PECAN OIL SUBSTITUTION FOR SHORTENING

IN YELLOW LAYER CAKES

By

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IN YELLOW LAYER CAKES

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CHAPTER I

PECAN OIL SUBSTITUTION FOR SHORTENING IN YELLOW LAYER CAKES

INTRODUCTION

Pecans (*Carya illinoensis*) are an important horticulture crop in Oklahoma. Texas, Alabama, Louisiana, Oklahoma, and Mississippi together account for ten million pounds of production annually. Georgia is the leading state with about 25% of the total national production (Heaton, et al., 1977). Native pecan trees are found in large numbers in Oklahoma and Texas (Atwood, 1949; Peterson and Johnson, 1978). Many of the small native pecans do not get harvested and hence are underutilized. These can probably be used for the extraction of oil.

A problem with pecans is that they are very susceptible to rancidity and staleness due to their high unsaturated oil content, which leads to flavor instability (Woodroof, 1967; Senter et al., 1980). They are also quite high in calories (667 kcal/ 100 g edible meat), so efforts have been made to extract the oil to increase the shelf life of the nuts, and also reduce the fat content to increase their marketability. An increase in marketability of pecans means an increase in the economy for Oklahoma pecan growers.

The total oil content of pecans is 67.6%. Fats can be saturated, monounsaturated or polyunsaturated. Fat is an essential component of the daily diet. It provides a high satiety value, palatability, flavor and mouthfeel. Fats are important in the absorption of vitamins A, D, E, and K. They are also a high source of energy and yield nine kilocalories per gram. In food preparation fat acts as a tenderizer, serves as a heating medium, enhances smoothness and texture, and adds flavor.

In the process of making healthy foods, the food industry is directing its preparations towards unsaturated fats (McGrady, 1994). Research has been conducted to test the health aspects of saturated fat versus unsaturated fats. Studies indicate that unsaturated fats have an effect in reducing the blood cholesterol and eventually reducing the risk of heart disease. Monounsaturated fats are associated with a decrease in serum cholesterol (LDL) and a decrease in risk of coronary heart disease. The high amount of monounsaturated fat in pecan oil has great significance in nutritional value.

Past studies have shown that the oil contained in pecans is highly unsaturated. Pecan oil is comparable to olive oil in many ways. Olive oil is mostly monounsaturated and is used in foods to increase monounsaturation. It is marketed as an alternative to other oils high in saturated fats for healthy cooking. Many food systems are not compatible with olive oil because of its unique, strong flavor, which is added to the foods it is used in, but pecan oil has a mild flavor and may be successfully used in baking.

The health benefits of pecan oil could make it a good substitution for shortening (has trans fatty acids) in cakes. Shortening, cake flour, salt, baking powder, milk, and eggs are the important ingredients in cakes. Shortening gives structure to the cake by entrapping air, water vapor and other leavening gases in the cells which expand during baking. Hydrogenated shortening has mono and diglycerides that aid in formation of fine grain of the cakes but the use of oil in place of shortening in cakes changes the texture. Use of oil makes crumb surface glossy, and forms small, uniform round air bubbles rather than the even grain seen in cakes made with hydrogenated shortening. Research has shown that the texture of cakes made with oil can be improved with the use of an appropriate emulsifier (Griffin and Lynch, 1972; Harnett and Thalheimer, 1979; Berglund and Hertsgaard, 1986; Schmall and Brewer, 1996). Gums have also been added to cake batters to improve the texture and to increase volume and moisture retention in cakes (Roberts, 1973; Anonymous, 1997).

Statement of problem

Oil is extracted as a by-product in the process of making pecans a reduced fat nut. A review of the literature has revealed that little research has been conducted on the utilization of pecan oil in food systems. Therefore, research is needed to find healthful and economic food uses for pecan oil. In this study pecan oil was substituted for hydrogenated shortening in a standard two-egg yellow layer cake.

Purpose and objectives

The main purposes of this study were: to make an acceptable cake using pecan oil, to determine its characteristics through objective and subjective (sensory evaluation) tests, and test the acceptability of this cake through consumer preference testing.

The objectives of this study were:

1. To determine whether the use of emulsifying agents and gums in cakes made with pecan oil in substitution for hydrogenated shortening will be effective in developing a fine grain texture similar to that of a cake made with hydrogenated shortening.
2. To compare sensory characteristics as measured by appearance (crumb surface shine), texture (graininess), moisture absorption, and flavor (sweetness) of a shortened cake (control) against a cake made with pecan oil with no emulsifier and xanthan gum (w/o e&g), and cakes made with pecan oil and three types of emulsifiers with added xanthan gum.
3. To compare the sensory characteristics of the cakes made with pecan oil with and without emulsifiers and xanthan gum.
4. To compare the sensory characteristics among cakes made with the three types of emulsifiers with added xanthan gum.
5. To compare objective tests as measured by specific gravity, line spread, mean height and texture gauge measurements of control against cake made with pecan oil w/o e&g, and cakes made with pecan oil and three types of emulsifiers and xanthan gum.
6. To compare objective tests of the cakes made with pecan oil with and without emulsifiers and xanthan gum.
7. To compare objective tests among cakes made with the three types of emulsifiers and xanthan gum.
8. To compare consumer preferences between a cake made from a leading brand commercial cake mix and a pecan oil cake made with emulsifier and xanthan gum.
9. To correlate objective and subjective data obtained in this study.

10. To make recommendations for further studies in this area.

Hypotheses

The following hypotheses were postulated for this research:

H_1: There would be no significant difference in cakes made with hydrogenated vegetable shortening (control) and pecan oil cakes with or with out added emulsifiers and xanthan gum as measured by:

1. Sensory attributes of appearance (crumb surface shine), texture (graininess), moisture absorption, and flavor (sweetness).
2. Objective tests of specific gravity, line spread, mean height, and texture gauge measurements

H_2: There would be no significant difference in pecan oil cakes with or with out added emulsifiers and xanthan gum as measured by:

1. Sensory attributes of appearance (crumb surface shine), texture (graininess), moisture absorption, and flavor (sweetness).
2. Objective tests of specific gravity, line spread, mean height, and texture gauge measurements

H_3: There would be no significant difference among pecan oil cakes with emulsifiers and xanthan gum as measured by:

1. Sensory attributes of appearance (crumb surface shine), texture (graininess), moisture absorption, and flavor (sweetness).

2. Objective tests of specific gravity, line spread, mean height, and texture gauge measurements.

H_4: There would be no significant difference in the consumer acceptance of a cake made from a leading brand cake mix and a pecan oil cake with emulsifier and xanthan gum.

Assumptions

The following assumptions were made by the author at the beginning of this study:

1. The formula selected for the preparation of the cakes yields an acceptable cake to serve as a control.
2. Adding an emulsifier and gum to a pecan oil cake improves the texture against a cake made with pecan oil w/o e&g.
3. The emulsifiers tested were chosen from among those widely used by manufacturers of confectioners and baked products.
4. The level of use of each emulsifier tested for this study adequately estimates an acceptable level for that emulsifier.
5. The consumer panel is representative of a large population.
6. The data produced by a semi-trained panel is adequate in determining the attributes tested.
7. After completion of the training, the panel used their developed skills to accurately evaluate the attributes of the cakes, and the data generated reflected the ratings of the panel, not preference.

Limitations

The limitations of this study are:

1. All the attributes of the pecan oil cakes could not be studied in sensory evaluation.
2. Consumer panel subjects may not represent a true random sample of the total population.
3. Due to the scope of the study it was not possible to test every allowable limit of the every available emulsifier.
4. All the available gums were not tested.
5. Xanthan gum was not tested at different levels, but only at a recommended level.
6. A combination of gums and emulsifiers at different levels was not tested.
7. The consumer test was based on a forced choice, that is, they were not given a choice of liking either or none of the cakes.
8. Vanilla, which plays an important role in enhancing the flavor of a cake, was not added to the pecan oil cake with emulsifier and gum used for consumer testing.

Format of thesis

The study discussed in this thesis was outlined and written according to the Style Guide for Research Papers of the Institute of Food Technologists.

CHAPTER II

REVIEW OF LITERATURE

INTRODUCTION

The purposes of this study were to develop a yellow layer cake recipe by substituting pecan oil for shortening and perform objective, sensory and consumer evaluations. The review of literature starts with an overview of past research conducted on pecans, their composition, composition of oil, chemical constituents of pecan oil, health benefits of consumption of monounsaturated fatty acids, overview of cakes, fats, shortening, use of oil in place of shortening, emulsifiers, gums and objective testing methods. This is followed by a brief discussion on the use of sensory evaluation as an effective tool to accumulate subjective data.

Overview of pecans

Pecans are a variety of hickory that is native only to North America. Spanish explorers used pecans as early as 1533. George Washington planted pecan trees in 1774. In 1846 Antoine was the first to graft pecans. On Apollo space missions, pecans were the first whole fresh food taken and shared with the Russian cosmonauts (Oklahoma Pecan Commission [n.d.]).

The paramount factors for the production of pecans are climate and soil. Pecan trees are deciduous and grow in regions with a long hot summer and mild to cold winters. These climatic factors are prevalent in the eastern and southern part of the state, particularly along rivers and creeks. The appropriate soil is a combination of fertile loam as topsoil for nourishment of the feeder roots, and a good clay mixture as subsoil for anchorage for the extensive root system (Atwood, 1949). Also a fairly long growing season is required in order for the nuts to reach maturity before frost. Due to the availability of these ideal conditions, pecan is a leading horticultural crop of Oklahoma.

Composition of pecan meats

The composition of dried pecan meats is summarized in Table 1. Pecans are high in unsaturated fat (59 g /100 g edible meat). The meats contain potassium and phosphorus and trace amounts of iron and sodium and are also a source of vitamin A, thiamin and riboflavin (Watt and Merrill, 1963).

Composition of pecan oil

Pecan oil is light yellow in color with a pleasant odor and taste (Boone, 1924; Chinta and Knight, 1998). Beuchat and Worthington (1978) reported that there was 70.3% oil in the pecan kernels. In the early days of pecan research little was known about the composition of the pecan kernels. After the emergence of analytical methods such as gas chromatography and electron microscopy, more is now known. Pecan oil is a triglyceride composed mostly of 18-carbon unsaturated fatty acids (Senter and Horvat, 1978).

Table 1. Composition of pecan meats (dried)

Nutrient	Units	Value per 100 grams of edible portion
Proximates		
Water	g	4.820
Energy	kcal	667.000
Protein	g	7.750
Total lipid (fat)	g	67.640
Carbohydrate, by difference	g	18.240
Fiber, total dietary	g	7.600
Ash	g	1.560
Minerals		
Calcium, Ca	mg	36.000
Iron, Fe	mg	2.130
Magnesium, Mg	mg	128.000
Phosphorus, P	mg	291.000
Potassium, K	mg	392.000
Sodium, Na	mg	1.000
Zinc, Zn	mg	5.470
Copper, Cu	mg	1.182
Manganese, Mn	mg	4.506
Selenium, Se	mcg	5.200
Vitamins		
Vitamin C, ascorbic acid	mg	2.000
Thiamin	mg	0.848
Riboflavin	mg	0.128
Niacin	mg	0.887
Pantothenic acid	mg	1.707
Vitamin B-6	mg	0.188
Folate	mcg	39.200
Vitamin E	mg_ATE	3.100
Vitamin A, IU	IU	128.000
Lipids		
Fatty acids, saturated	g	5.419
Fatty acids, monounsaturated	g	42.161
Fatty acids, polyunsaturated	g	16.746
Cholesterol	mg	0.000

Source: USDA Nutrient Database for Standard Reference, Release 12 (March 1998)

Researchers identified ten fatty acids initially (Woodroof and Heaton, 1961; French, 1961; Bailey et al., 1967; Pyriadi and Mason, 1968). Senter and Horvat (1978) later reported 23 fatty acids, which reconfirmed the initial ten and identified new ones. A list of the fatty acids is shown in Tables 2 and 3.

Table 2. Fatty acid composition of pecan oil

Total oil (%)	70.3
Fatty acid (%)	
16:0	5.7
16:1	0.11
17:0	trace
17:1	trace
18:0	2.2
18:1	66.9
18:2	22.1
18:3	1.1
20:0	0.21
20:1	0.39
Trace and unidentified	1.3
Unsaturated :Saturated ratio	11:2

Source: Beuchat, L. R., and Worthington, R. E. "Fatty acid composition of tree nut oils", J. Food Technol. (1978).

According to Heaton et al. (1977) mature pecans yield a higher percentage of oil with a higher degree of unsaturation than immature pecans. The amount of oil and the degree of unsaturation also vary with the geographical location. Increasing the production of pecans by enhancing the soil fertilization would influence the level and composition of oil in the nuts.

Table 3. Fatty acids in pecan oil

10:0	decanoic	17:0	heptadecanoic
12:0	dodecanoic	17:1	heptadecenoic
12:1	dodecenoic	17:2	heptadecadienoic
14:0	tetracecanoic	18:0	octadecanoic
14:1	tetradecenoic	18:1	octadecenoic
14:2	tetradecadienoic	18:2	octadecadienoic
15:0	pentadecanoic	18:3	octadecatrienoic
15:1	pentadecenoic	20:0	eicosanoic
15:2	pentadecadienoic	20:1	eicosenoic
16:0	hexadecanoic	20:2	eicosodienoic
16:1	hexadecenoic	21:0	heneicosanoic
16:2	hexadecadienoic		

Source: Senter, S. D., and Horvat, R. J. "Minor fatty acids from pecan kernel lipids", J. Food Sci. (1978).

Chemical constituents of pecan oil

Some of the chemical constituents are summarized in Table 4.

Table 4. Chemical constituents of pecan oil

Specific gravity, 20°/20° C	0.9118
Saponification value	191.5
Acid value	0.80
Iodine value	97.1

Source: Boone, P. D. "Chemical constituents of pecan oil", Indus. Eng. Chem. (1924).

Pecan meats are almost 68% (67.6 g/100 g meat) oil and 87% of that oil is unsaturated: 17 g/100 g of meat polyunsaturated, and 42 g/100 g of meat monounsaturated (USDA, 1998). Due to its high unsaturation, the large number of double bonds in the molecules increase the affinity for oxygen and hence the oil is susceptible to oxidative rancidity (Heaton et al., 1966). Studies have been conducted to improve the keeping quality of the pecans during processing, handling, and storage to retard rancidity (Forbus and Senter, 1976; Heaton et al., 1977; Forbus et al., 1980; Senter et al., 1980; Maness et al., 1996). However, Whitehead and Warshaw (1938) reported that pecan oil did not develop any rancidity when stored for twelve months in glass bottles and exposed to normal sunlight at room temperature. (This is surprising since UV light can catalyze rancidity, but oxygen was limited; and, further, pecan oil rancidity development is an autoxidation reaction that apparently never got started.) The ratio of unsaturated to saturated fatty acids is an important factor in predicting the rancidity of the oil. The ratio for pecan oil is 11:2, and this high ratio is a reason for its low keeping quality (Beuchat and Worthington, 1978).

Pecan oil is comparable to olive oil in all respects for use in manufacturing and as an edible oil. Whitehead and Warshaw (1938) prepared acceptable products like mayonnaise, french dressing and cold cream. However they did not report results with foods such as desserts. If pecans are used as high as 25% of the total ingredients of a product as in pecan pie, the polyunsaturated: saturated ratio is improved (Heaton et al., 1966).

Monounsaturated fatty acids

Pecans are high in unsaturated fatty acids — monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA). Dietary fatty acids and cholesterol are the most important components altering serum lipoproteins. Saturated fatty acids (SFA) raise low-density-lipoprotein (LDL) cholesterol, while short chain SFA do not alter LDL cholesterol (LDL-C). PUFA lower LDL-C slightly more effectively than MUFA, although MUFA also has a net LDL-C lowering activity (Grundy, 1989; McPherson and Spiller, 1996). High fat diets that are high in MUFAs and low in SFAs (total fat at 33% to 50% of energy, MUFAs at 17% to 33% of energy, and SFAs at less than 7% of energy) decrease LDL-C and increase HDL-C compared to lower fat diets. A low fat diet increases triglycerides and decreases HDL-C. Hence a high fat diet is suggested for people with low HDL-C and high triglycerides (Krummel et al., 1998).

Mata et al. (1992) showed that the HDL-C increased by 17% in men and 30% in women who were on a diet first enriched with PUFA and then MUFA. There was no significant change in the total triglyceride values or plasma LDL-C. Compared with PUFA, MUFA increased HDL cholesterol.

However, McLennan (1993) showed that dietary replacement of saturated fats by n-6 and especially n-3 PUFA but not MUFA reduced the likelihood of an ischemic event to sudden cardiac death in rats.

Cakes

Cakes are an important product in the baking industry and are high in calories. Changes in the fat content were recommended by the replacement of high fat ingredients with those lower in fat to improve the fatty acid profile (Saltz et al., 1982). Since pecan oil is high in monounsaturated fat, this would be a good replacement for the saturated fat in cakes.

Good quality cakes should have a large volume, a fine grain, and a moist, tender crumb (Ebeler and Walker, 1984). The first surfactants added to shortenings were mono and diglycerides (Paul and Palmer, 1972). These "high ratio" shortenings allowed cake formula to carry more sugar than flour; thus the term "high ratio". High ratio cakes are generally sweeter than their balanced ratio counterparts due to their higher sugar content.

Fats

Fats, which are a significant part of pecans, are classified as the most abundant types of lipids. Fats in the liquid state are called oils. Naturally occurring unsaturated fats have cis configuration at the double bond so that the hydrogens are on the same side of the double bond resulting in a bend. Molecules with this shape do not mesh well with each other and exist in the form of liquids with a low melting point. When these oils are hydrogenated, near the double bonds the hydrogens' structure changes to a trans configuration, with a straighter chain (Freeland-Graves and Peckham, 1996). The trans fatty acids and saturated fats are straight chains and will fit well together to form a solid. They also have a high melting point due to high intermolecular forces. These trans fatty acids, though still unsaturated, have the similar effect on blood cholesterol as saturated fatty acids. They decrease the high-density lipoprotein (HDL) and increase the low-density-lipoprotein (LDL) (Katan, 1995). Trans fatty acids have been associated with an increased risk of coronary heart disease (Anonymous, 1996; Watts et al., 1996).

Vegetable oils are hydrogenated to increase their melting point, which provides the functionality necessary for many food products. Hydrogenation also increases the stability of the fats by eliminating double bonds, which are vulnerable to oxidation.

Fats are a mixture of lipids. Lipid mixtures in the form of shortenings, frying fats and salad oils are commonly used in food preparation. Some of the major functions of fats in food preparation are 1) to tenderize, 2) to contribute batter aeration, 3) to serve as a heating medium, 4) to serve as a phase in an emulsion, 5) to contribute to flavor, and 6) to enhance smoothness, body or other textural changes (Penfield and Campbell, 1990). Some of the other uses of fat are in the baking industry to improve the texture of the baked goods, and in ice creams to prevent the formation of large ice crystals (Anonymous, 1986). A recent survey showed that 85% of American adults prefer high fat foods in spite of health concerns. Although some people are on a low fat diet, they would prefer some fat to make the food taste better (Sloan, 1994).

Shortening

Shortening is one of the important ingredients in cakes. The type of shortening used in cakes plays an important role in determining its structure (Mattil et al., 1964). A typical layer cake contains 10-12% shortening and its function is to entrap air during preparation of cake batter. These fat-enclosed air cells collect water vapor and carbon dioxide released during baking and expand improving the volume and structure of baked cakes (Vetter et al., 1984; Waring, 1988). Shortening acts as a tenderizer by disrupting the continuity of the starch particles by coating the protein and the starch molecules. Commercial shortening contains added mono and diglycerides which are emulsifiers. Pyler

(1973) observed that viewing a cake batter with fat under a microscope reveals the fat to be dispersed throughout its mass in the form of small irregularly shaped particles rather than spherical droplets. This is due to the plastic fat. These irregularly shaped particles, when observed more closely, revealed minute air bubbles which have been incorporated during the mixing process. Liquid oils do not have this ability to retain air. The dispersion of the fat in the batter and the ability of the fat to incorporate air were directly related to volume and grain in the finished product (Carlin, 1944). However, when liquid shortening is used in place of solid shortening, the fluidity is better for bulk handling operations of pumping and metering (Penfield and Campbell, 1990).

Use of oil in place of shortening

Plastic fats, particularly those containing emulsifiers, perform important functions in high-ratio shortened cakes including incorporation of air during creaming which contributes to cake volume, fine grain and texture in the baked product. Successful substitution of unsaturated oils, which are liquids at room temperature, will depend on the degree to which these fats will coat air bubbles which in turn, depends on the viscosity of the fat, the ability of the fat to spread into thin layers, and the degree to which the fats saturate solid ingredients, such as flour and sugar, altering their functionality in the batter system (McWilliams, 1993). A high-ratio cake formula (weight of sugar > weight of flour) is commonly used in the food industry due to greater richness, higher moistness and longer shelf life. When liquid shortening is used, the level of shortening is usually reduced somewhat (Penfield and Campbell, 1990). Rasper and Kamel (1989) have suggested that when replacing shortening with oil, a reduction by 33% in the lipid component of the formula is considered suitable for the production of a good cake when emulsifiers were added.

Several studies have been reported in the literature on the usage of vegetable oils in pastry and cake. Matthews and Dawson (1966) found vegetable oils were good shortening agents in pastry. Hartnett and Thalheimer (1979) replaced the plastic fat in cakes with vegetable oils and reduced the total fat. They tested different levels of reduction while incorporating emulsifiers containing a blend of mono and diglycerides and polysorbate. These cakes had good volume, grain, and crust appearance and were extremely tender. Subjective and objective tests showed that the 60% reduction in total fat in yellow cakes provided the best texture characteristics. They concluded that with a proper emulsifier, oil could be used as an effective alternative to plastic fats in breads, cakes and sweet goods, while using less total fat.

Shrestha et al. (1990) reported that cakes made with oil showed high specific gravity, low viscosity, and had poor volume and texture. They suggested that the use of an emulsifier would improve texture and volume. Schmall and Brewer (1996) reported that the replacement of solid shortening with corn oil or medium chain triglycerides (MCT) affected finished cake texture the most and finished cake flavor and color the least, but they did not use emulsifiers. Detrimental substitution effects were significant even at the 33% level. The other substitutions were at 50, 67 and 100% levels. They concluded that with the use of an appropriate emulsifier, a product with an acceptable texture might be obtained.

Three reduced levels of soybean and safflower oils used in commercial cake mixes did not change the subjective and objective data for appearance, moistness, flavor and overall preference. The objective data for color showed some variability, but the sensory scores for appearance were not significant (Berglund and Hertsgaard, 1986).

Emulsifiers

Emulsifiers are substances that reduce the surface tension at the interface of two normally immiscible phases, allowing them to mix and form an emulsion. The main functions of emulsifiers can be summarized as follows: 1) to promote stability of emulsions, stabilize aerated systems, and control agglomeration of fat globules, 2) to modify texture, shelf life and rheological properties by complexing with starch and protein components, 3) to improve texture of fat based foods by controlling the polymorphism of fats. In bakery products emulsifiers play a role in aeration, emulsification, and crumb softening and conditioning. In fat-containing batters, emulsifiers aid in stabilizing the aerated structure and promote a finer distribution of the fat droplets (Krog, 1977; Krog et al., 1985). Mono and diglycerides are the emulsifiers present in commercial plastic shortening. In cakes, they serve as an emulsifier for the fat-water-protein system. They enhance the formation of uniform oil droplets and gas bubbles within the batter system and improve the ability of the protein film to coat and entrap these particles, which results in a fine, uniform textured cake of good volume and eating quality (Peterson and Johnson, 1974).

Emulsifiers are considered as safe food additives (GRAS) by the United States Food and Drug Administration (FDA) but their level of usage is controlled. Griffin and Lynch (1972) have suggested that a blend of two or more emulsifiers, one with hydrophobic tendencies and the other with hydrophilic tendencies, imparts a greater stability than possible with a single emulsifier.

An emulsified shortening containing propylene-glycol monoester with a particular ratio of fatty acid ester chains had been formulated to add to the cake mixes, which gave a good grain structure and excellent eating quality (Gupta, 1971).

The use of liquid shortening in cakes did not give good volume to cakes and they had an open grain when compared to the cakes made with plastic fat. When an emulsifier was used, the results showed that it could overcome the negatives associated with the liquid fat (Harnett and Thalheimer, 1979).

Gums

Hydrocolloid is a term that describes the behavior and physical characteristics of food gums. The linear and branched nature of the molecules and the presence of various functional groups provide three-dimensional structures to the hydrocolloids. This property allows them to function as thickeners or gelling agents in food systems (Carr, 1993).

Xanthan gum, produced by *Xanthomonas campestris*, under proper conditions exhibits unique properties that are useful in foods. It is soluble in hot or cold water, has high viscosity at low concentrations with little or no change in solution viscosity in a wide temperature range (Whistler and BeMiller, 1997).

Gums were originally added to cake batters to increase moisture retention during baking and to prevent staling. There is also an added advantage of an increase in volume and texture (Roberts, 1973). Xanthan gum is said to increase moisture binding and retention during mixing and baking, improve cake volume, improve cell structure in baked cake, maintain good eating quality, and provide strength without toughness to high moisture cakes (Anonymous, 1997). Adding xanthan gum increased the volume of white layer cakes (Miller and Hoseney, 1993).

When the formulations of foods are changed to imitate their original counterparts in texture and structure, certain substitute ingredients should be used. Texture is an important property of a food product that determines its marketability. Gum stabilizer systems can be used to impart the qualities lost when the levels of fat, proteins, and sugars are changed. Gums help in preserving the texture of foods, stabilizing emulsions, controlling moisture transfer, imparting creaminess, enhancing mouthfeel, and controlling ice and sugar crystallization (Carroll, 1990). Xanthan gum at 0.1 % of batter was added to fat-free cake mixes and was found to make cakes with good cell structure and moistness and fragility (Waring, 1988). A list of foods containing xanthan gum is in Appendix A.

Guar gum is frequently used in cakes for batter viscosity. It hydrates during the batter preparation and baking of the cake. The use of this gum is limited due to its taste. The use of xanthan, locust bean and guar gums produced cakes with good cell structure, moist with slight differences in shades of brown color (Waring, 1988).

Objective tests

Tests that do not depend on the observation of an individual and can be repeated using an instrument are described as objective methods (IFT, 1964). They are reproducible and less subject to error than sensory methods (Penfield and Campbell, 1990).

Line spread

Line spread test is used to measure the consistency of foods in terms of the distance that they spread on a flat surface in a given period of time. This method which was described by Grawemeyer and Pfund (1943), is suitable for foods like white sauce, starch puddings, applesauce, and cake batters. Hunter et al. (1959) suggested that very viscous batters of a given specific gravity are indicative of fine dispersion of incorporated air, whereas a high line spread reading in association with the same specific gravity is indicative of the dispersion of air in larger units. Charley (1952) stated that the batters containing emulsifiers are thinner and have greater mobility, but his cakes did not contain gum.

Specific gravity

The determination of specific gravity is done by dividing the weight of the food packed into a small, even rimmed cylindrical container by the weight of the water held by the same container (Lee et al., 1982). Specific gravity indicates the amount of air in the batter. Handlemen et al. (1961) reported that specific gravity dropped as emulsifier was added and more air was incorporated. But Carlin (1944) reported that with the addition of an emulsifier, the specific gravity of the batter increased.

Sensory evaluation

Sensory evaluation is defined as "a scientific discipline used to evoke, measure, analyze, and interpret reactions to those characteristics of foods and materials as they are perceived by the senses of sight, smell, taste, touch, and hearing" (IFT, 1975). Failure of a product in the market may relate to differences in perceived quality by the manufacturer and the consumer. An elaborate advertising campaign would not help increase the market share of a product unless the consumers get the quality of the product they are promised. Quality plays an important role in determining its place in the market. Due to an increase in the awareness of consumers, manufacturers are turning towards sensory evaluation as a means to determine "quality" as perceived by the consumer (Stone et al., 1991).

Some of the common applications of sensory evaluation are in new product development, product matching, product improvement, process change, quality control, and storage-stability studies. Before proceeding with the evaluation of any product, it is important to understand the objectives of the experiment. The end use of the data should be decided before starting the process (IFT Sensory Evaluation Division, 1981; Lawless, 1994).

A flow chart for the steps to follow in product development and sensory testing are given in Fig. 1.

Sensory tests can be classified into two major categories: analytical tests and affective tests. Analytical tests are used to evaluate differences or similarities between products and identify and quantify sensory characteristics, and affective tests are used to evaluate preference and/or acceptance of products. Analytical tests are further divided into discriminative and descriptive tests, both of which employ trained panelists to generate reproducible results (IFT Sensory Evaluation Division, 1981). For analytical testing the primary goal is to use the sensory abilities of human beings, as complex laboratory instruments, to measure characteristics of food. Trained panelists should never be asked the question of preference as their perception of analyzing a product completely changes due to the training. They cease to be an untrained consumer. On the other hand, unlike analytical testing, affective testing panelists, such as consumers, should not be overfamiliarized with the product or they cease to be untrained (Rutledge and Hudson, 1990; Mancini, 1992; Lawless, 1994; O'Mahony, 1995).

Test	Function
Bench-top tasting	familiarize with product attributes, eliminate serious defective products.
↓	
Difference tests with lab panel	determine whether products can be discriminated
↓	
Descriptive tests	fully define important attributes-effects of process/ingredient variation
↓	
Hedonic tests-pilot consumer panels	establish degree of like/ dislike
↓	
Central location or home tests with representative consumers	test acceptability-probe consumer language

Source: Lawless H. T. "Getting results you can trust from sensory evaluation", Cereal Foods World. (1994).

Fig.1. Flow chart for steps to follow in product development.

Project design for sensory evaluation

Having clearly set objectives is very important before starting sensory evaluation. According to the objectives, the type of test is selected to answer the set questions. Panelists are used as human instruments and are screened on the basis of their ability to use their senses. Since there is a high variability in these measuring devices, they are trained by repeated familiarization with standards, to calibrate them (Lawless and Claassen, 1993; O'Mahony, 1995). The size of the panel depends on various factors. The British Standard suggests that at least five panelists are necessary and the larger the panel the greater the probability of revealing differences in ranks. King et al. (1995) concluded that a panel of 20 was justified in explaining treatment effects, but a panel of five would be adequate to indicate sample relationships.

Analytical panelists are trained to focus and identify the individual attributes of a product. They are trained to agree on what the sensory terms mean and what the high and low ranges on a scale are. They should not be used for testing acceptability of products combined with the analytical testing. Selection of an appropriate objective, test method, panelists, and careful planning are the keys to successful application of sensory evaluation (Lawless and Claassen, 1993).

Consumer Sensory Evaluation

Testing with real consumers in their most natural environment maximizes validity of product testing. However, the precision of the test is low and the variability is high due to the uncontrolled sources of error. Hence consumer tests are performed on large numbers of people to maintain the statistical balance (Lawless, 1994).

Consumer tests usually involve one or two samples: a reference (or control) and a test product. Increasing the number of samples increases the danger of confusion, and there is a likelihood of confusion among the consumers. "Untrained" consumers can make relative judgements but are poor at absolute judgements. Consumers are not trained or calibrated for testing. They view the product holistically.

A consumer test should involve not less than 50 people. The questionnaire should be as brief as possible asking just the amount of information required (ASTM, 1986; Lawless and Claassen, 1993). Camire et al. (1997) reported that age and gender did not affect the acceptability of cakes.

Preference testing allows a panelist to choose one sample over another, and a ranking test requires panelists to rank products in an order either of preference or based on a particular attribute. Paired-preference, ranking and rating tests are appropriate methods for consumer panel testing (IFT Sensory Evaluation Division, 1981).

Summary

Oil reduction of pecans does lower calories and extend shelf life and this also results in a new product, pecan oil. Pecan oil is very high in monounsaturated fatty acids and makes a healthy contribution to diet, but pecan oil does not have proven uses in foods. Attempts should be made to include pecan oil in a variety of foods such as cakes, but oils behave differently from shortening in cakes and most baked products. Perhaps addition of emulsifiers and gums to cakes made with oil may produce cakes more similar to ones made with shortening. This can be determined by objective and subjective (sensory) evaluations.

CHAPTER III

METHODOLOGY

Introduction

The primary objective of this study was to develop a cake with the substitution of pecan oil in place of shortening. The second objective was to evaluate sensory attributes of the cakes made with and without the three types of emulsifiers and xanthan gum against the control, with the help of a semi-trained sensory panel. The objective data of the cakes made with and without the three types of emulsifiers were also compared against the control. The third objective of this study was to use an untrained consumer panel to compare the overall acceptability of a cake made with pecan oil with added e&g against a cake made from a commercial cake mix. The following sections will cover the process of product development, sample preparation for data collection, data collection through objective tests, sensory evaluation participant selection and training, data collection through sensory and consumer testing, experimental design and statistical analysis of the data.

Materials and Methods

Product development

Extensive preliminary testing was conducted to determine the ratio of ingredients and type of flour to be used.

Step 1: Formula testing

Initial experiments were conducted to determine the ratio of sugar to flour, type of flour and the method of mixing for use during the entire experimentation. The following ratios and methods of mixing have been adapted from the recipe given by Charley (1982).

Table 5. Combination of flours, ingredients ratio and mixing methods tested.

Type of flour	Ratio of ingredients		Method of mixing	
	High ratio	Balanced ratio	Conventional method	Dump method
All purpose flour	√	√	√	√
Cake flour	√	√	√	√
White Lily™ flour	√	√	√	√

The ratio of ingredients and the procedures are in Appendix B. The cakes made with cake flour and White Lily™ flour had good texture but had a somewhat bitter or metallic off flavor. The cakes made with all-purpose flour had good texture and were most liked by the personnel in the food science lab. This team consisted of two graduate students and a food science professor. Therefore, the ingredients used in this study were all purpose flour, 2% milk, iodized salt, sugar, Janet Lee™ Imitation Vanilla and Grade A large eggs, all purchased from Albertson's grocery store. All the ingredients used to make cakes throughout this preliminary study were from the same batch and were weighed on a Fisher Scientific XT top loading balance.

A Rival high performance mixer, model 455 was used for mixing. The beating of the batter was performed on speed one. The cakes were baked in Maytag Model CRG9700CAE conventional gas oven. This was kept consistent throughout the study.

Step 2: Introduction of pecan oil

All-purpose flour was selected for use in subsequent preparations. As a part of the second round of experiments, four cakes were made with the ingredients weighed in grams. The weights of the ingredients are in Appendix C. Between the conventional balanced ratio and conventional high ratio cakes, the second was most liked by our team. The other two cakes were made with pecan oil, substituted in equal amounts for shortening. They were made with dump high ratio, and conventional balanced ratio methods. The cake made with high ratio ingredients and conventional method of mixing with Crisco™ and all-purpose flour was set as a control for all experiments throughout the entire study.

Vanilla was excluded from the recipe at this time, since it had no functional role in the cake and merely introduced an additional flavor factor, which might mask the flavor of pecan oil.

The steps followed for the conventional method of mixing were:

1. Measure and sift together three times flour, salt and baking powder.
2. Measure milk.
3. Measure fat into mixing bowl. Beat with electric mixer until it is creamy and fluffy.
4. Add sugar, two tablespoons at a time, beating ½ minute after each addition.

5. Add egg, stir until blended and beat for 3 minutes.
6. Add 1/3 of the flour mixture and 1/3 of the milk. Beat for ¼ minute.
7. Repeat above step twice. Continue beating for 1 minute.
8. Separate samples for line spread and specific gravity tests.
9. Pour the rest of the batter into 6" round, greased, lined pans and bake in preheated oven at 350° F until done (approximately 35minutes).

The four cakes were rated on the basis of texture, flavor, moisture and acceptability on a 0-10 scale. A copy of the preliminary score sheet is in Appendix D. The cakes made with pecan oil were less viscous, and had a higher specific gravity than cakes with shortening. The subjective and objective data are in Appendix B.

Step 3: Use of emulsifiers

The cakes made with oil had round uniform bubbles, shiny appearance and a tougher, chewier texture, not similar to the control. To overcome this problem, the use of emulsifiers was explored. Three emulsifiers Aldo™ MSLG, Aldo™ PGHMS, and Bealite 3401 L™ commonly used in the industry were received from manufacturers. Refer to Appendix E for specific information on these emulsifiers.

Following the manufacturers' recommended ranges of incorporation of the emulsifiers, cakes were made with 4, 5 and 6% of the three types of emulsifiers. MSLG and PGHMS were calculated based on weight of fat and Bealite was calculated based on weight of total dry ingredients. The emulsifier was added towards the end of preparation and the batter was then beaten for an additional minute before being poured into pans for baking. The subjective and objective data obtained on these cakes are in Appendix B. The cakes made with oil had a shiny crumb with rounded, uniform air bubbles. The pecan oil cake batters with emulsifiers were less viscous and the baked cakes had higher volume than the control. Bealite 6%, MSLG 6%, and PGHMS 4% made the most acceptable cakes. Solid shortening contributed to a finer grain in texture than pecan oil cakes.

Step 4: Change in oil content

Hartnett and Thalheimer (1979) reported that acceptable cakes were made with a reduction of oil up to 60%. This provided good texture characteristics without affecting any of the cake's other attributes. They also showed that the use of an emulsifier at 10-12% based on oil weight produced the most volume in the cakes. So in the next step, cakes were made by reducing the oil content in the cake and increasing the amount of emulsifier to 10% of oil weight. The subjective and objective data are listed in Appendix B. The amounts of the oil and emulsifiers added to pecan oil cakes are summarized in Table 6.

Table 6. Weight of oil and emulsifiers added in reduced oil cakes

Cake	Oil added (in g)	Emulsifier added (in g)
Control	42	none
Pecan oil cake with MSLG	16.8	1.7
Pecan oil cake with PGHMS	16.8	1.7
Pecan oil cake with Bealite	16.8	23.7

The cake to which emulsifier MSLG was added had the appearance of a cake very similar to one that was made with oil only. Bubbles were more uniform compared to the cake with the emulsifier PGHMS and it had a coarser texture than control, was slightly spongy and chewy.

In the cake to which PGHMS was added, the rounded bubbles were not very uniform in the crumb. The appearance of this cake was a slight deviation from that of a typical oil cake. In the cake using Bealite, emulsifier was calculated on the basis of dry ingredients. This resulted in a drastic increase in the amount of emulsifier which completely changed the texture of the cake. It was very tender to bite. The crumb had a smooth mouthfeel with a greater volume than the other cakes. However this cake fell in the center. Although the cakes made with the higher amounts of emulsifiers made cakes closer to the control in comparison to their counterparts with regular oil content, the amounts of emulsifiers used did not comply with the limits set by the FDA (Werstak, 1998). Also, high levels affected taste. Further contact with emulsifier companies revealed that Bealite was a combination of MSLG and PGHMS and should be as effective, if used at the same amounts, as the MSLG and PGHMS.

Step 5: Addition of xanthan gum

The pecan oil cakes with added emulsifiers had slightly dry mouthfeel. A review of literature stated that xanthan gum was added to cakes to improve texture of crumb, volume and moisture retention. So, Keltrol F^{TM} xanthan gum was added to the cakes along with emulsifiers in this step. A representative of Keltrol F^{TM} product provided data showing that using an emulsifier at 0.5% along with xanthan gum ranging between 0.1% and 0.2% of total formula weight would produce a good cake, even at a reduced fat level. To see the effect this would have, cakes were prepared using xanthan/ Bealite combination in both regular and reduced fat formulations. So 0.6 g xanthan gum and 2 g

Bealite were tested in pecan oil cakes. These cakes were very similar in texture, appearance and flavor as compared to each other. The objective and subjective data are shown in Appendix B. Cake batters with added xanthan gum had lower specific gravity and were more viscous than the earlier pecan oil cakes with just emulsifier.

Although our results as well as literature suggest that a reduced fat (oil) formula would be possible, the objective of this study was to show whether pecan oil could be used as a substitution for solid shortening in cakes. Therefore the cake formula used for data collection was finalized at 100 g flour, 132 g sugar, 1 g salt, 4 g baking powder, 42 g pecan oil, 106 g milk, 44 g eggs, 2 g emulsifier, and 0.6 g xanthan gum.

Sample preparation for data collection

The ingredients used for the final control cakes were all-purpose enriched, bleached, presifted flour; 2% milk; all-vegetable shortening; iodized salt; pure cane sugar; Grade A large eggs; pecan oil; PGHMS; MSLG; Bealite; and xanthan gum. The ingredients for each test were obtained from the same batch and weighed on a Fisher Scientific XT top loading balance. Cakes were made fresh the same day for testing. A high ratio formula was used and the conventional method of mixing was followed. The proportions of the ingredients are in Appendix C expressed as grams with all ingredients adjusted to 100 g flour (baker's %). After the batter was ready, samples were taken for line spread and specific gravity tests. The rest of the batter was poured into 6" round, greased, lined pan and baked in a preheated oven at 350° F until done (approximately 35minutes). The cakes were baked in a Maytag model CRG9700CAE conventional gas oven. After the cakes were tested for doneness by inserting a cake tester, they were removed and cooled on a wire rack to room temperature.

An electric knife was used to cut through the diameter of the cake at the peaked center. The height was measured at the center and the two ends (approximately 1cm in from edge) and the mean height was calculated.

The test cakes were a control cake made with vegetable shortening; pecan oil cake made without added emulsifier and xanthan gum (w/o e&g); pecan oil cake made with 2 g of PGHMS and 0.6 g of xanthan gum; pecan oil cake made with 2 g of MSLG and 0.6 g of xanthan gum; and pecan oil cake made with 2 g of Bealite and 0.6 g of xanthan gum. Emulsifiers and xanthan gum were added to the dry ingredients and sifted to mix thoroughly.

Data collection

Objective tests

Specific gravity

Specific gravity was determined by dividing the weight of the batter (large bubbles removed, top leveled with straight edge) in a one-ounce soufflé cup by the weight of the water measured in the same container.

Line spread test

A two-inches diameter, two-inches high metal ring and a diagram consisting of concentric circles drawn 3.5 mm apart, the smallest having a diameter equal to the inside edge of the metal ring were used. To conduct the test, a transparency film was placed on the diagram. The metal ring was placed directly over the center ring and the batter that was measured for the specific gravity was poured into this ring. The ring was lifted and the batter was allowed to flow until it came to a stop. Then the readings were taken on the four equally spaced axes. The average of the four readings is the line spread value for that batter. A copy of the line spread sheet is in Appendix F.

Texture gauge

The cake top, bottom and the side crusts were removed and a crumb sample of 6½ x 6½ x 4 inches was cut from the center of the cake and tenderness was measured on a TG4C Texturegage using a Model CS-1 Standard Shear Compression Cell. Penetration force was measured in pounds. This method is similar to that described by Ebeler and Walker (1984).

Sensory evaluation participant selection and training

Twenty-one panelists were selected from among the students of Oklahoma State University and residents of Stillwater. They were questioned for any allergic reactions to nuts or nut oils and were informed that the product to be tested could contain those ingredients. A consent form was signed agreeing that participation was voluntary and, they were informed of all the ingredients in the product to be tested. (See Appendix G for a sample of the consent form.)

Panelists were first screened for their ability to identify the four basic tastes: sweet, sour, salt and bitter. Panelists then participated in two one-hour training sessions. In the first session they were familiarized with the terminology and procedures of testing the attributes (see Appendix H). The panelists assigned intensity values to the reference standards through discussion and consensus. The reference standards were obtained from

Spectrum Intensity Scales (Meilgaard et al., 1991). The intensity values were assigned to the control by marking a horizontal line on a numerical scale (0-10) as shown in Fig. 2. Panelists practiced to evaluate the intensity of the sample and assign numerical values to those intensities by using reference standards. Five panelists' ratings were very inconsistent throughout the testing, hence their data were dropped, leaving a final sixteen panelists.

Sensory evaluation

Cakes were baked in 8x8x2 square pans (with the basic formula doubled), for sensory evaluation. Fresh cakes were made every day for testing. After the cakes were cooled, the crust from the sides and top and bottom were removed. Bite size cake crumb pieces (approximately 5 inches by 2.5 inches) were cut and four pieces of each of the baked cakes were transferred into number coded two-ounce soufflé cups. The code numbers were picked from a random number table.

Panelists evaluated cakes in a randomized complete block design by scoring each cake four times. Testing sessions took place over four days for four replicates. Sessions were held in a room with ambient temperature and lighting with environmental sounds and odors minimized. The procedure and definitions were provided during each testing session. Fig. 2 is a copy of the score sheet. The reference standards were kept available for panelist use as needed. Each panelist was given four testing samples and a control. They tested each of the test samples against the control and marked their rating on a hedonic scale that was marked from 0-10. The hedonic scale was divided into equally marked lines to make it easier for the panelists to identify the numbers on the scale. They were requested to restrain from discussion during the sessions. To achieve this, the

Sensory Evaluation Form

Panelist code: ________

- **Appearance- surface shine**

0 (Dull) 5 (Shiny) 10

- **Texture (oral)**

0 (Smooth) 5 (Grainy) 10

- **Moisture absorption**

0 (No absorption)/loose 5 (Large amount)/mass 10

- **Flavor (sweetness)**

0 (Not sweet) 5 (Very sweet) 10

Fig. 2. A copy of the sensory evaluation sheet used by the trained panelists.

panelists were seated in individual booths. For each session the panelists had unlimited supply of distilled water and unsalted crackers to cleanse their palates. Spit cups were provided.

Consumer testing

Consumer panelists were 129 volunteers from the Stillwater community. The testing was conducted at midmorning in a local grocery store on a Saturday when a good cross-section of the community was expected. The panelists ranged from adolescent students to retired people. No training was given to these panelists. Previous studies indicated that no correlation was found between gender and age on acceptability of the cakes (Camire et al., 1997). To keep the questionnaire as brief as possible, these questions were not included in the test.

A cake made with Bealite and xanthan gum was chosen to be tested against a commercial cake mix, since the taste panel data showed this formula to be closest to the control in two out of four sensory attributes. The commercial cake mix used was a Betty Crocker Pound Cake Mix. Both the cakes were prepared and stored overnight before testing. The sample presentation was randomized, that is, an equal number of people tested one of the cakes first. The consumers were asked to not participate if they were allergic to nuts or any of the other ingredients and a list of the ingredients in the cakes was posted at the site of the testing. Fig. 3 is a copy of the scorecard used for consumer evaluation.

Consumer Preference Testing

Both or neither of the cakes contains nut oil. **Please do not taste if you are allergic to any nuts.**

Taste sample S first and then sample N. Mark the box of the cake which you like the **most**:

Sample S	Sample N
☐	☐

We would appreciate any comments:

____

____

____

Thank you for helping out in this research.

Fig. 3. A copy of consumer evaluation score card used by untrained panelists.

Experimental design and statistical analysis

The objective data were subjected to one-way Analysis of Variance (ANOVA) on the four characteristics – specific gravity, line spread, mean height, and texture gauge readings for all the cakes on the averages of four replicates. A Least Significant Difference (LSD) Means test was performed when a significant difference ($p \leq 0.05$) was found among the characteristics.

The cakes were tested in four replicates following a complete block randomized design (blocking variable cake) for sensory evaluation. The attributes selected for testing were: appearance (surface shine); texture (graininess of the crumb); moisture absorption; and flavor (sweetness). For each session the samples were identified by random numbers. At each session the high ratio conventional cake with vegetable shortening was used as the control, against which the rest of the cakes were tested.

An average of the panelist ratings for each of the attributes was taken. The ratings of the panelists are in Appendix I. The data were analyzed using SPSS Inc. Repeated measures Analysis of Variance was performed using General Linear Model (GLM) on the values for the four days for each sensory attribute.

A one sample t-test was performed on the attributes to test the level of difference for each cake against the control. Since there was no variability in the values of the control, a GLM could not be performed to test the levels of significance.

The consumer preference study was a forced choice test. Consumers were not given a choice of liking both or liking neither cake. A total of 129 consumers tested both the cakes. A binomial test was performed on that data.

CHAPTER IV

RESULTS AND DISCUSSION

This study compared pecan oil cakes with and without emulsifiers and xanthan gum against a control cake made with hydrogenated shortening. The objective data depicted differences in mean height and specific gravity of the emulsified cakes against the control. A sensory evaluation of the cakes showed no differences in some attributes such as moisture absorption. A consumer study was also done comparing acceptability of an emulsified pecan oil cake against a commercial cake mix cake and both were found to be equally acceptable.

All the emulsified cakes used the same amount of xanthan gum (0.6 g) and each had the same weight of a different emulsifier (2 g emulsifier).

Objective data

One-way Analysis of Variance (ANOVA) was performed on the objective data (specific gravity, line spread, mean height and texture gauge readings) for all the cakes for four replicates. Significant differences were found for specific gravity ($p = 0.005$), mean height ($p = 0.001$), and line spread tests ($p < 0.001$). The texture gauge readings were not significant at the 0.05 level ($p = 0.093$).

A Least Significant Difference (LSD) Means test was performed on the data to identify the differences among the cakes ($p = 0.05$).

Table 7. Means* and standard errors of objective data for cakes.

Attributes / Cakes	Specific gravity	Line spread readings	Mean height (cm)	Texture gauge (lb force)
Control	$1.00^{a} \pm 0.006$	$1.4^{a} \pm 0.217$	$4.9^{c} \pm 0.058$	$66.8^{ab} \pm 2.56$
Pecan oil cake w/o emul	$1.01^{a} \pm 0.009$	$6.8^{b} \pm 0.323$	$5.3^{b} \pm 0.000$	$73.0^{a} \pm 3.16$
Pecan oil cake w/ PGHMS	$1.05^{b} \pm 0.011$	$1.9^{a} \pm 0.767$	$5.5^{ab} \pm 0.166$	$64.5^{b} \pm 2.02$
Pecan oil cake w/ MSLG	$1.06^{b} \pm 0.004$	$1.8^{a} \pm 0.657$	$5.6^{ab} \pm 0.150$	$70.5^{ab} \pm 0.65$
Pecan oil cake w/ Bealite	$1.04^{b} \pm 0.002$	$1.6^{a} \pm 0.650$	$5.7^{a} \pm 0.063$	$68.3^{ab} \pm 1.11$

*Means are the results of four replicates

**Within a single attribute, means having a common superscript are not significantly different at $\alpha > 0.05$.

Specific gravity

The amount of air or leavening gas (CO_2) incorporated into a batter can be determined by measuring its specific gravity. A number greater than 1 means that the batter is more dense than an equal volume of water, and a number less than 1 means that the batter is less dense than an equal volume of water. LSD Means indicated that, for specific gravity, the control was not significantly different from the pecan oil cake with no emulsifier or xanthan gum ($p = 0.549$). But all three emulsified oil cakes were significantly more dense than the control as seen in Fig. 4.

Specific gravity of pecan oil cake was significantly lower from the emulsified oil cakes. Pecan oil cakes with emulsifiers were not significantly different from each other.

Specific gravity increased in pecan oil cakes with emulsifier and xanthan gum over the control (see Table 7). Handlemen et al. (1961) reported that specific gravity dropped as emulsifier was added and more air was incorporated, but Carlin (1944) reported an increase in specific gravity with added emulsifier. Our data agreed with that of Carlin's. The gum and emulsifier having a water binding capacity could be holding water and dissolved sugar, making the batter heavy. The leavening produced by the baking powder did not have enough time to lighten the batter, as the test was conducted immediately after mixing the batter.

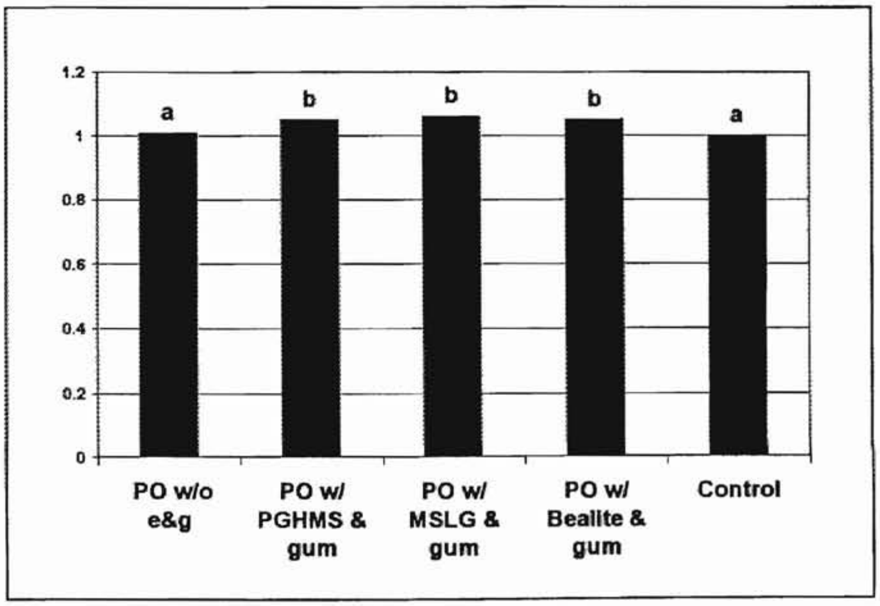


Fig. 4. Comparison of specific gravities of cakes.

Line spread

The line spread test of the cake batters is a measure of their viscosity. Observation of the cake batters before baking showed the appearance of the batter made with pecan oil and no emulsifiers was glossy and very fluid, whereas the control batter with shortening was more viscous (Table 7) and had a "curdled" appearance. The line spread values showed the control batter was significantly more viscous than the pecan oil batter ($p < 0.001$). A cake with vegetable oil substituted gram for gram for shortening will have a more runny batter. This was true of the pecan oil as well, but the addition of emulsifier and gum increased the viscosity compared to the pecan oil cake without e & g. These batters were not significantly less viscous than the control batter, but had large air bubbles. These air bubbles were also seen in the baked cake crumb (see Appendix J).

The pecan oil batter was significantly less viscous than the emulsified batters ($p < 0.001$). The addition of emulsifier and gum made the batter fluffier and more viscous. There was no significant difference in the line spread values among the three emulsified pecan oil cakes (see Fig. 5).

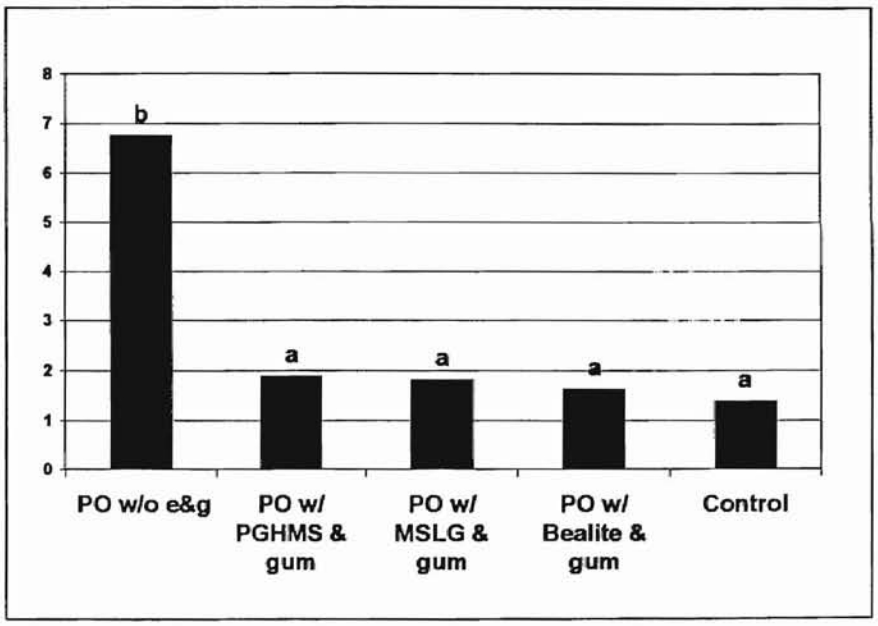


Fig. 5. Comparison of line spread values of cakes.

Charley (1952) stated that the batters containing emulsifiers were thinner and had greater mobility. However, Charley's cakes did not have gum, which was the prime factor in increasing viscosity. According to Campbell et al. (1979), cake batters containing oil do not hold air well. Shrestha et al. (1990) reported that cakes made with oil (without gum) showed high specific gravity and low viscosity. In this study the pecan oil only cake batters were very fluid but had a lower specific gravity compared to the other cakes with emulsifier and xanthan gum.

Mean height

The mean height (mean of two edge and one center readings) of the control was significantly different (less high) from the pecan oil cake (p = 0.018), and also significantly less high than the three emulsified cakes (Fig. 6).

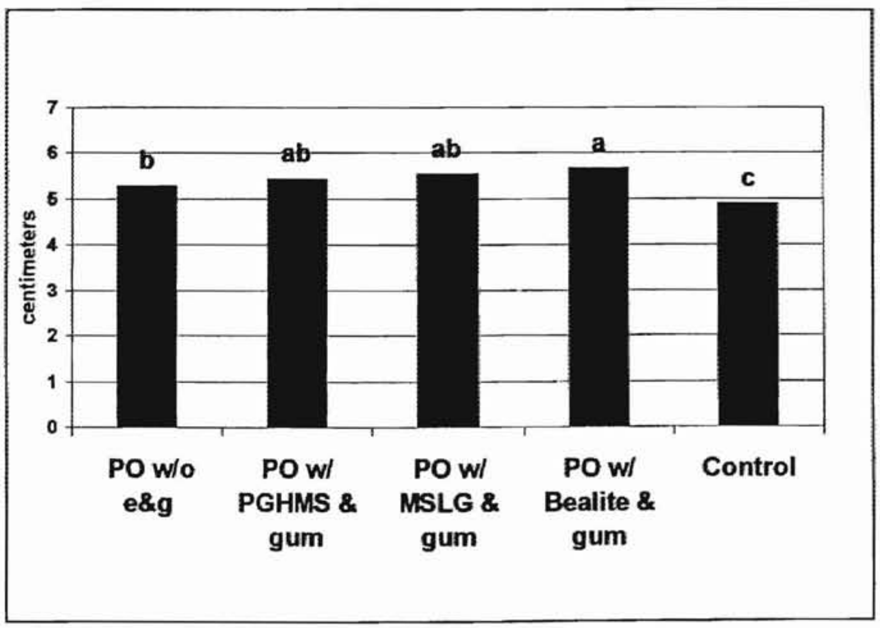


Fig. 6. Comparison of mean heights of cakes.

The mean height of the pecan oil cake was significantly less than the cake with Bealite (p = 0.026), but not significantly less than other two emulsified cakes. There were no significant differences in mean heights among the three emulsified pecan oil cakes (Table 7).

The mean height was higher in the emulsified pecan oil cakes compared to the control and pecan oil cake. This did not agree with Shrestha et al. (1990) who reported that due to high specific gravity and low viscosity the oil cakes had poor volume, but their cakes also did not have xanthan gum, which increased viscosity and helped entrap gases. Miller and Hoseney (1993) reported that incorporation of xanthan gum increased volume of white layer cakes.

The pecan oil cakes with xanthan gum had peaked tops. This was probably due to the addition of xanthan gum and not emulsifiers because this peaking was not seen with the addition of emulsifier alone. This was also not observed in cakes with the pecan oil without emulsifier, and the control. As the cakes cooled, the peaked top was not as prominent, but the top surface, even when completely cool, was not as flat as that of the control.

Texture

The emulsified pecan oil cakes had good volume and were more tender in texture than the pecan oil cake, due to the presence of emulsifiers and xanthan gum. Emulsifiers act as tenderizing agents by retaining the air incorporated during the mixing process (Hartnett and Thalheimer, 1979).

The texture gauge readings of the control were not significantly different from the pecan oil cake ($p = 0.054$) or from the three emulsified pecan oil cakes. The only significant difference was that the pecan oil cake w/o e&g required significantly more force to penetrate than the pecan oil cake with PGHMS and xanthan gum ($p = 0.012$). In fact in the raw mean values, the pecan oil cake was toughest of all and the emulsified cake with PGHMS was most tender, even more tender than the control, but not significantly (see Fig. 7).

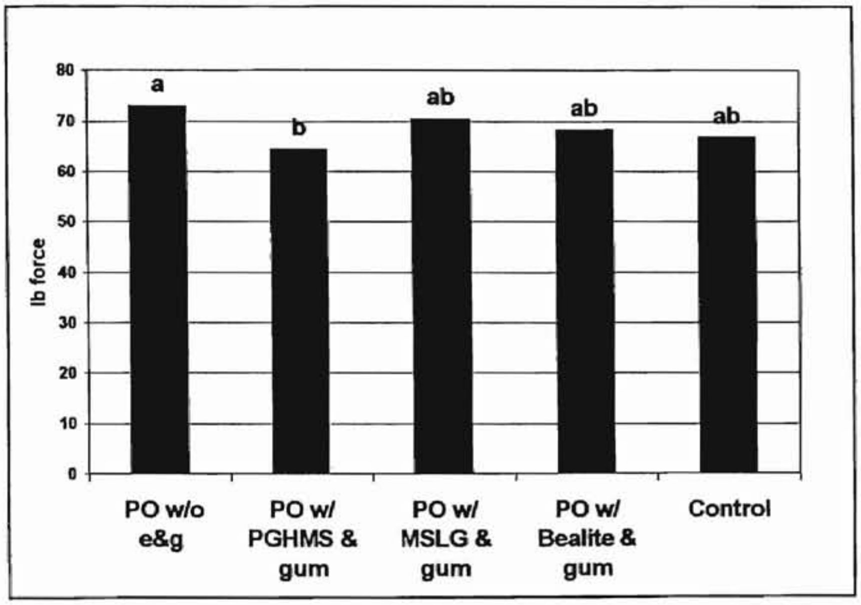


Fig. 7. Comparison of toughness of cakes.

Sensory evaluation data

A panel of 16 members tested four sensory attributes over four days as four replicates. The level of training achieved was evident by the second session of training, when they were given a test sample and all the ratings were very close. The training and testing were performed on consecutive days. This was beneficial, as the training was fresh in the panelists' memory.

Analysis of Sensory Data

The analysis of data was done by two methods, one sample t-test and repeated measures. One sample t-test were performed on the attributes to test the level of difference between each cake and the control.

Appearance (surface shine)

Pecan oil substitution in shortened cakes increased sensory scores for shininess against the control. The surface of control cake had significantly less shine than the rest of the cakes made with pecan oil. Typically cakes made with oil have a glossy surface compared to cakes made with shortening. The scale for surface shine was 0 for dullness and 10 for shiny (Table 8).

Table 8. T-test means and p values of each pecan oil cake compared against control.

Attributes / Cakes	Appearance (shine)	Texture (graininess)	Moisture absorption	Flavor (sweetness)
Control	1	4	6	5.5
Pecan oil cake w/o emul	1.5** *(p = 0.014)*	4.4** *(p = 0.007)*	6.1 *(p = 0.597)*	5.0** *(p = 0.009)*
Pecan oil cake w/ PGHMS	1.5** *(p = 0.008)*	4.2 *(p = 0.318)*	6.1 *(p = 0.704)*	4.9** *(p = 0.008)*
Pecan oil cake w/ MSLG	1.6** *(p = 0.001)*	4.2 *(p = 0.411)*	6.1 *(p = 0.551)*	5.0** *(p = 0.002)*
Pecan oil cake w/ Bealite	1.4** *(p = 0.023)*	4.1 *(p = 0.756)*	6.1 *(p = 0.406)*	4.9** *(p = 0.007)*

*Values for control cake are the numbers set by sensory panel

**Within a single attribute means are significantly different at $\alpha < 0.05$ from the control.

Texture (graininess)

Only the texture of pecan oil cake w/o e&g was significantly different (more grainy) than the control (Table 8). The scale for texture was a 0 for smooth and a 10 for grainy.

Carlin (1944) said that liquid oils do not have the ability to retain the air that has been incorporated during the mixing process and hence, produce low volume and poor grain. However, our cake with the oil only, did have good volume although the texture was more grainy. Solid shortening such as the one used (Crisco™) has mono and diglycerides that are emulsifiers and give a good texture to the cake. These emulsifiers strengthen batters by aiding in finely distributing the air during mixing (Ebeler et al., 1986). The replacement of this shortening by oil depletes the cake of these emulsifiers, so this grainier texture in the cake made with just the oil could be expected. The three cakes that had the added emulsifiers were not significantly different from the control (Fig. 8). Since the emulsified oil cakes were not significantly different from the control but oil only cake was different from the control, the emulsifier and gum apparently contributed to the desired texture.

Moisture absorption

No significant difference in the moisture absorption was found between any of the pecan oil cakes against the control cake (see Table 8). The amount of moisture left in the mouth and effort to swallow were the same. This means that one cake did not make the mouth feel drier than the other.

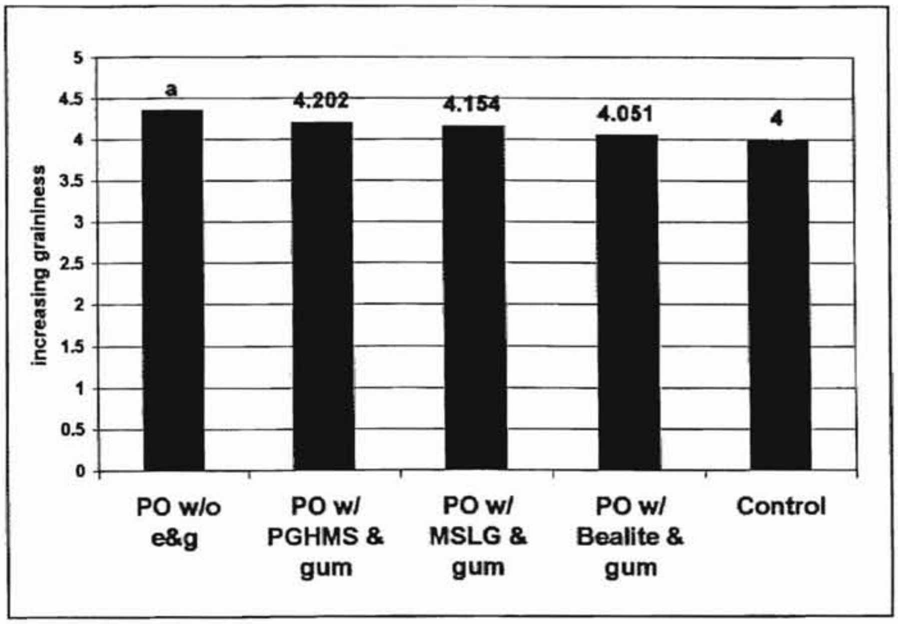


Fig. 8. Comparison of graininess of cakes

Flavor (sweetness)

Sensory scores for flavor (sweetness) were significantly less in all the pecan oil cakes than the control. Zero was marked for no sweetness and 10 for very sweet. Although the amount of sugar added was the same, it was interesting that the perceived sweetness was different (Fig. 9).

Analysis of pecan oil cakes with and without e & g

Repeated measures Analysis of Variance was performed using the General Linear Model (GLM) on the values for the four days for each sensory attribute. Sensory evaluation panelists did not indicate significant differences for the appearance (crumb surface shine), texture (graininess), moisture absorption, and flavor (sweetness) among the four cakes ($p > 0.05$) (see Table 9).

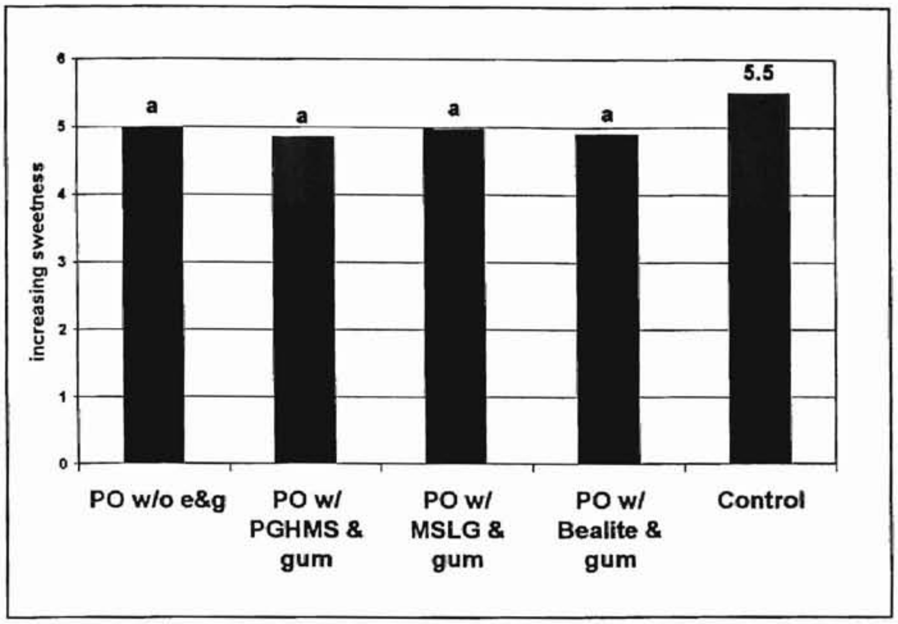


Fig. 9. Comparison of sweetness among cakes

Table 9. Means* and standard errors of sensory attributes of pecan oil cakes.

Attributes / Cakes	Appearance (shine)	Texture (graininess)	Moisture absorption	Flavor (sweetness)
Pecan oil cake w/o emul	1.5 ± 0.164	4.4 ± 0.113	6.1 ± 0.137	5.0 ± 0.175
Pecan oil cake w/ PGHMS	1.5 ± 0.173	4.2 ± 0.196	6.1 ± 0.183	4.8 ± 0.217
Pecan oil cake w/ MSLG	1.6 ± 0.138	4.2 ± 0.182	6.1 ± 0.154	5.0 ± 0.145
Pecan oil cake w/ Bealite	1.4 ± 0.164	4.1 ± 0.161	6.1 ± 0.135	4.9 ± 0.197

*Means are the results of four replicates by 16 panelists

There was a significant difference in sweetness of the pecan oil cakes with and without e&g against the control (Table 8), but there were no differences among the pecan oil cakes themselves (Table 9). A possible reason for this decreased sweetness could be that the flavor of the pecan oil masked some of the sugar flavor, which was perceived as a reduction in sweetness by the panelists.

In comparing the subjective and objective data on texture for the five cakes, both data sets show that the pecan oil cake w/o e&g was the toughest and had the grainiest texture. The subjective data measured the graininess of the cake crumb and the objective data measured its toughness.

Consumer testing data

A total of 129 people tested the pecan oil cake with Bealite and xanthan gum against the cake made from a commercial cake mix. This was a forced choice test and an option for choosing neither or both of the cakes was not given. Of the total consumers, 53.5% preferred the cake made from the cake mix and 46.5% preferred the pecan oil cake. When the test was conducted, many people expressed their liking for both the cakes. When they were forced to pick one, some of them at random selected the cake mix. Hence this does not indicate that the 53.5% liked only the cake mix, but some also liked the pecan oil cake and vice versa. This acceptance is not shown in the data. A binomial test on the consumer data showed that there was no significant difference in the acceptance of the cakes.

Several of the consumers reported that the top crust of the pecan oil cake was "sticky". This did not seem to be a major factor in their choice however.

Nutrition label

Nutrition labels were developed for this project using ESHA Genesis R&D. Labels were made for a cake made with shortening and a cake made with pecan oil with MSLG and xanthan gum (Fig. 10). These show that there was a 40% decrease (1 g) in saturated fat and a 25% increase in monounsaturated fat (1 g) in the cake made with pecan oil over the cake made with shortening. The differences may be more significant when the amount of oil added to the pecan oil cake is reduced and there would be a difference in the amount of calories and the type of fat ingested.

Nutrition Facts
Serving Size (80g)
Servings Per Container 5.36

Amount Per Serving	% Daily Value*
Calories 250	
Calories from Fat 80	
Calories from Saturated Fat 25	
Total Fat 9g	14%
Saturated Fat 2.5g	13%
Polyunsaturated Fat 2.5g	
Monounsaturated Fat 4g	
Cholesterol 35mg	12%
Sodium 150mg	6%
Total Carbohydrate 40g	13%
Dietary Fiber less than 1 gram	2%
Sugars 26g	
Protein 4g	
Vitamin A 2% • Vitamin C 0%	
Calcium 4% • Iron 6%	

*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

	Calories:	2,000	2,500
Total Fat	Less than	65g	80g
Saturated Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

Calories per gram:
Fat 9 • Carbohydrate 4 • Protein 4

Cake made with shortening

Nutrition Facts
Serving Size (80g)
Servings Per Container 5.4

Amount Per Serving	% Daily Value*
Calories 260	
Calories from Fat 90	
Calories from Saturated Fat 15	
Total Fat 9g	15%
Saturated Fat 1.5g	7%
Polyunsaturated Fat 2g	
Monounsaturated Fat 5g	
Cholesterol 35mg	12%
Sodium 150mg	6%
Total Carbohydrate 40g	13%
Dietary Fiber less than 1 gram	3%
Sugars 26g	
Protein 4g	
Vitamin A 2% • Vitamin C 0%	
Calcium 4% • Iron 6%	

*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

	Calories:	2,000	2,500
Total Fat	Less than	65g	80g
Saturated Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

Calories per gram:
Fat 9 • Carbohydrate 4 • Protein 4

Cake made with pecan oil, MSLG and xanthan gum

Fig. 10. Nutrition label

CHAPTER V

SUMMARY, CONCLUSION AND HYPOTHESIS TESTING

The replacement of vegetable shortening with a highly monounsaturated oil yielded an acceptable cake when xanthan gum and emulsifiers were added. This may have a nutritional advantage due to the high monounsaturated/saturated ratio.

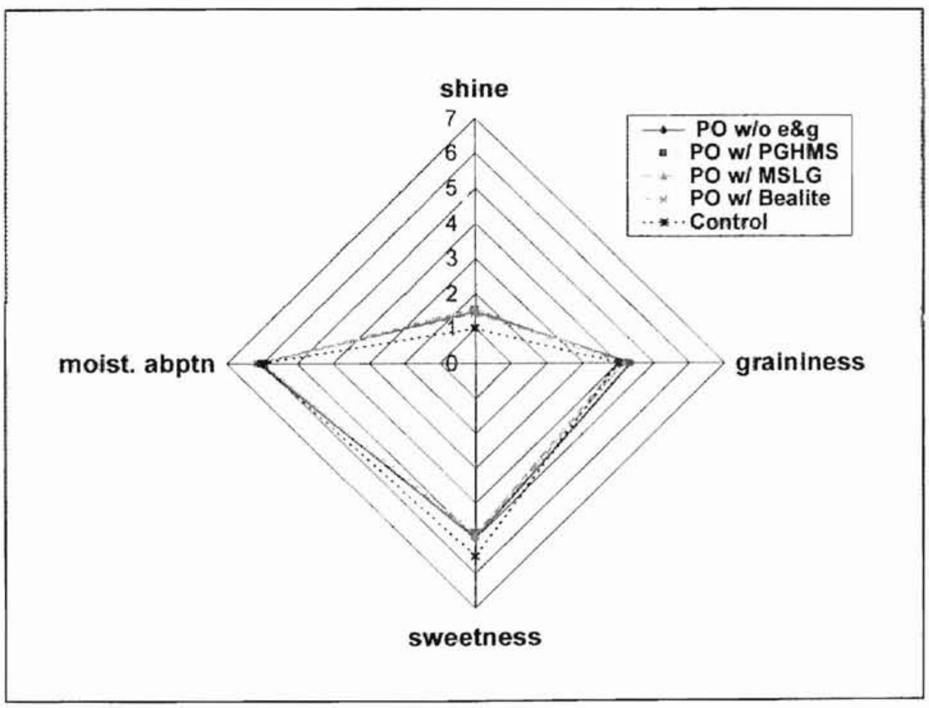
The pecan oil cake batter w/o e&g was very fluid and had a specific gravity close to the control. It was the toughest among all the cakes. The mean height of the pecan oil cakes with or without emulsifier and gum was found to be higher than the control. Use of oil does not incorporate enough air into the batter during mixing.

Yellow cakes made with pecan oil with or without emulsifier and gum were judged equal in appearance (crumb surface shine), texture (graininess), moisture absorption, and flavor (sweetness). Sensory scores for texture and moisture absorption of the pecan oil cakes against the control were the least affected; appearance and flavor were the most affected. The texture of the pecan oil cake w/o e&g was the most grainiest, and this was the only significant difference.

A pecan oil cake with Bealite and xanthan gum was as acceptable to consumers as a cake made from a commercial cake mix. Some of the comments of the consumers were that the pecan oil cake was more moist and the commercial cake felt dry. Some felt one cake was sweeter than the other.

A comparison of the different cakes – control cake, pecan oil cake w/o e&g, pecan oil cake with PGHMS and xanthan gum, pecan oil cake with MSLG and xanthan gum, pecan oil cake with Bealite and xanthan gum, for the sensory attributes – appearance (crumb surface shine), texture (graininess), moisture absorption, and flavor (sweetness) is shown in Fig. 11.

With the current recommendations for a decrease in the saturated fat and an increase in the monounsaturated fat in the diet, the results of this study indicate that oil/fat replacements can be successful without undesirable sensory changes.



Surface shine (0-dull to 10-shiny)
Sweetness (0-no sweet to 10-very sweet)
Texture (0-smooth to 10-grainy)
Moisture absorption (0-no absorption to 10-lot of absorption)

Fig. 11. Contrast of sensory attributes and cakes.

Hypothesis testing

H_1: 1. There were significant differences in sensory attributes of appearance (crumb surface shine), texture (graininess), and flavor (sweetness), between control and some pecan oil cakes with or without added emulsifiers and xanthan gum.

2. There were significant differences in objective tests of specific gravity, line spread, mean height, and texture gauge measurements between control and some pecan oil cakes with or without added emulsifiers and xanthan gum.

Therefore we reject the hypothesis H_1 that there would be no significant differences in the sensory attributes and objective tests between control and pecan oil cakes with or without added emulsifiers and xanthan gum.

H_2: 1. There were no significant differences in the sensory attributes of appearance (crumb surface shine), texture (graininess), moisture absorption, and flavor (sweetness), in pecan oil cakes with or without added emulsifiers and xanthan gum.

2. There were significant differences in objective tests of specific gravity, line spread, mean height, and texture gauge measurements in pecan oil cakes with or without added emulsifiers and xanthan gum.

Therefore we reject H_2 that there would be no significant differences in the sensory attributes and objective tests in pecan oil cakes with or without added emulsifiers and xanthan gum.

H_3: 1. There were no significant differences in the sensory attributes of appearance (crumb surface shine), texture (graininess), moisture absorption, and flavor (sweetness), among pecan oil cakes with emulsifiers and xanthan gum

2. There were no significant differences in objective tests of specific gravity, line spread, mean height, and texture gauge measurements among pecan oil cakes with emulsifiers and xanthan gum.

Therefore we accept H_3 that there would be no significant differences in the sensory attributes and objective tests among pecan oil cakes with emulsifiers and xanthan gum.

H_4: There was no significant difference in the consumer acceptance of a pecan oil cake with emulsifier and xanthan gum compared to a cake made from a commercial cake mix. So we accept hypothesis H_4.

CHAPTER VI

SUGGESTIONS FOR FUTURE STUDY

This study showed that a good cake could be made by the substitution of pecan oil in place of shortening. The fine grain seen in a control cake could be obtained by adding a combination of emulsifier and xanthan gum. Sensory analysis has shown that there is little difference between the control cake and pecan oil cakes with emulsifier and gum. Consumer acceptance testing showed that the pecan oil cake with emulsifier and gum was as acceptable as a cake made from a commercial cake mix. Following are suggestions for future study:

The review of literature indicated that a reduction of total fat in cakes is possible when oil is substituted for solid shortening. Research can be conducted by reducing levels of the total amount of oil added and determine the lowest level that would still make the most acceptable cake. Since pecan oil is high in monounsaturated fat, even though fat is present at low levels, it could improve the health aspects.

Large air bubbles in the battered cakes with emulsifier and gum were obvious and these increased with the increase in beating time. It was hypothesized that the reduction of the large air bubbles can be attained by reducing the amount of beating time after the addition of xanthan gum and/or by reducing the amount of xanthan gum added to the batter. Both of these solutions can be explored in further studies.

A cake mix using pecan oil can be made from the final formula. Since today's world is a busy world and no one has the time to make a cake from scratch, a cake mix would be easier to market than a recipe. Research needs to be conducted to develop an acceptable cake mix with pecan oil.

Sensory and consumer evaluations were conducted on freshly baked cakes. Research needs to be conducted on storage studies to see if the addition of pecan oil, gum and emulsifiers affect the shelf life. A highly trained sensory panel could perform a descriptive analysis on the storage of the cakes.

Only a few sensory attributes of freshly baked cakes were studied in this research. It would be interesting to test some other attributes, like flavor profile, to compare how they differ from the control.

Different levels or combinations of emulsifiers and xanthan gum should be tested to determine if one is better than the other. This study was not designed to identify a single critical point if there is one.

Only three of the emulsifiers commonly used in the baking industry were tested for this study. Further studies could investigate other emulsifiers, to see if there would be a difference in any attributes of the cakes.

This study researched only one type of gum (xanthan gum). Further research can be conducted to test the use of other gums in cakes.

Many of the consumers indicated that the pecan oil cake crust was sticky. Research can be conducted to test its cause and explore for a solution.

Also, the crust was sweeter than the crumb showing that the sugar migrated to the crust. Studies can be conducted to determine the cause for this migration and a solution to eliminate it.

Consumer testing could be conducted on pecan oil cake with emulsifier and xanthan gum with vanilla added, against a cake made from a commercial cake mix to determine the difference in the acceptability as compared to the pecan oil cake with e&g and without vanilla.

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APPENDIX A

Typical products containing Xanthan gum

Bakery products
- Cake mixes
- Danish fillings
- Pie crust
- Pie crust fillings
- Poptarts

Cereal bars

Condiments
- Pickle relish
- Salsa

Dairy products
- Cheesecake
- Cheese spreads
- Cottage cheese
- Cream cheese
- Frozen cheese
- Whipped toppings

Frozen foods
- Frozen cheese
- Frozen fish florentine
- Frozen guacamole
- Frozen lasagna
- Frozen pizza
- Frozen rice

Honey-roasted peanuts

Meat products
- Breakfast slices
- Poultry breast slices

Mixes
- Cake mixes
- Cocktail mixes
- Fruit drink mixes
- Gravy mixes
- Pie filling mixes
- Pudding mixes

Salad dressings, etc.
- Low-calorie pourable salad dressing
- Pourable salad dressings
- Reduced-calorie mayonnaise

Sauces
- Barbecue sauces
- Cocktail sauces
- Mushroom sauce
- Oriental sauce
- Pizza sauces
- Sloppy Joe sauce
- Taco sauces
- Tartar sauce

Spreads
- Margarine spreads
- Sandwich spreads

Syrups
- Chocolate syrup
- Pancake syrup

Toppings
- Marshmallow toppings

Source: Whistler, R. L., and BeMiller, J. N. Carbohydrate Chemistry for Food Scientists (1997).

APPENDIX B

Raw data on product development

Step 1

High ratio cake:

1 cup + 2 Tbsp. flour	A	1 egg, unbeaten	C
¾ cup sugar	A	3 Tbsp. milk	C
1 ½ tsp. baking powder	A	½ tsp. vanilla	C
¼ cup shortening	B		
¼ tsp. salt	B		
5 Tbsp. milk	B		

Quick mix (Dump) method of mixing: this method of mixing employs the following. Sift together A ingredients to mix well. Add B's and beat 2 minutes with an electric mixer. Add C's and beat for 2 more minutes. Pour the batter into greased 6" round pan and bake at 350° F till done. The cake is done when the top touched lightly springs back. A cake tester when inserted at the center comes out clean, is a confirmation of doneness.

Balanced ratio cake:

1 cup flour	A	¼ cup shortening	B1
¼ tsp. salt	A	¾ cup sugar	B2
1 ½ tsp. baking powder	A	½ tsp. vanilla	C
3 Tbsp. milk	D		

Conventional method of mixing: sift together A's to mix well. Cream B1, add B2 and beat till light and fluffy. Add C's and beat. Add A's alternately with D and stir thoroughly till well mixed. Pour the batter into a 6" round pan and bake at 350° F till done. The combination of high ratio and conventional method of mixing and balanced ratio and quick mix method were also prepared.

Step 2:

Subjective ratings for the cakes during preliminary testing.

Cake	Texture	Flavor	Moisture	Acceptability	Comments
Conv. HR	9.0	9.5	9.0	10.0	Good moisture. seems heavy at the bottom
Conv. BR	7.5	7.0	6.5	8.0	Gums up in mouth. Texture slightly dense, flavor doesn't seem full.
Dump HR (pecan oil)	8.0	8.5	9.0	9.0	Bubbles round, had greater vol. at center. Has strong pecan flavor
Conv. BR (pecan oil)	7.0	8.0	7.5	7.0	Bubbles rounder, spongy than std. Strong pecan flavor

HR- High ratio cake

BR- Balanced ratio cake

Objective test readings of the cakes during preliminary testing.

Cake	Mean height (cm)	Line spread	Specific gravity
Conv. HR	4.3	1.25	0.94
Conv. BR	4.0	0	0.96
Dump HR (pecan oil)	4.3	7.50	1.03
Conv. BR (pecan oil)	4.2	6.25	1.04

Step 3:

Subjective ratings for the cakes tested with levels of three different emulsifiers.

Cake	Texture	Flavor	Moisture	Acceptability	Comments
Control	9.0	9.5	9.0	10.0	Fine grain
PO 4% Bealite	5.0	6.0	8.5	6.0	Strong pecan flavor, texture-uniform bubbles
PO 5% Bealite	5.0	8.0	8.0	8.0	texture-uniform bubbles
PO 6% Bealite	5.5	8.0	7.0	9.0	More volume than control. Good
PO 4% MSLG	8.0	7.0	6.0	6.0	Few large bubbles in crumb.
PO 5% MSLG	8.0	7.0	6.0	7.0	Uniform bubbles
PO 6% MSLG	8.0	7.0	8.0	8.0	Good
PO 4% PGHMS	8.0	6.0	8.0	8.0	Bubbles small and uniform. Good grain
PO 5% PGHMS	8.0	6.0	7.0	7.0	
PO 6% PGHMS	8.0	6.0	7.0	6.0	Too high emulsifier. Anaesthetic feeling

PO- cake with pecan oil substituted for shortening

Objective data for the cakes tested with levels of three different emulsifiers.

Cake	Mean height (cm)	Line spread	Specific gravity
Control	4.5	2.6	1.08
PO 4% Bealite	4.5	8.1	1.00
PO 5% Bealite	4.6	9.0	1.09
PO 6% Bealite	4.6	8.0	1.06
PO 4% MSLG	5.0	6.3	1.02
PO 5% MSLG	5.4	8.5	0.96
PO 6% MSLG	5.3	8.8	1.01
PO 4% PGHMS	5.0	7.5	0.95
PO 5% PGHMS	5.0	9.3	1.03
PO 6% PGHMS	5.2	8.8	0.97

Step 4

Subjective ratings for the cakes tested at increased levels of emulsifiers.

Cake	Texture	Flavor	Moisture	Acceptability	Comments
Control	9.0	9.5	9.0	10.0	
PO 10% Bealite	9.0	9.0	7.0	8.0	Very tender
PO 10% MSLG	6.0	8.0	6.5	7.0	Bubbles uniform, coarse than control
PO 10% PGHMS	6.0	8.0	6.5	7.0	Texture coarse, chewy

Objective test readings of the cakes tested at increased levels of emulsifiers.

Cake	Mean height (cm)	Line spread	Specific gravity
Control	4.8	2.00	1.00
PO 10% Bealite	5.0	1.75	0.77
PO 10% MSLG	5.0	8.00	1.07
PO 10% PGHMS	5.3	7.25	1.00

Step 5

Subjective ratings for the cakes made with one type of emulsifier and gum.

Cake	Texture	Flavor	Moisture	Acceptability	Comments
Control	9.0	9.5	9.0	10.0	
PO xanthan gum and Bealite	8.0	8.0	6.0	8.0	Peaked tops, good
PO reduced oil, xanthan gum and Bealite	7.0	8.0	6.5	7.0	Peaked tops, good

Objective test readings of the cakes made with one type of emulsifier and gum.

Cake	Mean height (cm)	Line spread	Specific gravity
Control	5.0	2.00	1.00
PO xanthan gum and Bealite	5.6	3.25	1.18
PO reduced oil, xanthan gum and Bealite	5.6	2.25	1.12

APPENDIX C

Weights of the ingredients used in cakes

Ingredient	Balanced ratio cake (in g)	High ratio cake (in g)
Flour	100	100
Sugar	100	132
Salt	1.8	1
Baking powder	3.1	4
Shortening	32	42
Milk	80	106
Eggs	32	44

APPENDIX D

Pecan oil cake preliminary testing score sheet

Over-all Texture

0---------------------10
smooth coarse

Over-all Acceptability

0-----------------------10
dislike like

Flavor

0---------------------10
dislike like

Moisture

0-------------------------10
dry wet

Comments: ____

____

____

APPENDIX E

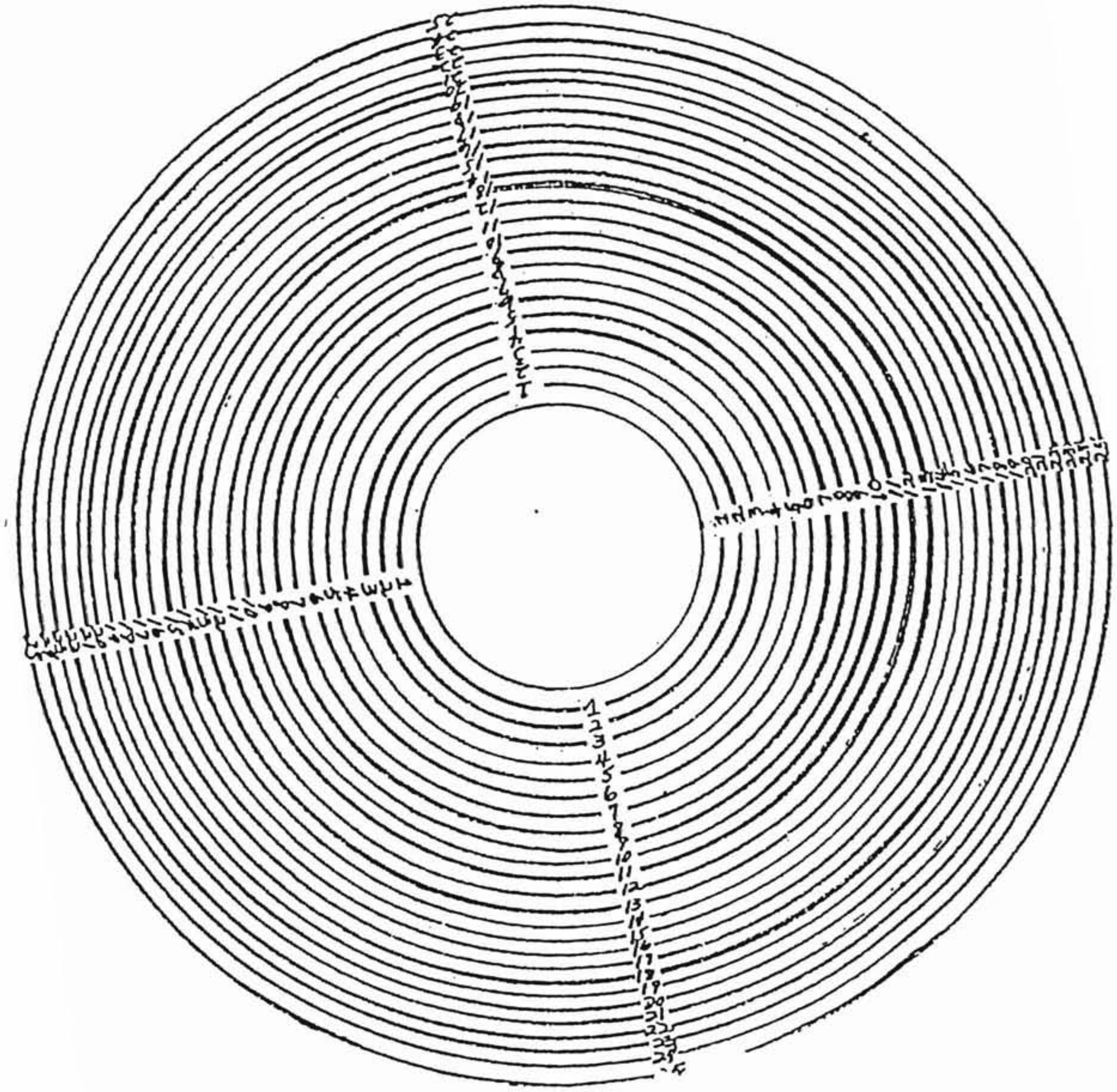
Components and nutritional value of emulsifiers

(Expressed in Kcal/100 g, and grams/100 g of product as sold)

Emulsifier	Description	Addition level	Kcal .	Kcal. from fat	Total fat (g)	Saturated fat (g)
Aldo MSLG	Mono & diglycerides	4-6% of fat	870	747	83	83
Aldo PGHMS	Propylene glycol monostearate	4-6% of fat	920	792	88	88
Bealite 3401 L	Propylene glycol mono & di esters of fats and FA, mono & diglycerides, partially hydrogenated soybean oil with lecithin, disodium phosphate,	4-6% dry weight	730	630	70	27

APPENDIX F

Line spread sheet
(78% of original size)



APPENDIX G

Consent to participate in research
Sensory Evaluation of Pecan Oil Cakes

I, ______________________________, voluntarily agree to participate in the above titled research that is sponsored by the College of Human Environmental Sciences at Oklahoma State University.

I understand that:

(1) I will be participating in research to test the sensory qualities of pecan oil cakes

(2) the sensory panel will be drawn from faculty, staff, parents and students of Oklahoma State University.

(3) this study will take place during the 1998 school year.

(4) participation or non-participation in this study will in no way affect my grade or performance rating; but by participating in this research I will see how sensory evaluation can contribute to scientific research designed to encourage economic development in Oklahoma.

(5) I will be informed of all foods and ingredients that I will be asked to evaluate. If I know or suspect that I am allergic to any of them, I will withdraw myself from testing that product.

(6) all results obtained from my participation in this research will be recorded by code number; my identity will be kept confidential, and I will not be identified as an individual or by response in any presentation of the results.

(7) my participation is voluntary, and I have the right to withdraw from this study at any time with no penalty by contacting the principal investigators;

(8) I have not waived any of my legal rights or released this institution from liability for negligence.

I may contact Dr. Sue Knight at (405)744-5043 or Anu Srireddy (405)707-0217 should I wish further information. I may also contact Gay Clarkson in the office of University Research Services, 305 Whitehurst, Oklahoma State University, Stillwater, OK 74078 at (405)744-5700.

I have read and fully understood this consent form. I sign it freely and voluntarily. A copy has been given to me.

Date__________________ Time ___________(am/pm)

Signed ______________________________

I certify that I have personally explained all elements of this form to the subject before requesting the subject to sign it.

Signed ____
(project director or her authorized representative)

Printed name Dr. Sue Knight
(project director or her authorized representative)

APPENDIX H

Terminology and procedure

***Appearance- surface shine:**

Definition- amount of light reflected from the product's surface.

Test Method- look at the gloss of the sample.

***Texture (oral)**

Definition- the texture of particles in the mouth (mouthfeel of the texture of the cake)

Test Method- chew corn bread 10 times and feel the particles in your mouth. Chew cake 5 times. Evaluate with your tongue.

***Moisture absorption:**

Definition- the amount of saliva absorbed by sample during chew down.

Test Method- chew sample with molars until just before you are ready to swallow. Then feel the amount of wetness absorbed by the sample and the amount of mass formation in the mouth. This can be described by the amount of saliva left in the mouth.

***Flavor (sweetness):**

Definition- taste stimulated by sucrose and other sugars, such as fructose, glucose, etc., and by other sweet substances such as saccharin, and Aspartame.

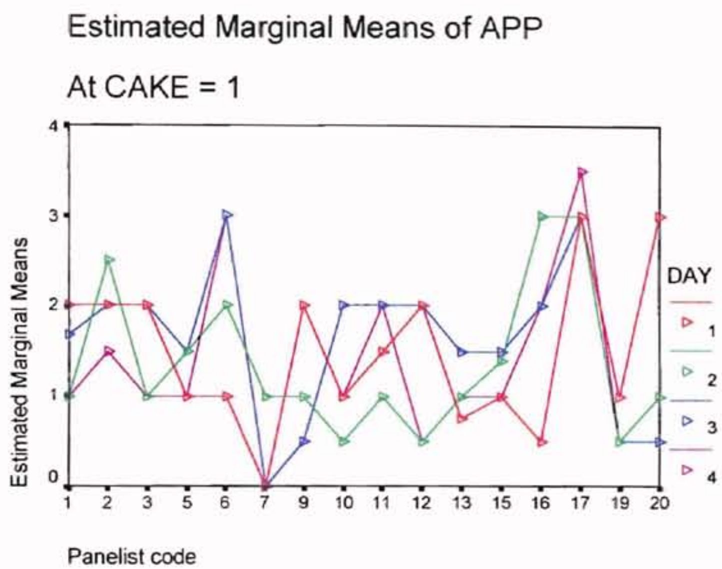
Test Method- take a sip of the solution, sqoosh it around in your mouth. Taste the sweetness.

Source: Meilgaard, M., Civille, G. V., and Carr, T. B. *Sensory Evaluation Techniques* 1991.

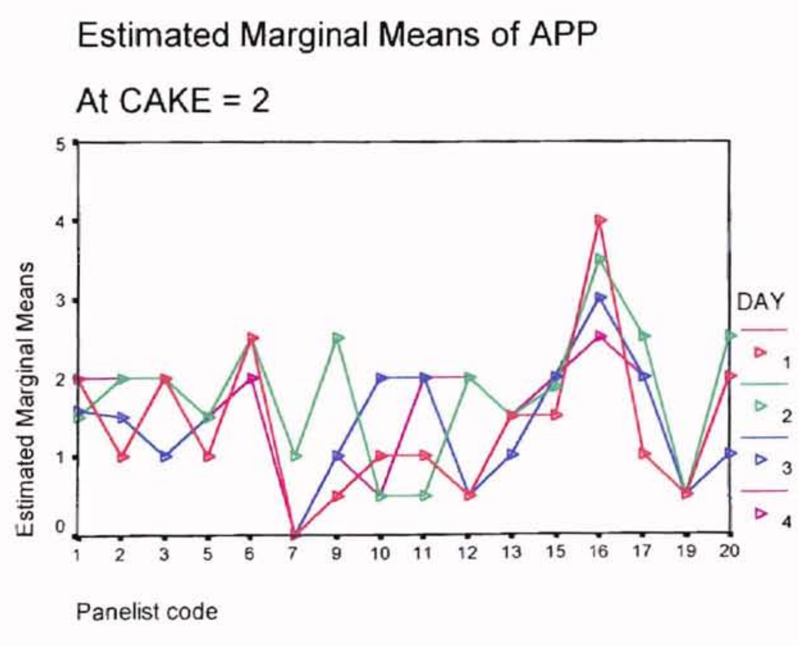
APPENDIX I

Panelist ratings

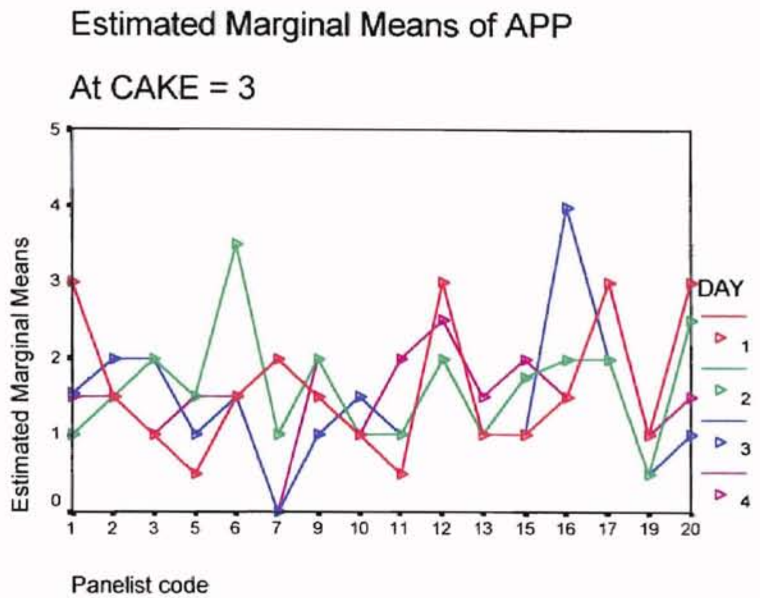
Panelist ratings for pecan oil cake without emulsifier and gum on four days for appearance (surface shine).
On the scale, 0 was dull and 10 shiny.



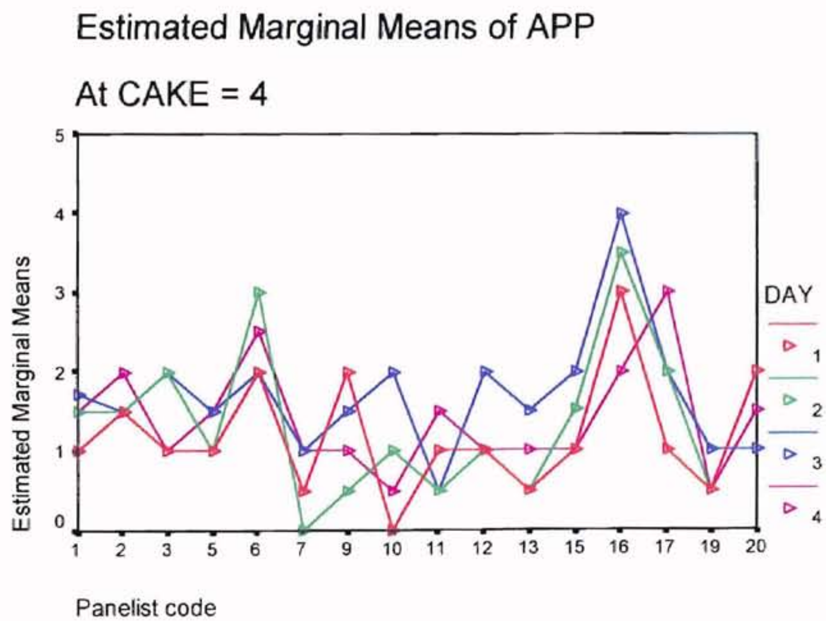
Panelist ratings for pecan oil cake with PGHMS and xanthan gum on four days for appearance (surface shine)



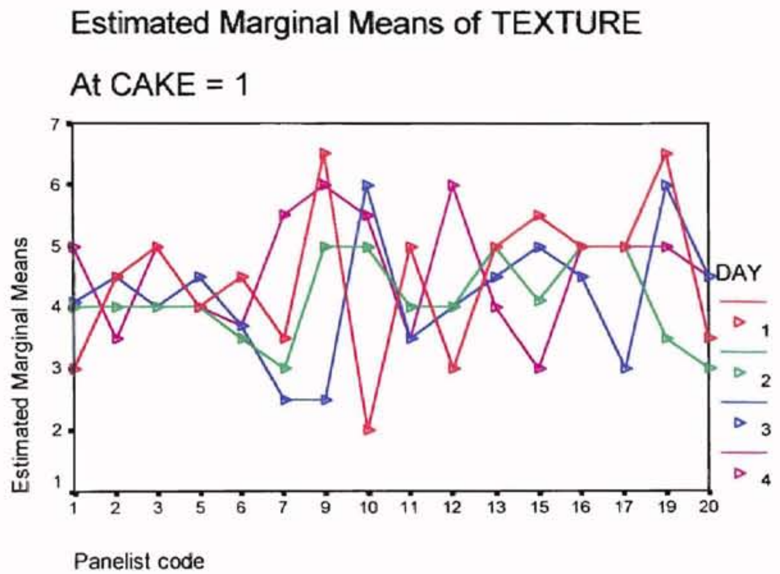
Panelist ratings for pecan oil cake with MSLG and xanthan gum on four days for appearance (surface shine)



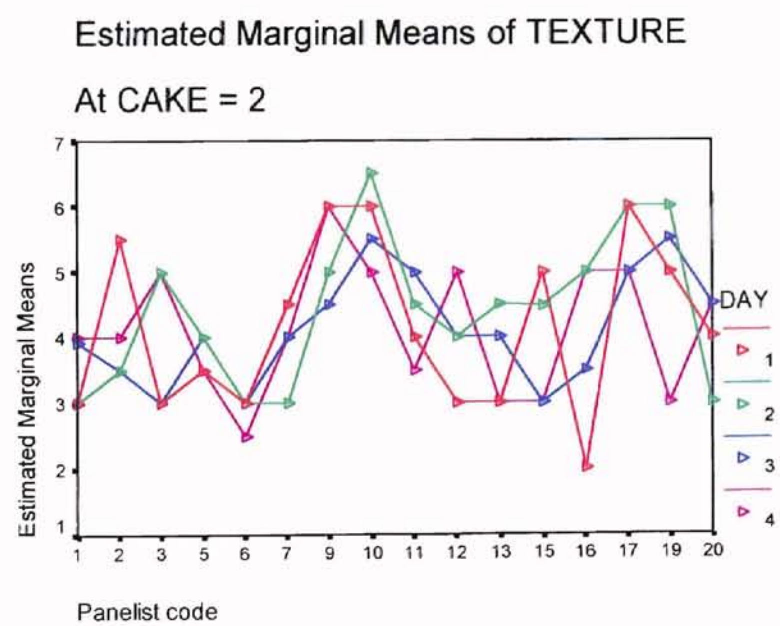
Panelist ratings for pecan oil cake with Bealite and xanthan gum on four days for appearance (surface shine)



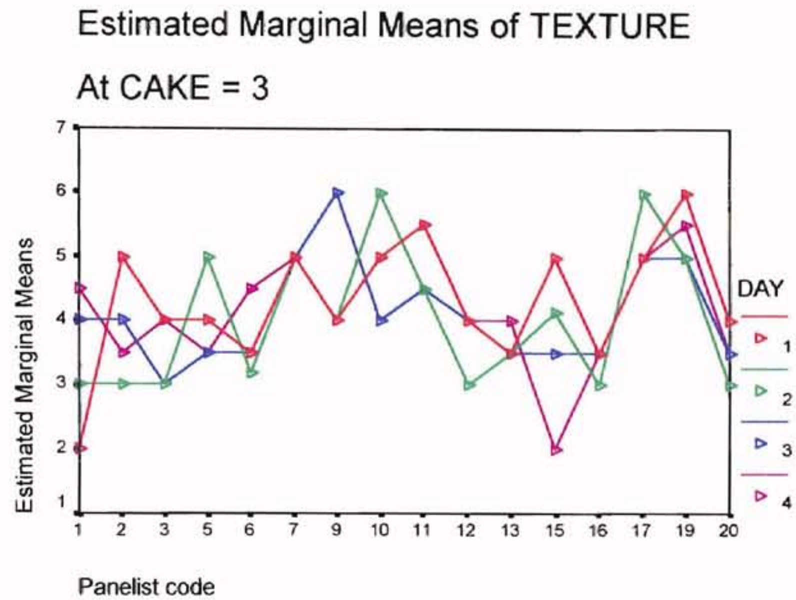
Panelist ratings for pecan oil cake without emulsifier and gum on four days for texture (graininess).
On the scale 0 was smooth and 10 was grainy.



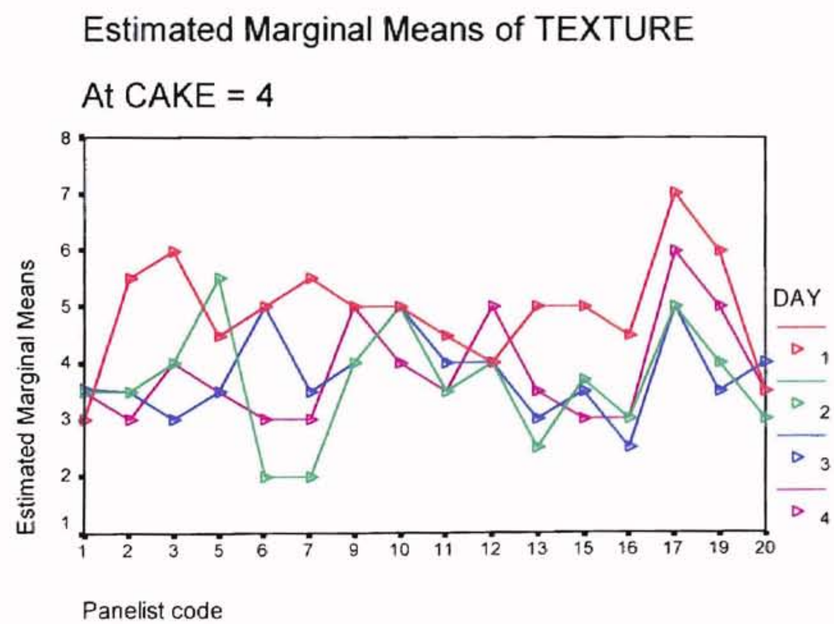
Panelist ratings for pecan oil cake with PGHMS and xanthan gum on four days for texture (graininess).



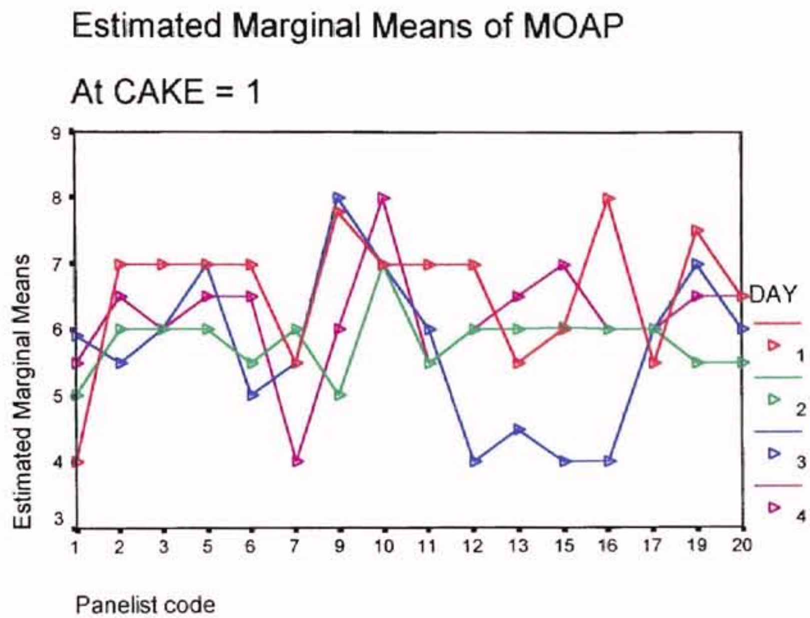
Panelist ratings for pecan oil cake with MSLG and xanthan gum on four days for texture (graininess).



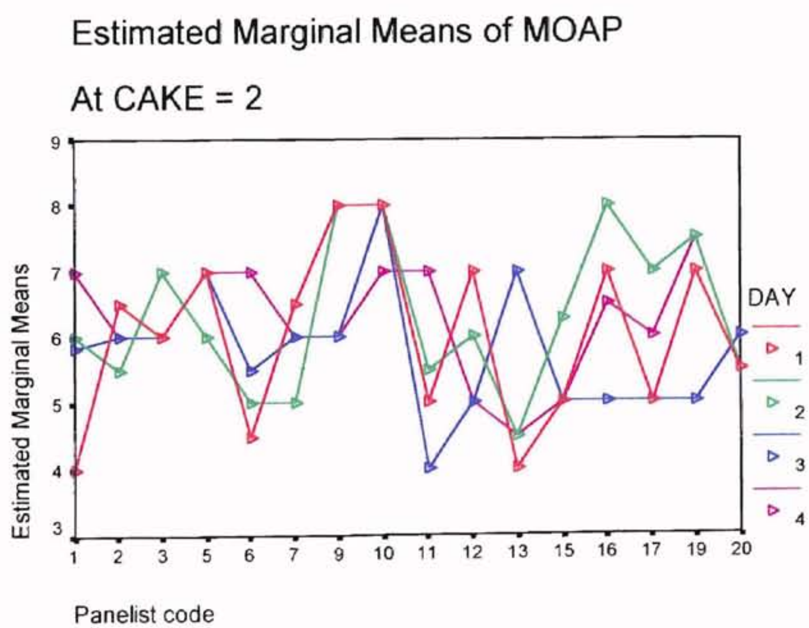
Panelist ratings for pecan oil cake with Bealite and xanthan gum on four days for texture (graininess).



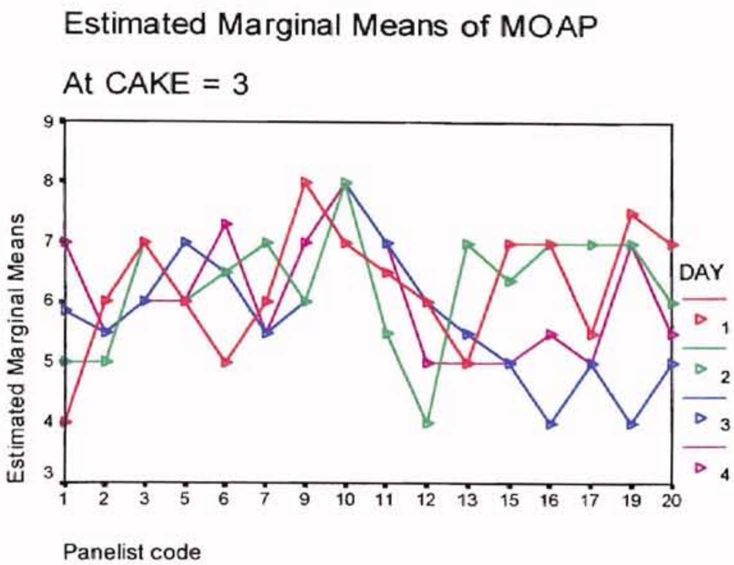
Panelist ratings for pecan oil cake without emulsifier and gum on four days for moisture absorption.
On the scale, 0 was no absorption and 10 for lot of absorption.



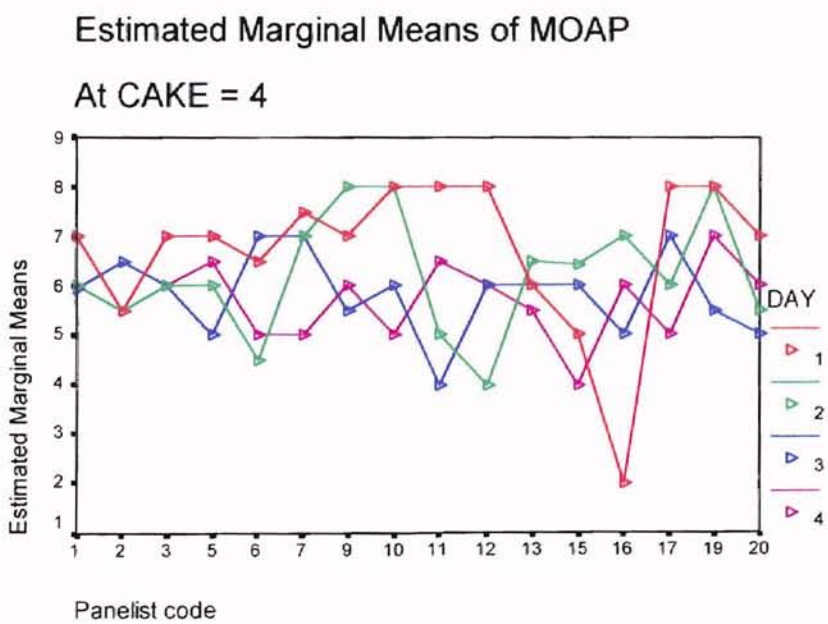
Panelist ratings for pecan oil cake with PGHMS and xanthan gum on four days for moisture absorption.



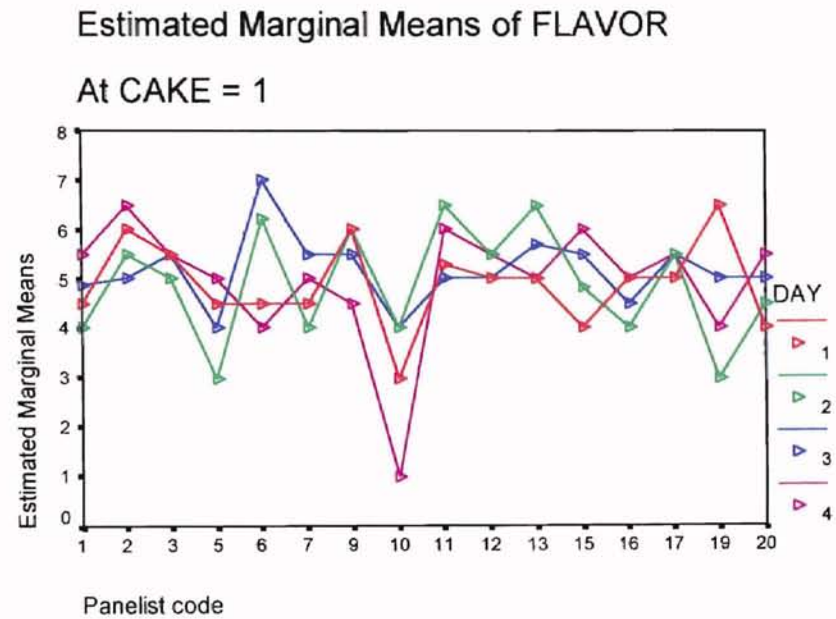
Panelist ratings for pecan oil cake with MSLG and xanthan gum on four days for moisture absorption.



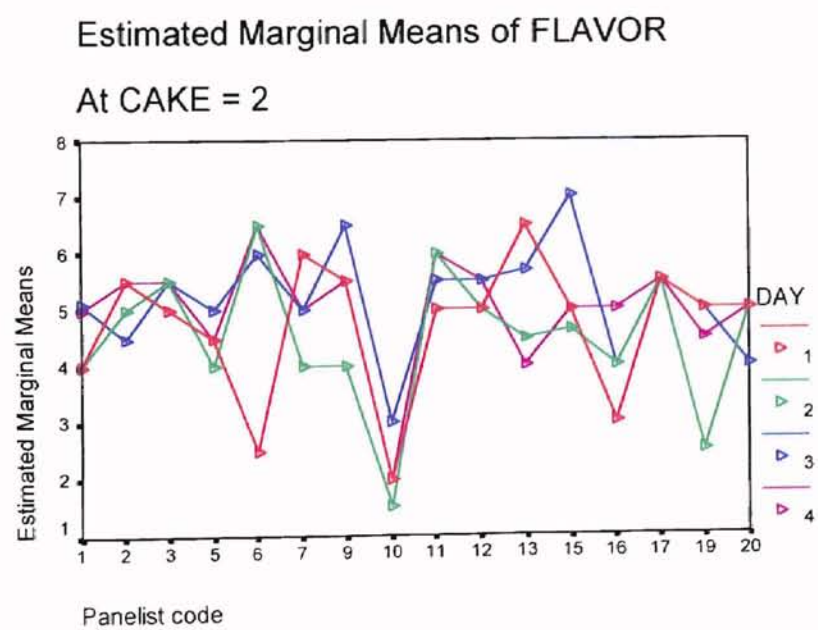
Panelist ratings for pecan oil cake with Bealite and xanthan gum on four days for moisture absorption.



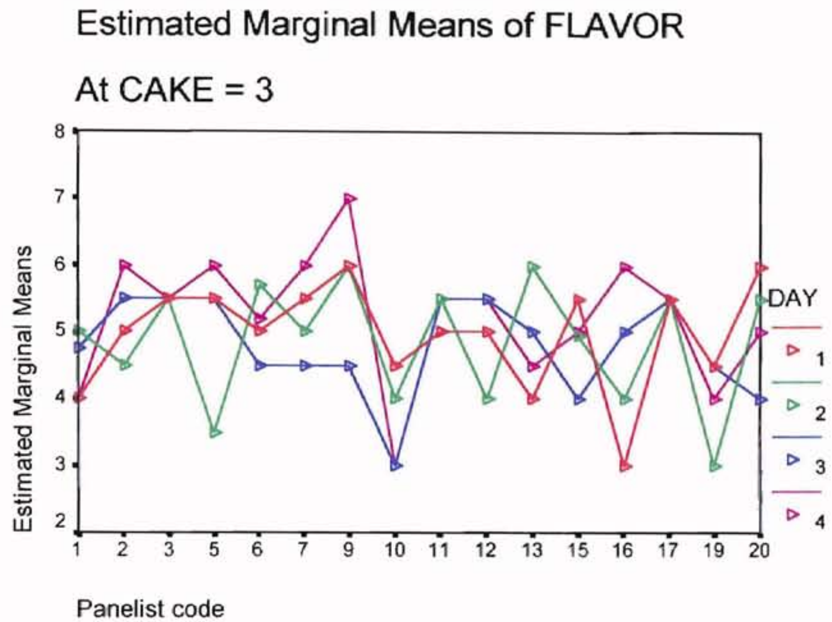
Panelist ratings for pecan oil cake without emulsifier and gum on four days for flavor (sweetness).
On the scale, 0 was for no sweetness and 10 for very sweet.



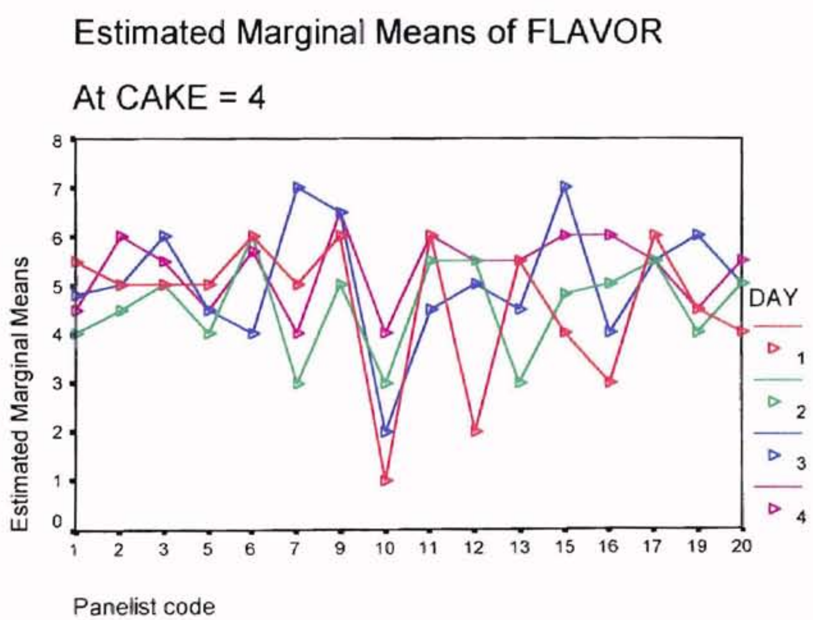
Panelist ratings for pecan oil cake with PGHMS and xanthan gum on four days for flavor (sweetness).



Panelist ratings for pecan oil cake with MSLG and xanthan gum on four days for flavor (sweetness).



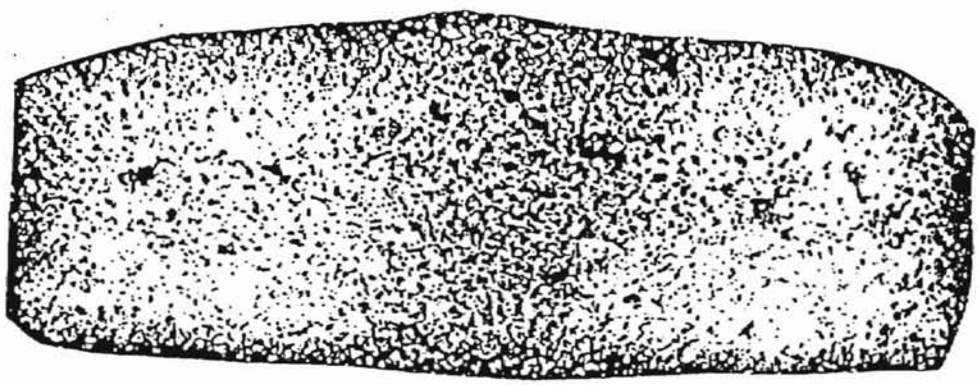
Panelist ratings for pecan oil cake with Bealite and xanthan gum on four days for flavor (sweetness).



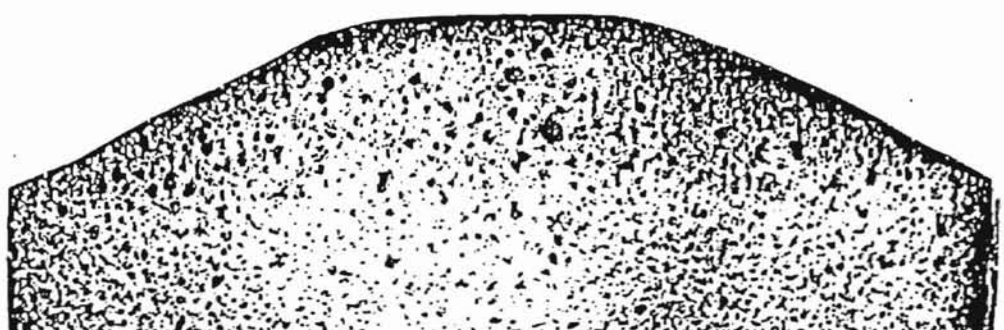
APPENDIX J

Effect of emulsifier and gum on cake texture

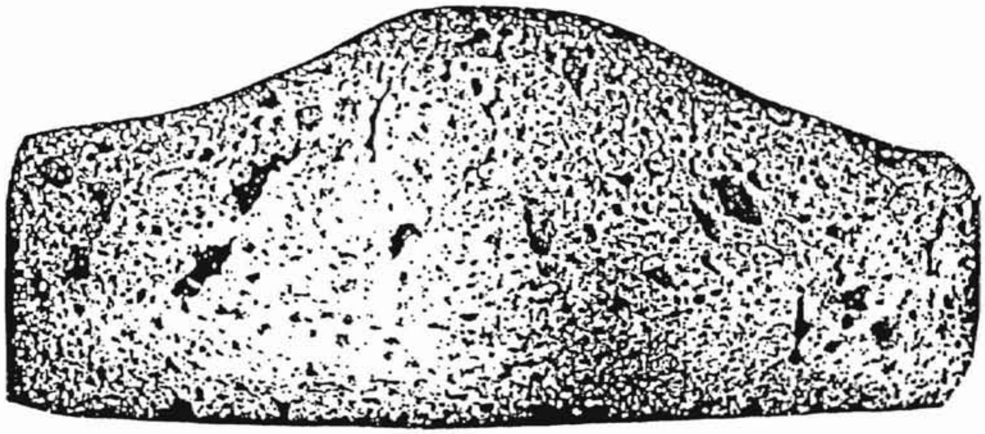
Control



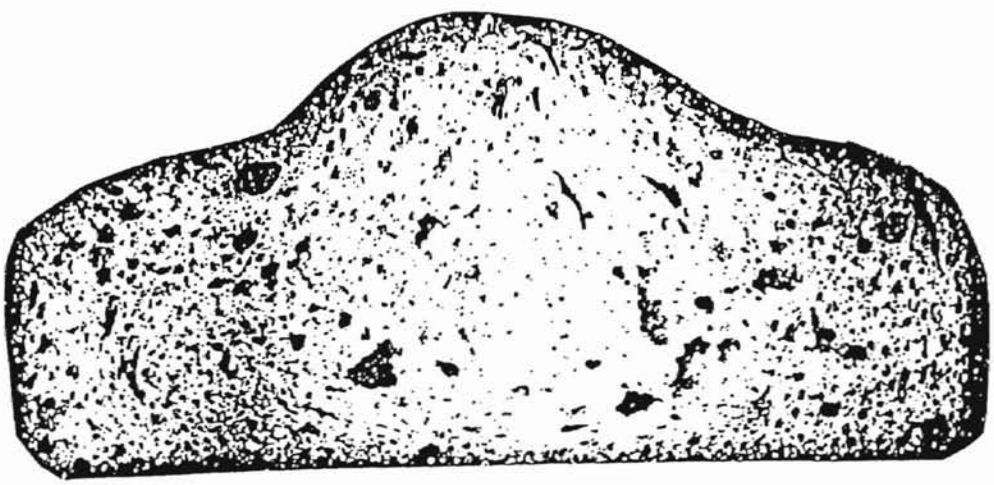
Pecan oil cake without emulsifier and xanthan gum



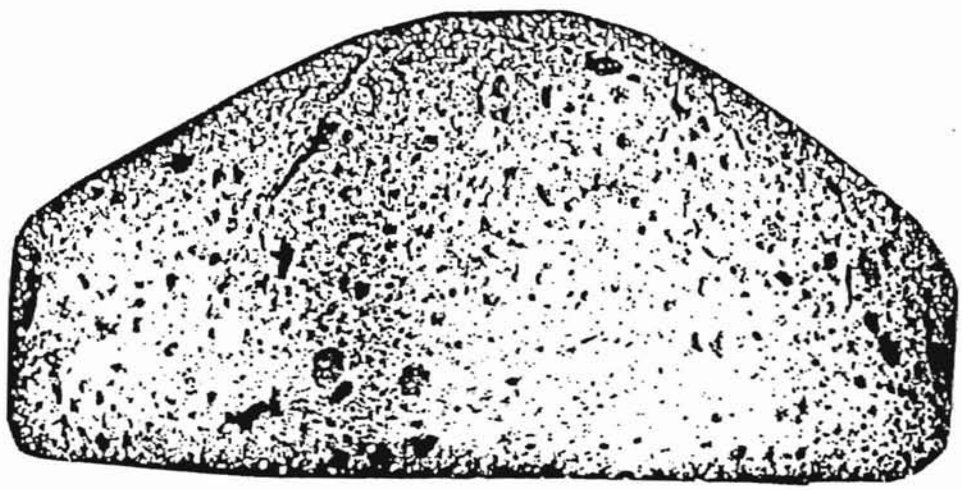
Pecan oil cake with emulsifier PGHMS (2gms) and xanthan gum (0.6gms)



Pecan oil cake with emulsifier MSLG (2gms) and xanthan gum (0.6gms)



Pecan oil cake with emulsifier Bealite (2gms) and xanthan gum (0.6gms)



APPENDIX K

OKLAHOMA STATE UNIVERSITY
INSTITUTIONAL REVIEW BOARD
HUMAN SUBJECTS REVIEW

Date: 08-26-98 **IRB #:** HE-99-009

Proposal Title: SENSORY EVALUATION OF PECAN OIL CAKES

Principal Investigator(s): Sue Knight, Anupama Srireddy

Reviewed and Processed as: Exempt

Approval Status Recommended by Reviewer(s): Approved

ALL APPROVALS MAY BE SUBJECT TO REVIEW BY FULL INSTITUTIONAL REVIEW BOARD AT NEXT MEETING, AS WELL AS ARE SUBJECT TO MONITORING AT ANY TIME DURING THE APPROVAL PERIOD.
APPROVAL STATUS PERIOD VALID FOR DATA COLLECTION FOR A ONE CALENDAR YEAR PERIOD AFTER WHICH A CONTINUATION OR RENEWAL REQUEST IS REQUIRED TO BE SUBMITTED FOR BOARD APPROVAL.
ANY MODIFICATIONS TO APPROVED PROJECT MUST ALSO BE SUBMITTED FOR APPROVAL.

Comments, Modifications/Conditions for Approval or Disapproval are as follows:

Signature: Thomas C. Collins

Date: August 26, 1998

Interim Chair of Institutional Review Board
and Vice President for Research

cc: Anupama Srireddy

VITA

Anupama Srireddy

Candidate for the Degree of

Master of Science

Thesis: PECAN OIL SUBSTITUTION FOR SHORTENING IN YELLOW LAYER CAKES.

Major Field: Food Science - Nutritional Sciences

Biographical:

Personal Data: Born in Poona, India, on December 16, 1972, the only daughter of Rama Rao and Rama.

Education: Graduated from St.Ann's High School, India in 1990; received Bachelor of Science degree in Nutrition and Dietetics from St.Ann's Degree College for Women, India in 1993; received Graduate Diploma in Nutrition and Dietetics from Institute for Social Sciences and Research, India in 1995; completed Masters in Business Administration from Newport University, India in 1996; completed requirements for the Master of Science degree with major in Food Science at Oklahoma State University in December, 1998.

Experience: Intern Dietician at Apollo Hospital, India 1993-1994. Graduate Teaching Assistant, Department of Nutritional Sciences, Oklahoma State University, January 1998 – December 1998. Graduate Research assistant, Department of Nutritional Sciences, Oklahoma State University, May 1998 – December 1998.

Professional Memberships: Institute of Food Technologists; Oklahoma Institute of Food Technologists; Phi Tau Sigma (Honor Society for Food Science and Technology)