energy (kcal)	% Reduction of energy	Fat (g)	% Reduction of fat
Control	444	5	28.1	16
F75R0	420	8	23.7	18
F75R5	408	8	23.1	18
F75R10	408.	12	23.1	34
F50R0	391	13	18.7	34
F50R5	386	14	18.4	35
F50R10	383	19	18.3	54
F25R0	361	20	12.9	55
F25R5	353	22	12.5	56
F25R10	345	28	12.3	80
F0R0	321	28	5.7	80
F0R5	321	29	5.7	80
F0R10	314	5	5.6	16

[1]F=Level of butter (fat) reduction, R=Level of mucilage used. For cake identification (code), see **Table 4.2**.

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CHAPTER VI
DISCUSSION

A growing awareness of obesity and coronary heart disease has led to a widespread recognition about the importance of reducing fat and total energy consumption. Fats and oils are important for their nutritional, functional and organoleptic properties. As the most concentrated source of energy, they supply approximately 9 kcal per g, over twice that delivered by protein and carbohydrate. This explains why fats are such the target for replacement. Therefore, attempts have been made to develop food products with a lower fat content. One of the common types of foods which have been targeted is bakery products including butter cakes. Formulating cakes with a lower fat content requires alternative ingredients to replace the functionality of fat.

In this study, *Ocimum canum* mucilage acted as a fat replacer to replace butter in the control cake formula. In general, carbohydrate-based fat replacers are suitable for baking because they adsorb a substantial amount of water. In food systems, carbohydrate-based fat replacers can increase viscosity, form gel, provide mouthfeel and texture and increase water-holding capacity (63).

Generally, fat contributes a good texture to food. In shortened cake it also serves as a means of incorporating air into the batter. Therefore, it contributes to tenderness, volume and moistness of the cake (58, 59).

Preparation of *Ocimum canum* Mucilage

Ocimum canum mucilage was prepared from fully swollen seeds (in water). The amount of water used to soak the seeds was based on a previous study that one g of seeds could swell into 45 ml (72). Therefore, the volume of water should be around 45 times the amount of seeds. In this study 200 g of seeds were soaked in 800 ml water (about 40 times the volume) since this volume of water was sufficient to provide slurry that could be manually manipulated to separate the mucilage from the

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pulp. For household or institutional application the hydrated mucilage could be added directly to replace butter in the cake formula. However, in the research it was necessary to prepare a large batch of mucilage for use in all experiments so the mucilage was dried in a hot air oven and ground into powder. When required the mucilage powder was rehydrated to form 1% (w/w) slurry and added to the cake batter.

Quality Characteristics of Modified fat Cakes

Sensory Qualities

The results of sensory evaluation suggested that butter cake is suitable for the study on using a natural fat replacer, namely *Ocinum canum* mucilage to develop a modified fat product. The test-panelists could not differentiate the quality characteristics among the majority of the samples. The exceptions were only on color, texture and acceptability of 5 and 10% mucilage added to the cake containing 25 and 0% butter. This suggested that the adjustment of fat content to a very low level is difficult because palatability is an important aspect of food choice and consumption, and certainly fat increases palatability (80). Considering the results from sensory evaluation, the amount of butter used in the cake could be decreased at least to 50% of the original formula. The concentration of mucilage at any levels of fat in the modified fat samples did not significantly affect the acceptability of flavor. This implies the possibility of the replacing butter with *Ocinum canum* mucilage.

Most food items prepared with a fat replacer are often perceived by consumers as lacking in taste since they can only carry water soluble flavor but not lipid soluble flavor. Nevertheless, the amount of egg within the cake formula of this study not only provided the emulsifying ability but also helped to dissolve lipid soluble flavors (63, 81) resulting that the cake containing 0% butter could still be accepted with 10% mucilage added. Its flavor was judged as slightly inferior to the original control cake.

It was interesting to note that the cake containing 0% butter with 10% *Ocinum canum* mucilage showed good appearance and acceptability, especially its texture that was not different from the control cake.

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Physical Qualities

Reducing the amount of butter in the cake formula did not result in a significant change in the volume of the modified fat cakes. When *Ocimum canum* mucilage was used to replace butter in the cake formula, the volume of modified fat cakes, containing 75, 50 and 25% butter was not significantly different from the control cake. A similar result was reported by Zambrono *et al.* (82). They found that the volume of modified fat cakes in which the fat was substituted with up to 75% with either guar or xanthan gum did not differ significantly. On the contrary, Borneo *et al.* (9) showed that as the substitution level of fat with chia (*Salvia hispanica* L.) gel approached about 50%, the cake volume significantly decreased. In this experiment only the volume of cakes containing 0% butter was significantly lower than that of the control cake. Cake volume could be affected by fat replacer levels, fat replacer types and emulsifier level. According to Khalil (64), cake volume increased as the fat replacer (N-flate, litesse and paselli MD) level increased. Addition of emulsifiers (mono- and di-glycerides) was found to improve cake volume (64).

The firmness of modified fat cake in this experiment, except the one containing 0% butter, was found to be higher than that of the control cake. Addition of mucilage to the cakes containing 75 and 50% butter, the firmness significantly increased. In the modified fat cake with 25% butter the firmness did not change much while it was slightly decreased for the formula containing 0% butter. In muffin, increasing the level of peach dietary fiber above 2% increased the hardness and chewiness of muffins. The effect was more pronounced in muffins with low oil content (83). On the other hand, addition of soluble cocoa fiber as a fat replacer in chocolate muffins gave more tender and crumbly muffin(66). A similar result was observed in this study at low level of butter. In such case the added mucilage may absorb and help to retain moisture within the cake resulting in a softer texture. While in modified fat cake with limited amount of butter and no fat replacer the texture became more compact. The springiness values of the muffins fell significantly as soluble cocoa fiber was used to increasingly substitute for fat (66). In the current study, the springiness of modified fat cakes was higher than that of the control and was found be highest in the cake containing 0% butter. Adding mucilage did not seem to have any pronounced effects on the springiness of the modified fat cakes.

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Concerning the color of the samples, the results revealed that the lightness value (L*) significantly increased when the amount of butter decreased. This was due to a reduction of pigments particularly carotenoids provided by butter. An opposite results were observed when mucilage was applied. Addition of 10% mucilage to the cakes containing 50 and 25% butter significantly decreased the lightness. The results are in agreement with those obtained by Akesowan (65). He found that the addition of konjac flour and soy protein isolated to chiffon cakes significantly decreased the L* value. Khalil (64) also reported that increasing the levels of fat replacers significantly decreased the brightness of modified fat cakes.

Lowering the amount of fat at certain levels affected the color of the product. The yellowness value (b*) of the modified fat cakes containing 75 and 50% butter was not significantly different from that of the control. However, changes in the b* value occurred in the cakes containing 25 and 0% butter. The different appearance might be due to the color of butter used in the formula. In addition, the color of the fat replacer may contribute to the color of the final product. The addition of various levels of konjac flour and soy protein isolate to chiffon cakes made their overall color significantly darker than that of the control (65). The color of shortened cake prepared by replacing fat with pawpaw fruit (*Asimina triloba*) puree (higher than 25%) was the other example that the color values of the final products significantly increased because the color of such puree ranged from yellow to orange (84). However, *Ocinum canum* mucilage might have an advantage over some other mucilagse since it is opaque and white. It did not affect the yellowness of all modified fat cakes in the present study.

In terms of water activity, the control and all modified fat cakes yielded a value around 0.90 which is highly susceptible to microbial spoilage. The use of mucilage as a fat replacer in these cakes, nonetheless, did not cause a significant increase in the water activity value.

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Fat and Energy Content

The fat content of the modified fat cake containing 75, 50, 25 and 0 % butter showed about 17, 34, 55 and 80% reduction, respectively from the control formula (100% butter) while the energy content decreased 7, 13, 20 and 28%, respectively. Reduction of fat and energy intake from foods, especially those of desserts, is becoming an important concern in Thailand because the number of obese children and adults is now growing (85). Aekplakorn and Mo-Suwan (86) revealed a disproportionate increase of obesity in the rural area, which indicates that the problem no longer restricts to the higher socioeconomic group (86). Thus, researches in using any fat replacers to modify commonly consumed foods and desserts to be healthier are needed. Moreover, the reduction of nutritional energy intake often reduces the incidence of both spontaneous and induced cancers in humans and experimental animals in an approximately dose dependent manner (87).

Besides energy difference between the control and modified fat cakes, the other difference is the content of mucilage. It is well known that mucilage is a kind of soluble fiber which is non-digestible carbohydrate. Hence, it can provide the benefits of dietary fiber in the diet (88).

Effect of storage

The cake samples were separately kept in sealed plastic boxes at room temperature for 5 days. The surface of the cakes was examined visually for the presence of molds every 24 hours in order to make a decision to stop the analyses of texture and water activity. It was not surprised to find the molds on the surface of some cake samples on day 5 since the water activity of all samples was in the range of 0.89-0.92. This range is suitable for most mold growth (89) because it is higher than the minimum requirement of 0.80 for mold (90, 91). The room temperature is the other factor of concern since the range of room temperature during the study was around 24-30^{o}C that certainly supported the cultivation of mold (90). In general, lowering water activity below the optimum range for microbial growth can alter the growth rate and inactivate the microorganism. Furthermore, other environment parameters such as pH and temperature can influence the minimum water activity value for growth of molds. The optimum temperature ranges for growth of molds are

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18-30^{o}C and the maximum is 55^{o}C. Therefore, to decrease molds growth, the cake products should be kept at the temperature lower than 18^{o}C such as in the refrigerator. If stored at room temperature, the fresh modified fat cakes could be kept at least 3 days without the use of any preservatives.

Zambrano *et al*. developed modified fat cakes by substituting the fat with either guar or xanthan gum. At time zero, they found that water activity of the cakes with fat substitution show no significant differences when compared with the standard cake. Water activity of their cake was in the range of 0.837-0.865. They found molds growth after 20-25 day storage at 25^{o}C. They also found that after 5, 10 and 15 days of storage, the cake with 50% substitution with guar or xanthan gum, the cakes showed no significant differences in elasticity. This result could be related to the capacity of the gums to retain water and avoid its migration (82)

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CHAPTER VII
CONCLUSION

Reduction of fat and energy intake from foods, especially those of desserts, is becoming an important concern in Thailand because the number of obese children and adults is now growing. Moreover, the reduction of nutritional energy intake often reduces the incidence of both spontaneous and induced cancers in humans and experimental animals. Thus, researches in using any fat replacers to modify commonly consumed foods and desserts to be healthier are needed. Application at a household level is of particular interest since it will help consumers to modify their diet more freely and conveniently.

In this study, *Ocimum canum* mucilage acted as a carbohydrate-based fat replacer to replace butter in the control cake formula. Adding mucilage seemed to have effects on the physical properties of the modified fat cakes. When *Ocimum canum* mucilage was used to replace butter in the cake formula, the volume of modified fat cakes was not significantly different from the control cake while the firmness of modified fat cake, except the one containing 0% butter, was found to be higher than that of the control cake. Springiness of modified fat cakes was higher than that of the control and was found be highest in the cake containing 0% butter. Lowering the amount of fat at certain levels affected the color of the product. The lightness value (L*) significantly increased when the amount of butter decreased while the change in yellowness value (b*) occurred in the cakes containing 25 and 0% butter. The different appearance might be due to the change in the contribution of the color of butter used in the formula. Considering the results from sensory evaluation, the amount of butter used in the cake could be decreased at least to 50% of the original formula. All modified fat cakes were accepted to the panelist as “liked slightly” to “liked moderately”. The concentration of mucilage at any levels of fat in the modified fat samples did not significantly affect the acceptability of flavor. It was also interesting to note that the cake containing 0% butter with 10% *Ocinum canum*

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mucilage showed good appearance and acceptability, especially its texture that was not different from the control cake. This implies the possibility of the replacing butter with *Ocinum canum* mucilage.

The fat content of the modified fat cakes gave 17- 80% reduction while the energy content decreased 7- 28% from the control formula (100% butter). Besides the benefit of energy difference between the control and modified fat cakes, the other is the content of mucilage. It is well known that mucilage is a kind of dietary fiber which is non-digestible carbohydrate. Hence, it can provide the benefits of soluble dietary fiber in the diet. Furthermore, *Ocinum canum* mucilage might have an advantage over some other mucilage since it is opaque and white in color. It did not affect the yellowness of all modified fat cakes in the present study. The concentration of mucilage at any levels of fat in the modified fat samples did not significantly affect the acceptability of flavor.

Mold growth was seen on the surface of some cake samples on day 5 of storage at room temperature since the water activity of the samples was around 0.90 which was suitable for most mold growth. The use of mucilage as a fat replacer did not cause a significant change in the water activity value. To prevent mold growth, the cake products should be kept at the temperature lower than 18^{o}C such as in the refrigerator. If stored at room temperature, the fresh modified fat cakes could be kept at least 3 days without the use of any preservatives.

In conclusion, *Ocinum canum* mucilage has a good potential to be used as a fat replacer in butter cake. The current study could be used as a guideline for developing other modified fat foods containing the mucilage that can be prepared at household or institutional level. Moreover, it may be possible to apply the mucilage in some other low-calorie food items. Thus, further research in this area needs to be undertaken.

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APPENDICES

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APPENDIX A
FLOW CHART OF MUCILAGE PREPERATION

20 g dry seeds

↓

Soak in 800 ml DI water

↓

Blend

↓

Separate mucilage from seeds (manually)

↓

Dry mucilage in a hot-air oven (60^{o}C, 24h)

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APPENDIX B

แบบสอบถามการประเมินผลทางประสาทสัมผัส

ผลิตภัณฑ์เค้กทดแทนไขมัน

ชื่อผลิตภัณฑ์…….เค้ก……. หมายเลขที่.....

วันที่ …….. เวลา …….

อายุ …….. ปี เพศ (.....) ชาย (.....) หญิง

คำชี้แจง : แบบสอบถามมีทั้งหมด 2 ตอน กรุณาตอบแบบสอบถามทั้งหมด

ตอนที่ 1 ก่อนชิมผลิตภัณฑ์ เมื่อท่านได้รับผลิตภัณฑ์ กรุณาให้คะแนนความชอบของท่าน โดยการมอง แล้ว ขีดเครื่องหมาย ✓ ลงในช่องที่ตรงกับความคิดเห็นของท่านมากที่สุด

1. ความชอบต่อลักษณะโดยรวม เมื่อได้เห็นผลิตภัณฑ์	2. สีของผลิตภัณฑ์	3. รูปร่างของผลิตภัณฑ์ เช่น ความนูน ความฟู เนื้อละเอียด หยาบ ฯลฯ
….. ชอบมากที่สุด	….. ชอบมากที่สุด	….. ชอบมากที่สุด
….. ชอบมาก	….. ชอบมาก	….. ชอบมาก
….. ชอบปานกลาง	….. ชอบปานกลาง	….. ชอบปานกลาง
….. ชอบเล็กน้อย	….. ชอบเล็กน้อย	….. ชอบเล็กน้อย
….. เฉย ๆ *	….. เฉย ๆ *	….. เฉย ๆ *
….. ไม่ชอบเล็กน้อย	….. ไม่ชอบเล็กน้อย	….. ไม่ชอบเล็กน้อย
….. ไม่ชอบปานกลาง	….. ไม่ชอบปานกลาง	….. ไม่ชอบปานกลาง
….. ไม่ชอบมาก	….. ไม่ชอบมาก	….. ไม่ชอบมาก
….. ไม่ชอบมากที่สุด	….. ไม่ชอบมากที่สุด	….. ไม่ชอบมากที่สุด
ข้อเสนอแนะ……	ข้อเสนอแนะ……	ข้อเสนอแนะ……

* เฉย ๆ หมายถึงความรู้สึกระหว่างชอบและไม่ชอบ

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ตอนที่ 2 หลังชิมผลิตภัณฑ์ เมื่อท่านได้ชิมผลิตภัณฑ์แล้ว กรุณาขีดเครื่องหมาย ✓ ลงในช่องที่ตรงกับความรู้สึกและความชอบของท่านมากที่สุด

1. ความชอบต่อผลิตภัณฑ์โดยรวม	2. ความชอบเฉพาะกลิ่นรส	3. ความชอบในลักษณะเนื้อสัมผัส**
….. ชอบมากที่สุด	….. ชอบมากที่สุด	….. ชอบมากที่สุด
….. ชอบมาก	….. ชอบมาก	….. ชอบมาก
….. ชอบปานกลาง	….. ชอบปานกลาง	….. ชอบปานกลาง
….. ชอบเล็กน้อย	….. ชอบเล็กน้อย	….. ชอบเล็กน้อย
….. เฉย ๆ *	….. เฉย ๆ *	….. เฉย ๆ *
….. ไม่ชอบเล็กน้อย	….. ไม่ชอบเล็กน้อย	….. ไม่ชอบเล็กน้อย
….. ไม่ชอบปานกลาง	….. ไม่ชอบปานกลาง	….. ไม่ชอบปานกลาง
….. ไม่ชอบมาก	….. ไม่ชอบมาก	….. ไม่ชอบมาก
….. ไม่ชอบมากที่สุด	….. ไม่ชอบมากที่สุด	….. ไม่ชอบมากที่สุด
ข้อเสนอแนะ……	ข้อเสนอแนะ……	ข้อเสนอแนะ……
……	……	……
……	……	……
	…	

* เฉย ๆ หมายถึงความรู้สึกระหว่างชอบและไม่ชอบ

** ความชอบในลักษณะเนื้อสัมผัส ขึ้นกับผลิตภัณฑ์นั้น ๆ เช่น

- เค้ก ให้ท่านสังเกตถึงความละเอียดของเนื้อ ฟองอากาศ และความนุ่ม

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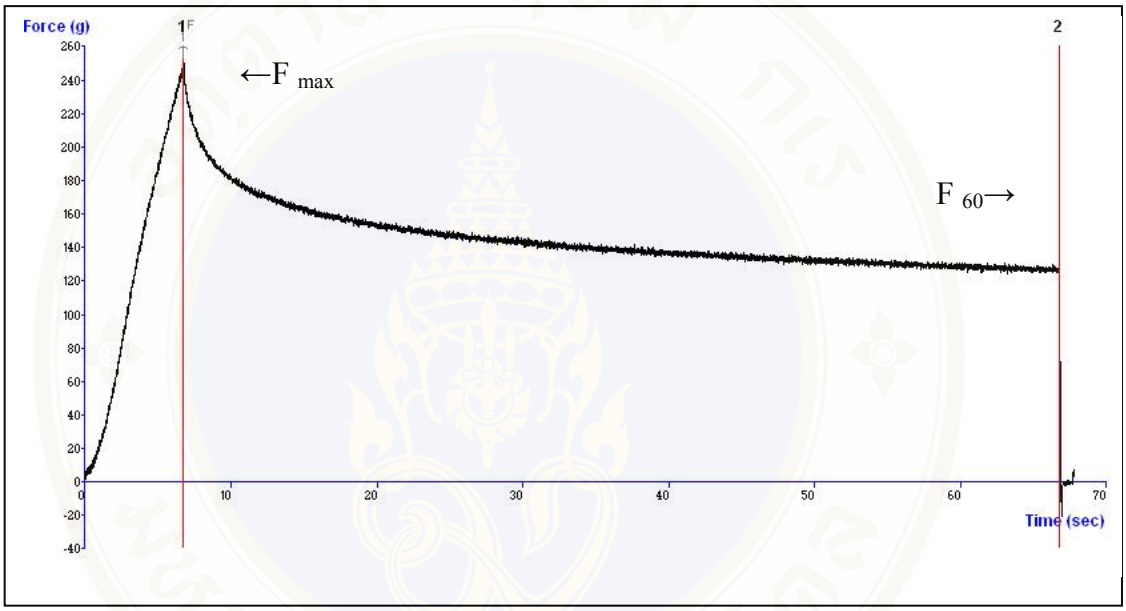
APPENDIX C

AN EXAMPLE GRAPH OF TEXTURE ANALYSIS OF CAKE



Where Firmness = Maximum force (F_{max})

Springiness = % Recover = $\frac{F_{60}}{F_{max}}$ x 100

F_{60} = Force after 60 seconds

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APPENDIX D
PHOTOGRAPHS OF CONTROL AND MODIFIED FAT BUTTER CAKE

Figure D1: Photograph of control formula cake

Figure D2: Photograph of F75R0 formula cake

Figure D3: Photograph of F75R5 formula cake

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Figure D4: Photograph of F75R10 formula cake

Figure D5: Photograph of F50R0 formula cake

Figure D6: Photograph of F50R5 formula cake

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Figure D7: Photograph of F50R10 formula cake

Figure D8: Photograph of F25R0 formula cake

Figure D9: Photograph of F25R5 formula cake

Figure D10: Photograph of F25R10 formula cake

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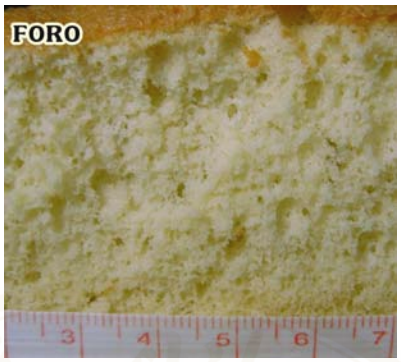

Figure D11: Photograph of F0R0 formula cake

Figure D12: Photograph of F0R5 formula cake

Figure D13: Photograph of F0R10 formula cake

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A PPENDIX E

ANOVA TABLE OF THE RESULTS OF QUALITY EVALUATION

Sensory Evaluation

		Sum of Squares	df	Mean Square	F	Sig.
Overall Appearance	Between Groups	37.293	12	3.108	1.970	.025
	Within Groups	973.407	617	1.578		
	Total	1010.700	629			
Color	Between Groups	39.807	12	3.317	2.347	.006
	Within Groups	872.187	617	1.414		
	Total	911.994	629			
Texture Appearance	Between Groups	41.921	12	3.493	1.953	.026
	Within Groups	1103.420	617	1.788		
	Total	1145.341	629			
Overall Acceptability	Between Groups	48.447	12	4.037	2.217	.010
	Within Groups	1123.680	617	1.821		
	Total	1172.127	629			
Flavor	Between Groups	51.556	12	4.296	2.299	.007
	Within Groups	1152.967	617	1.869		
	Total	1204.522	629			
Texture Acceptability	Between Groups	83.686	12	6.974	2.527	**.003**
	Within Groups	1702.900	617	2.760		
	Total	1786.586	629			

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Volume

volume					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	120.200	12	10.017	33.389	.000
Within Groups	35.100	117	.300		
Total	155.300	129			

Texture Analysis

		Sum of Squares	df	Mean Square	F	Sig.
Firmness	Between Groups	1011413.741	12	84284.478	60.977	.000
	Within Groups	161722.368	117	1382.242		
	Total	1173136.109	129			
Springness	Between Groups	879.150	12	73.262	36.985	.000
	Within Groups	231.761	117	1.981		
	Total	1110.911	129			

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Color Measurement

		Sum of Squares	df	Mean Square	F	Sig.
L	Between Groups	180.181	12	15.015	30.069	.000
	Within Groups	12.983	26	.499		
	Total	193.164	38			
a	Between Groups	11.663	12	.972	14.362	.000
	Within Groups	1.760	26	.068		
	Total	13.423	38			
b	Between Groups	295.955	12	24.663	95.759	.000
	Within Groups	6.696	26	.258		
	Total	302.652	38			

Water Activity

Aw

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.008	12	.001	2.642	.019
Within Groups	.006	26	.000		
Total	.014	38			

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Texture Analysis (Storage)

Control

		Sum of Squares	df	Mean Square	F	Sig.
FirmnessControl	Between Groups	7063.950	1	7063.950	4.522	.048
	Within Groups	28118.898	18	1562.161		
	Total	35182.848	19			
SpringinessControl	Between Groups	5.412	1	5.412	6.324	.022
	Within Groups	15.406	18	.856		
	Total	20.818	19			

F75R0

		Sum of Squares	df	Mean Square	F	Sig.
FirmnessF75R0	Between Groups	28816.586	2	14408.293	8.340	.002
	Within Groups	46648.328	27	1727.716		
	Total	75464.914	29			
SpringinessF75R0	Between Groups	84.451	2	42.225	63.682	.000
	Within Groups	17.903	27	.663		
	Total	102.354	29			

F75R5

		Sum of Squares	df	Mean Square	F	Sig.
FrimnessF75R5	Between Groups	13621.113	2	6810.556	6.409	.005
	Within Groups	28690.381	27	1062.607		
	Total	42311.494	29			
SpringinessF75R5	Between Groups	16.053	2	8.026	17.786	.000
	Within Groups	12.185	27	.451		
	Total	28.238	29			

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F75R10

		Sum of Squares	df	Mean Square	F	Sig.
FirmnessF75R10	Between Groups	3785.514	1	3785.514	2.914	.105
	Within Groups	23383.904	18	1299.106		
	Total	27169.418	19			
SpringinessF75R10	Between Groups	9.494	1	9.494	19.751	.000
	Within Groups	8.653	18	.481		
	Total	18.147	19			

F50R0

		Sum of Squares	df	Mean Square	F	Sig.
FirmnessF50R0	Between Groups	12067.360	1	12067.360	17.941	.000
	Within Groups	12107.126	18	672.618		
	Total	24174.486	19			
SpringinessF50R0	Between Groups	27.601	1	27.601	142.259	.000
	Within Groups	3.492	18	.194		
	Total	31.093	19			

F50R5

		Sum of Squares	df	Mean Square	F	Sig.
FrimnessF50R5	Between Groups	38861.016	1	38861.016	45.764	.000
	Within Groups	15284.914	18	849.162		
	Total	54145.930	19			
SpringinessF50R5	Between Groups	102.954	1	102.954	111.742	.000
	Within Groups	16.584	18	.921		
	Total	119.538	19			

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F50R10

		Sum of Squares	df	Mean Square	F	Sig.
FirmnessF50R10	Between Groups	43524.450	1	43524.450	20.309	.000
	Within Groups	38575.085	18	2143.060		
	Total	82099.535	19			
SpringinessF50R10	Between Groups	6.596	1	6.596	29.196	.000
	Within Groups	4.067	18	.226		
	Total	10.663	19			

F25R0

		Sum of Squares	df	Mean Square	F	Sig.
FirmnessF25R0	Between Groups	297121.432	2	148560.716	38.088	.000
	Within Groups	105313.302	27	3900.493		
	Total	402434.734	29			
SpringinessF25R0	Between Groups	128.587	2	64.294	131.311	.000
	Within Groups	13.220	27	.490		
	Total	141.807	29			

F25R5

		Sum of Squares	df	Mean Square	F	Sig.
FirmnessF25R5	Between Groups	55375.717	2	27687.858	15.617	.000
	Within Groups	47868.800	27	1772.919		
	Total	103244.516	29			
SpringinessF25R5	Between Groups	77.110	2	38.555	103.415	.000
	Within Groups	10.066	27	.373		
	Total	87.176	29			

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F25R10

		Sum of Squares	df	Mean Square	F	Sig.
FirmnessF25R10	Between Groups	117700.786	2	58850.393	13.013	.000
	Within Groups	122106.879	27	4522.477		
	Total	239807.665	29			
SpringinessF25R10	Between Groups	43.728	2	21.864	19.462	.000
	Within Groups	30.333	27	1.123		
	Total	74.061	29			

F0R0

		Sum of Squares	df	Mean Square	F	Sig.
FirmnessF0R0	Between Groups	22719.178	2	11359.589	6.398	.005
	Within Groups	47940.370	27	1775.569		
	Total	70659.548	29			
SpringinessF0R0	Between Groups	116.981	2	58.490	19.600	.000
	Within Groups	80.575	27	2.984		
	Total	197.556	29			

F0R5

		Sum of Squares	df	Mean Square	F	Sig.
FirmnessF0R5	Between Groups	193214.765	2	96607.382	35.643	.000
	Within Groups	73182.239	27	2710.453		
	Total	266397.004	29			
SpringinessF0R5	Between Groups	151.790	2	75.895	18.507	.000
	Within Groups	110.726	27	4.101		
	Total	262.516	29			

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F0R10

		Sum of Squares	df	Mean Square	F	Sig.
FirmnessF0R10	Between Groups	160426.966	2	80213.483	56.813	.000
	Within Groups	38120.706	27	1411.878		
	Total	198547.672	29			
SpringinessF0R10	Between Groups	120.769	2	60.385	40.305	.000
	Within Groups	40.451	27	1.498		
	Total	161.220	29			

Water Activity (Storage)

Water Activity

		Sum of Squares	df	Mean Square	F	Sig.
AwControl	Between Groups	.001	1	.001	20.220	.011
	Within Groups	.000	4	.000		
	Total	.002	5			
AwF75R0	Between Groups	.001	2	.001	14.498	.005
	Within Groups	.000	6	.000		
	Total	.001	8			
AwF75R5	Between Groups	.002	2	.001	22.899	.002
	Within Groups	.000	6	.000		
	Total	.002	8			
AwF75R10	Between Groups	.000	1	.000	1.330	.313
	Within Groups	.000	4	.000		
	Total	.000	5			
AwF50R0	Between Groups	.000	1	.000	.096	.772
	Within Groups	.000	4	.000		
	Total	.000	5			
AwF50R5	Between Groups	.000	1	.000	3.056	.155
	Within Groups	.000	4	.000		
	Total	.001	5			

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Water Activity

		Sum of Squares	df	Mean Square	F	Sig.
AwF50R10	Between Groups	.000	1	.000	24.000	.008
	Within Groups	.000	4	.000		
	Total	.000	5			
AwF25R0	Between Groups	.001	2	.000	10.887	.010
	Within Groups	.000	6	.000		
	Total	.001	8			
AwF25R5	Between Groups	.000	2	.000	10.979	.010
	Within Groups	.000	6	.000		
	Total	.000	8			
AwF25R10	Between Groups	.000	2	.000	2.465	.165
	Within Groups	.000	6	.000		
	Total	.000	8			
AwF0R0	Between Groups	.000	2	.000	.981	.428
	Within Groups	.001	6	.000		
	Total	.001	8			
AwF0R5	Between Groups	.001	2	.000	7.456	.024
	Within Groups	.000	6	.000		
	Total	.001	8			
AwF0R10	Between Groups	.001	2	.001	.826	.482
	Within Groups	.005	6	.001		
	Total	.007	8			

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APPENDIX F

BAR GRAPHS OF THE RESULTS OF QUALITY EVALUATION

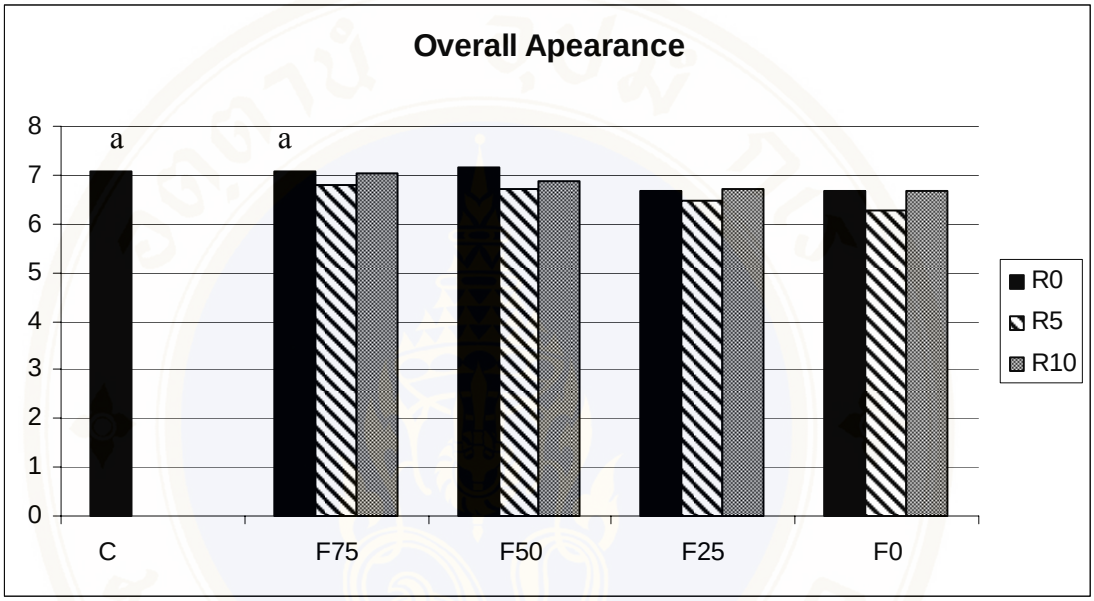

Figure F1. Sensory scores of overall appearance

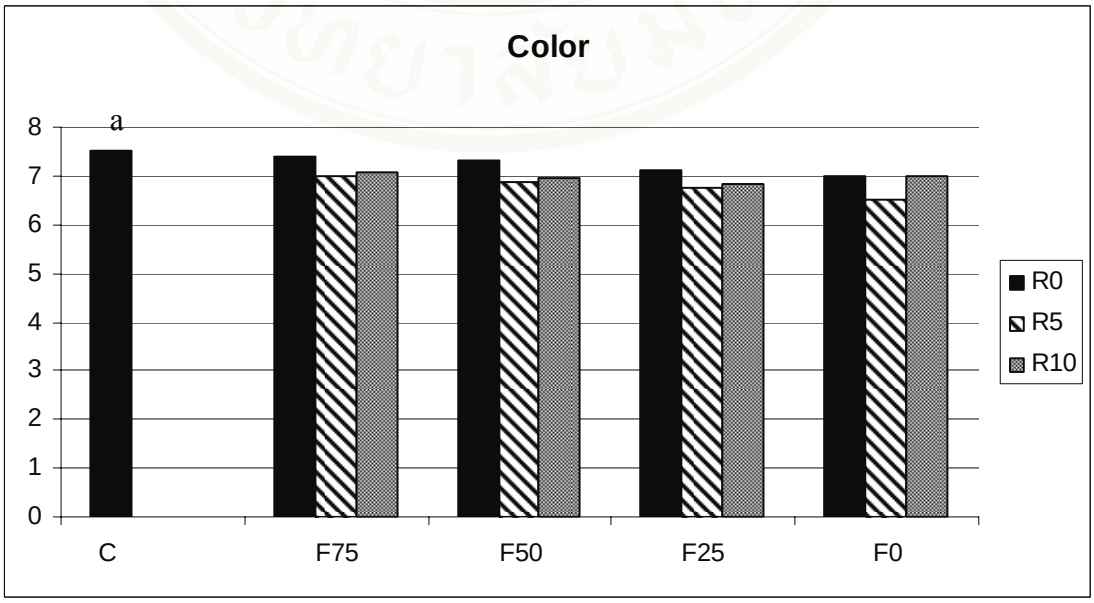

Figure F2. Sensory scores of color

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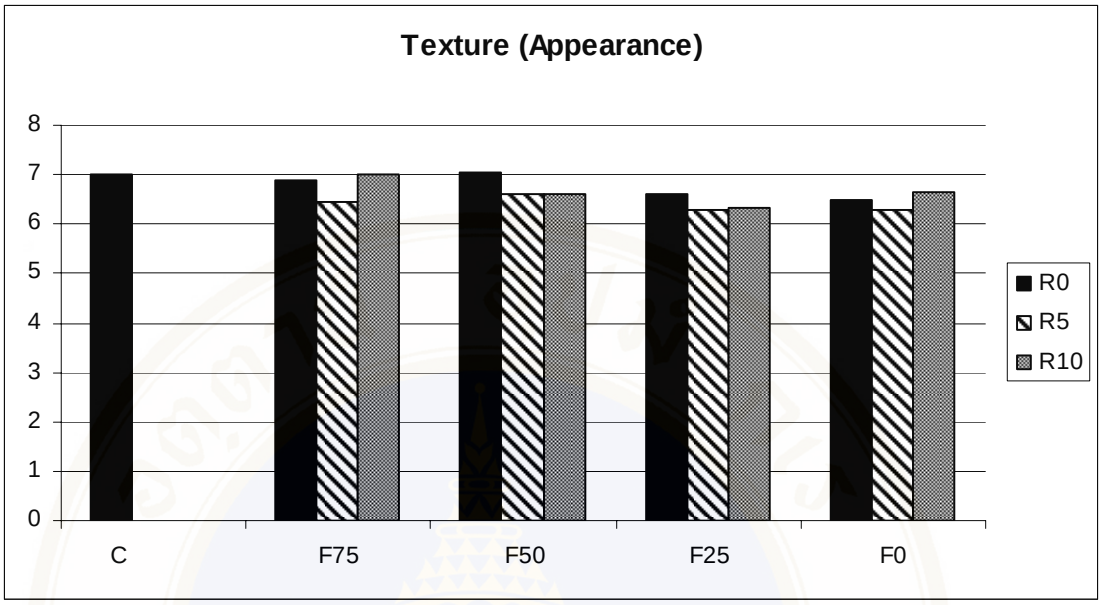

Figure F3. Sensory scores of apparent texture

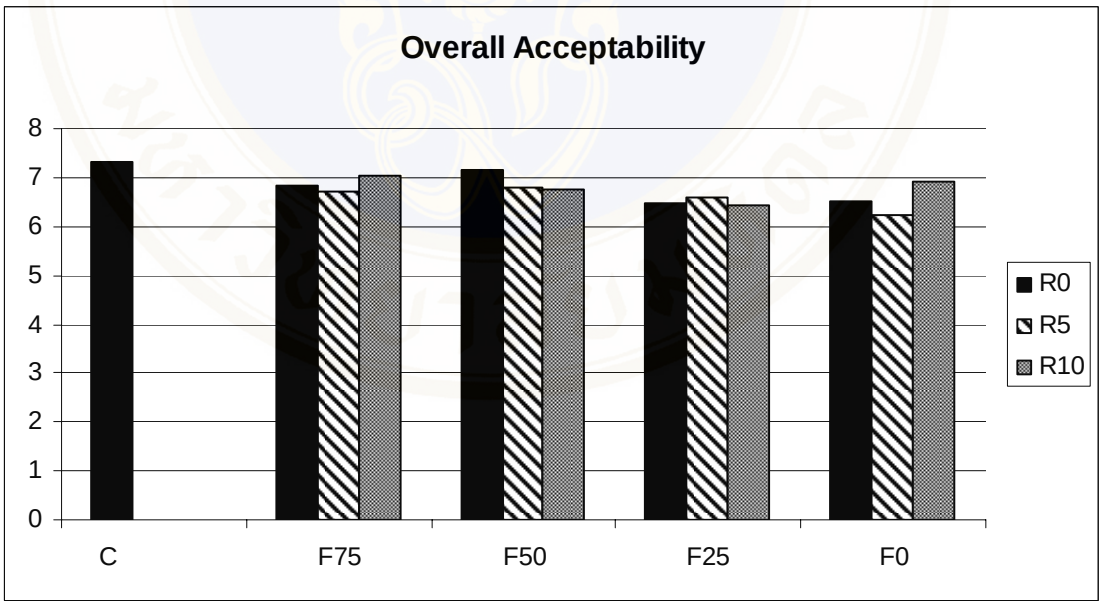

Figure F4. Sensory scores of overall acceptability

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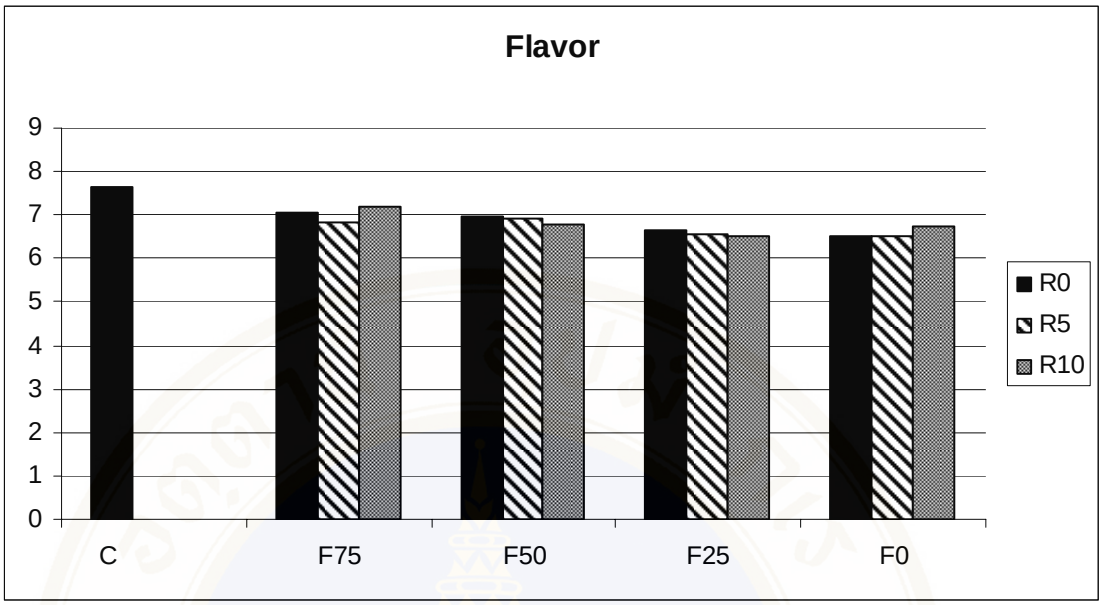

Figure F5. Sensory score of flavor

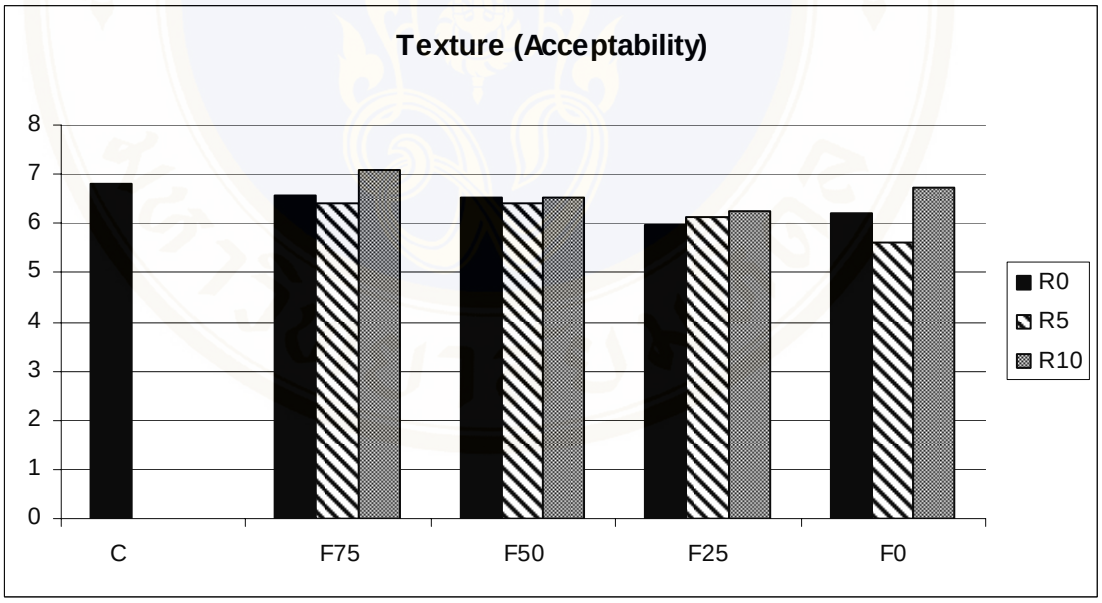

Figure F6. Sensory score of texture

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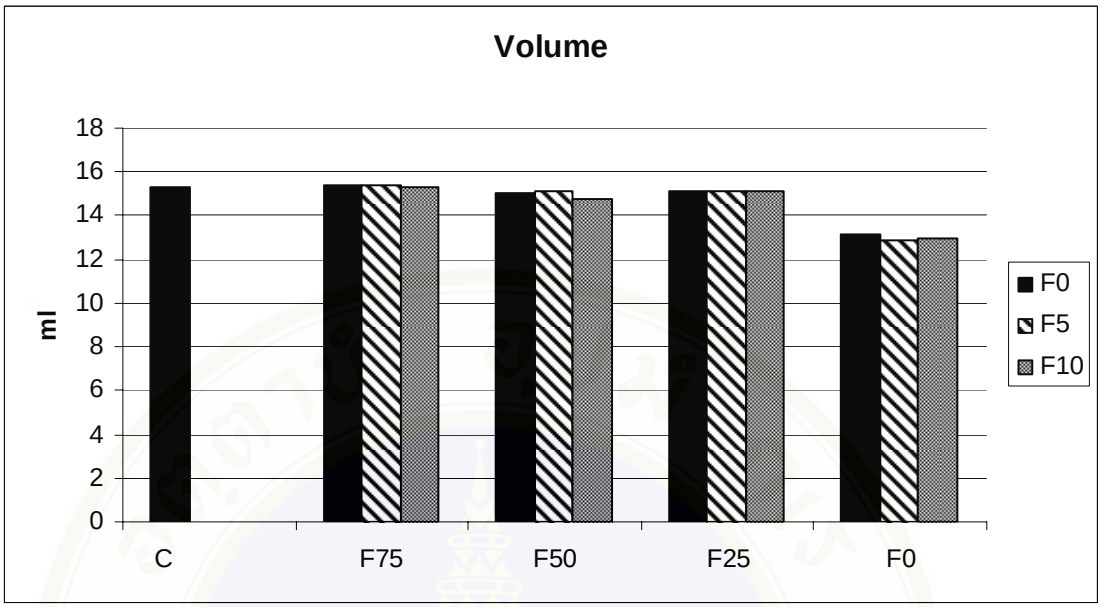

Figure F7: Volume of cake

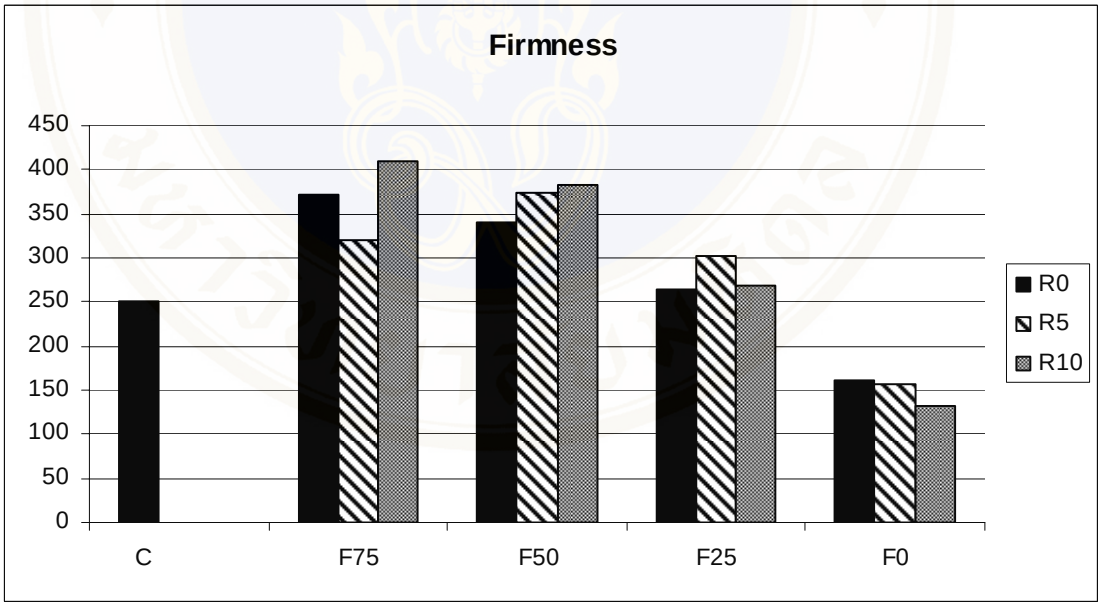

Figure F8: Firmness of cake

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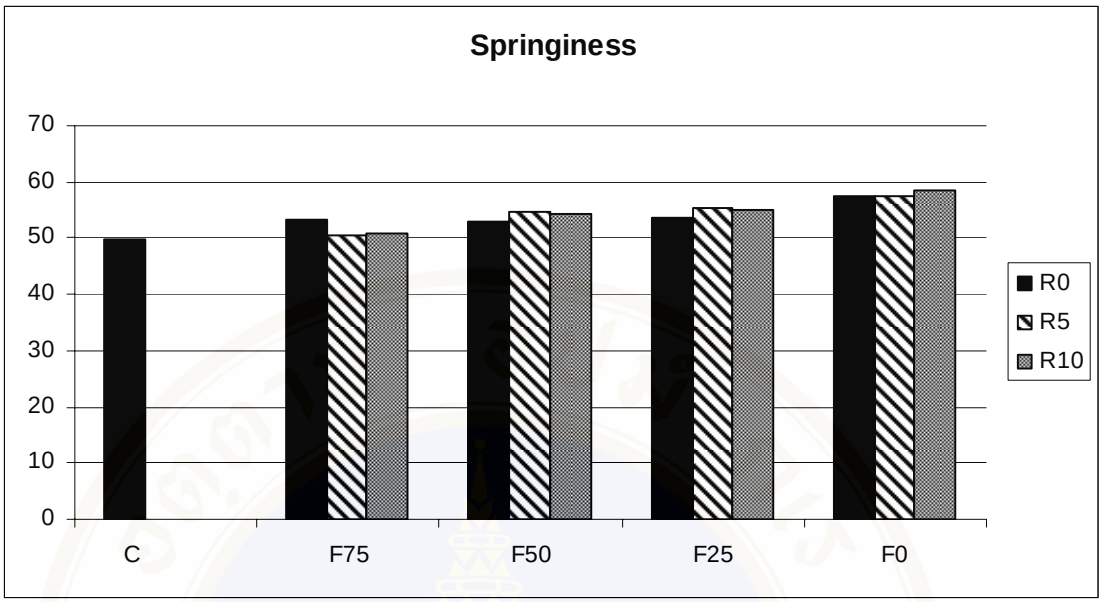

Figure F9: Springiness of cake

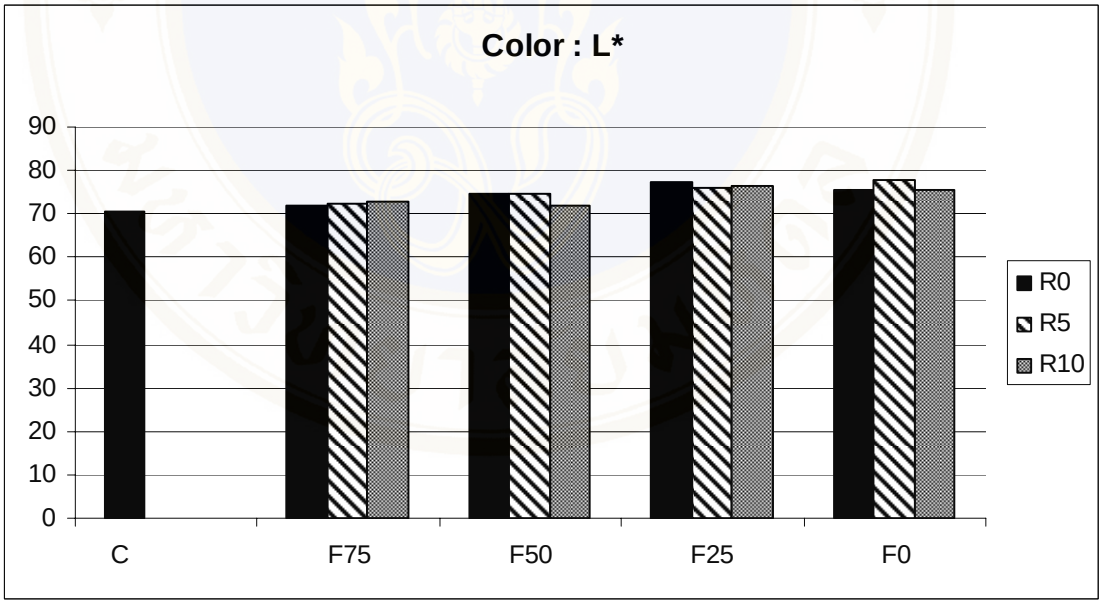

Figure F10. Lightness value (L*) of cake

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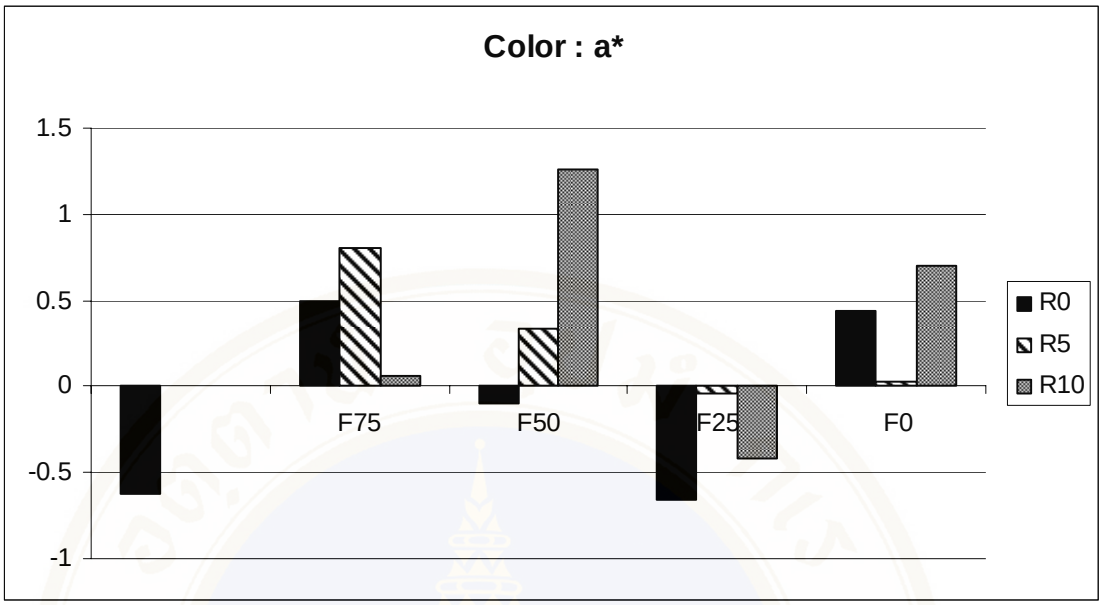

Figure F11. Redness value (a*) of cake

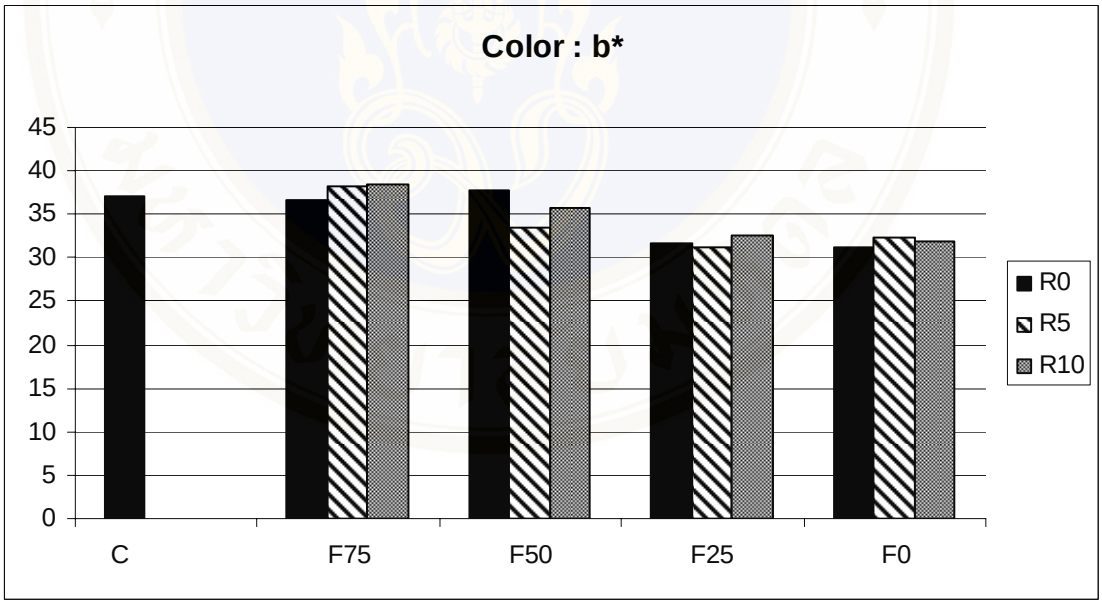

Figure F12 Yellowness value (b*) of cake

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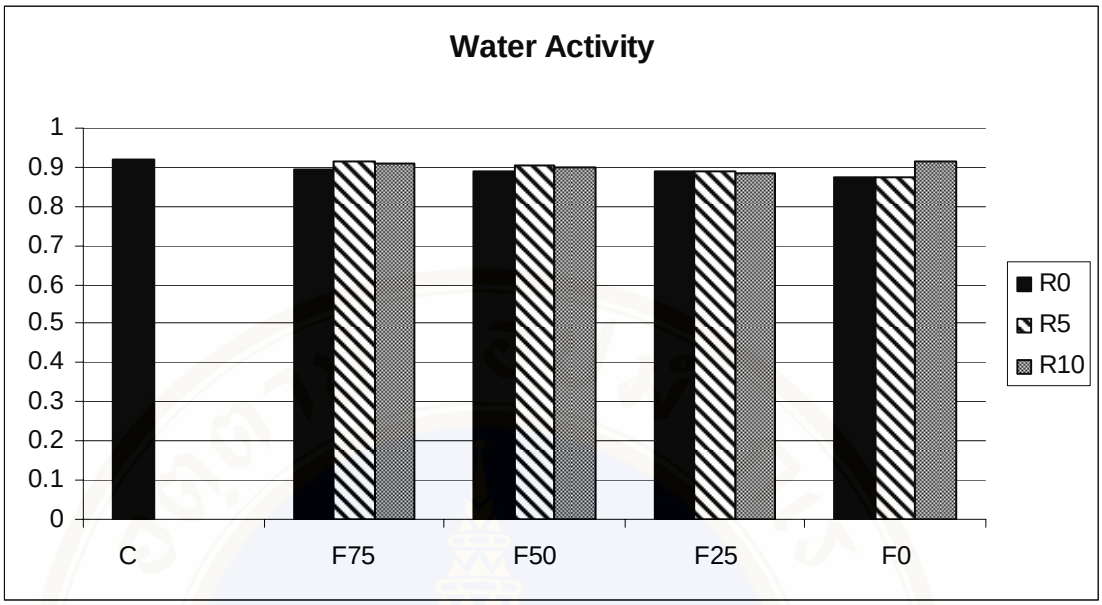

Figure F13. Water activity of cake

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APPENDIX G
NUTRITIVE VALUE PER 100 GRAM FOOD

Food	Energy (kcal)	Protein (g)	Fat (g)	Carbohydrate (g)	Water (g)
All Purpose Flour	349	11.0	0.9	74.1	13.3
Sugar	385	0	0	99.5	0.5
Egg	163	12.9	11.5	0.8	73.7
Butter	729	0.9	82.4	0.2	14.7

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BIOGRAPHY

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