FATTY ACID COMPOSITION AND

OTHER CHARACTERISTICS OF SHORTENED CAKES

by

Mercy Mnyembezi Mafuleka

Thesis submitted to the Faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

Human Nutrition and Foods

APPROVED:

Jean A. Phillips, Chairman

Julein M. Axelson

Richard G. Krutchkoff

August, 1982

Blacksburg, Virginia

ACKNOWLEDGMENTS

The author is greatly grateful to Dr. Jean A. Phillips, major professor, for her encouragement, understanding and patience during the program of study, research and writing of this thesis. Dr. Phillips' personal interest in the author's well-being and academic work made her stay a memorable one.

The author is also greatly indebted to Drs. Julein Axelson and Richard G. Krutchkoff for their suggestions and advice. Thanks to Dr. Roderick Young and Mrs. Jean Dickinson for their help with the gas chromatograph. It is the sincere wish of the author to thank Dr. Ryland Webb for his kindness and encouragement and Mr. David Banks for his help with the statistical analyses.

Special thanks go to Dr. Laura J. Harper for her kindness, moral support and friendship offered to the author. The author would also like to thank all people and friends that helped in one way or the other throughout her program of study.

Finally, the author wishes to express her deep appreciation to Mr. and Mrs. M. W. Mafuleka (her parents), her brothers and sisters in Malawi for their spiritual and moral support throughout her study.

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

CHAPTER ONE

INTRODUCTION

"Cake is a semi-dry foam that results from the setting of a liquid medium which has been expanded therein" (Yamakazi and Kissell, 1978). A good quality cake has "light weight, even grain (small holes which are evenly distributed), delicate flavor (not masked by over-sweetness), a velvet feeling inside on the tongue or fingers, and lastly it has a delicate structure that almost melts in the mouth" (Halliday and Noble, 1946).

Ingredients within a cake formula play special roles which are important to the success of the product. Flour and eggs provide structure to the cake (Campbell, Penfield, and Griswold, 1979). In addition the latter assists in the foaming and aeration of the product (Kamat, Lawrence, Hart, and Yoell, 1973). Shortening and sugar tenderize the gluten and starch particles of the batter (Lawson, 1970). Furthermore, the former helps leaven the cake (Jooste and Mackey, 1951). Liquid in the formula helps dissolve sugar, salt, and chemical leavening (Peckham and Graves, 1979). Lastly, leavening aerates the product during the baking process (Hood and Lowe, 1948).

In the United States, the food industry has recently developed egg substitutes which can be used to make cakes, as an alternative to fresh whole eggs (Zabik and Lang, 1978; Childs and Ostrander, 1976). Vegetable oils may also be used to make cakes, as alternatives to hydrogenated vegetable shortening, a traditionally used ingredient

(Ohlrogge and Sunderlin, 1948). Use of a stiff meringue has been recommended by Zabik and Lang (1978) and by Ohlrogge and Sunderlin (1948) when oil or egg substitutes are used.

The objectives of the present study were (1) to prepare cakes using fat (hydrogenated vegetable shortening, corn oil, soybean oil and peanut oil) with fresh whole eggs and egg substitutes (Egg Beaters and Scramblers); (2) to determine apparent viscosity of the batter and height, compressibility and moisture content of baked cakes; (3) to determine fatty acid composition by gas liquid chromatographic (GLC) analysis of methyl esters of fatty acids in the crude lipid extracted from baked cakes.

Considering the above objectives it was hypothesized that apparent viscosity of batter, and the baked cake characteristics (height, compressibility, and moisture content) are not influenced by the type of fat or egg used.

CHAPTER TWO

LITERATURE REVIEW

The interest in fatty acid composition of food products has been expressed by some food specialists and nutritionists, due to the high correlation between coronary heart diseases, and ingestion of saturated fats (Turpeinen, 1979; Childs and Ostrander, 1976). Shortened plain cakes are a product comprised of flour, liquid (water or milk), leavening, eggs, sugar, salt, and shortening (Lawson, 1970; Hindman and Marbut, 1962; Ohlrogge and Sunderlin, 1948). Among the above mentioned ingredients shortening and eggs contain a substantial amount of fat. The fatty acid compositions, as reported in Handbook Number 8 (United States Department of Agriculture, 1981), for these ingredients (shortening and eggs) are shown in Table 1.

Information verifying the fatty acid pattern of baked cakes is desirable to have for use by interested parties. Phillips (1966) concluded that there were no significant changes in the fatty acid pattern of cakes due to exposure to oven heat. A hydrogenated vegetable shortening, a corn oil margarine, or corn oil were used with fresh whole eggs to prepare the cakes.

Ingredients within a cake formula have functions other than the nutritional aspect. It seems appropriate for one to know the characteristics of a product before considering the contributions that each ingredient has towards those characteristics. Halliday and Noble (1946) described the following to be characteristics of a good

Table 1: Fatty acid composition of various ingredients of plain cake, grams per 100 grams of edible portion

	Food Item					
Fatty acids*	Fresh whole eggs	Egg substitutes (frozen)	Hydrogenated vegetable shortening	Corn oil	Soybean oil	Peanut oil
Total saturated (g)	3.35	1.93	30.6	12.7	14.9	16.9
C_{4}:0						
6:0						
8:0			0.1			
10:0			0.1			
12:0			0.4			
14:0	0.03	0.01	0.4	0.00	0.1	0.10
16:0	2.46	1.50	19.3	10.90	9.8	9.50
18:0	0.86	0.44	9.9	1.80	5.0	2.20
Total monounsaturated (g)	4.46	2.43	50.8	24.20	43.0	46.20
C_{16}:1	0.37	0.00		0.00	0.4	0.10
18:1	4.08	2.44	50.6	24.20	42.5	44.80
20:1						1.30
22:1						
Total polyunsaturated (g)	1.45	6.24	14.2	58.70	37.6	32.00
C_{18}:2	1.24	6.18	13.5	58.00	34.9	32.00
18:3	0.03	0.06	0.6	0.70	2.6	0.00
18:4						
20:4	0.09					
20:5						
22:5	trace					
22:6	trace					

*Data were obtained from scientific and technical literature, special bulletins, research reports and other documents containing data, taken directly from USDA Handbook Number 8, 1981.

shortened cake: "Light weight, even grain (small holes which are evenly distributed); delicate flavor (not masked by over sweetness); soft velvet feeling of the inside of the cake on the tongue, or fingers, and delicate structure that almost melts in the mouth."

I. INGREDIENT CONTRIBUTION TOWARDS THE CHARACTERISTICS OF A GOOD SHORTENED CAKE OTHER THAN THE NUTRITIONAL ONE

A. Eggs

Eggs play an important role towards quality of a cake. The two major components of egg are egg white and egg yolk. Kamat, Lawrence, Hart, and Yoell (1973) indicated the functions of egg white to be aeration and provision of foam, foam stabilization, and heat setting. Kamat *et al*. (1973) also stated that egg yolk has two major components that contribute to the quality of a cake. Plasma which contributes 66 percent of the yolk solids is composed of low density lipoproteins (LDL), and yolk granules which account for 23 percent of yolk solids are composed of high density lipoproteins (HDL).

The LDL is composed of 62 percent triglycerides, 27 percent phospholipids and 11 percent proteins. Its molecular weight ranges between 2.5 to 10 million, and particle diameter is between 45 to 150 Angstroms (Kamat *et al*., 1973). The model for LDL (biochemical and physical studies), described by Kamat *et al*. (1973) is a nucleus of triglycerides covered by a monomolecular layer of phospholipids and proteins. The central lipid core is apolar and liquid-like. The function of LDL, as reported by Kamat *et al*. (1973) includes aeration and foam formation (sponge type of batter).

The yolk granules (HDL) consist of 10 percent triglycerides, 12 percent phospholipids and 78 percent protein. These granules dissociate reversibly in alkaline media into subunits, and in this case they behave like molecules while LDLs behave like micelles. HDLs are considered to have more ordered structure and integrity than LDLs. Kamat et al. (1973) described the function of HDLs as that of helping retain air, whipped in by the egg white and yolk plasma. On the other hand, HDLs are believed to inhibit aeration even by egg whites (Kamat et al., 1973).

B. Egg Substitutes

Egg substitutes, recently developed by the food industry in the United States, may be used as ingredients in cakes to replace fresh whole eggs (Zabik and Lang, 1978; Childs and Ostrander, 1976). These products (egg substitutes) contain egg white, and the yolk is replaced by vegetable oils, certain gums, different kinds of cellulose and mono and diglycerides. The functions of egg yolk reported by Kamat et al. (1973): aeration of batter, retention of whipped-in air, are therefore eliminated in egg substitutes.

Zabik and Lang (1978) examined the functions of three egg substitutes (Egg Beaters, Second Nature and Eggstra) in yellow cake. These researchers added a stiff meringue towards the end of the mixing process, and their results showed a more viscous batter for cakes made with fresh eggs or Second Nature. Cakes prepared with egg substitutes had slightly sunken centers; those made with Second Nature had the lowest volume of all cakes. These researchers concluded that all cakes were acceptable, and then suggested that water levels should be optimized in cakes containing egg substitutes to produce maximum quality. In addition, they concluded that any of these egg substitutes (Egg Beaters, Second Nature or Eggstra) could be successfully used to prepare cakes for persons who have been advised to restrict their cholesterol intake. Research work on egg substitutes seems to suggest that good quality cakes can be produced if a stiff meringue is incorporated into the batter.

C. Shortening

Fat in cake batter serves to tenderize the gluten and starch granules (Lawson, 1970; Mathews and Dawson, 1966). In addition, a plastic fat entraps air during the creaming process, thereby leavening the product (Jooste and Mackey, 1951). Mathews and Dawson (1966) said that the eating quality characteristics of cake--velvetiness, tenderness and even grain--were significantly influenced by the kind and amount of fat in the formula. They reported that a panel of tasters rated cakes made with butter the highest for tenderness and velvetiness, and those made with hydrogenated vegetable fat highest for evenness of grain, as compared to the ones made with hydrogenated vegetable and animal fat, corn oil margarine, and regular margarine. Hood and Lowe (1948) reported that cakes made with oil showed more evidence of harshness and crumbliness than cakes made with other fats. Hartnett and Thalheimer (1979) indicated that plastic fat was superior to oils in the incorporation of air into batter. Considering this, the degree of aeration one can get from a particular fat depends on its form. Plastic fats aerate the batter more than liquid fats. This is due to differences in the morphology (Hoerr, 1960).

D. Flour

Flour in a cake forms the main core of structure of the product (Howard, Hughes, Strobel, 1979; MacRitchie, 1978). Upon hydration of the flour the gluten protein components (gliadin and glutenin) react and bind to form gluten (Kasarda, Bernardin and Nimmo, 1976). The formed protein complex is responsible for the elasticity of the batter, believed to contribute to rising of the cake in the oven, in addition to the expanding gases (Moss, 1980; MacRitchie, 1978).

The binding mechanism between gliadin and glutenin to form gluten is not clearly understood. So far, two mechanisms have been proposed. One model says that the hydration and manipulation of flour causes cross linking of the protein subunits by way of sulfhydryl and disulfide bonds (Mecham, 1972). The details of this mechanism have not yet been clearly established (Kasarda et al., 1976). The other model proposed by MacRitchie (1978), Kasarda et al. (1976), Hoseney, Finney and Pomeranz (1970), and Baldi, Little and Hester (1965) indicates that hydration of the flour causes the binding of gliadin and gluten through hydrophilic, hydrophobic, ionic and hydrogen bonds. Further, these protein components are believed to be bound together by polar lipids (glycolipids).

The gluten complex has been reported to stabilize the batter by binding the ingredients. It has also been indicated that the gluten complex provides adequate structure to retain expanding gases during baking (Baldi, et al., 1965). These same researchers have reported that flour with a high gluten content produces cakes with larger volume, compared to that with little gluten. However, too much gluten has been found to cause a dry crumb texture of cakes (Baldi et al., 1965).

Campbell et al. (1979) stated that cake or all-purpose flour may be used to make a cake, and that the former contains about 8.5 percent protein, and the latter about 10.5 percent. Campbell et al. (1979) also indicated that cake flour is the most suitable for the product (cake), because of its low protein (gluten) content. The above authors pointed out that cakes made with cake flour are more tender, compared to those made with all-purpose flour. Cake flour is made from soft wheat, while all-purpose flour is made from a mixture of soft and hard wheat (Vail, Phillips, Rust, Griswold, and Justin, 1978).

E. Liquid

Peckham et al. (1979) said that the liquid in cake serves as a solvent for sugar, salt and chemical leavening agents. Liquids in a cake, therefore, provide a good environment for chemical reactions to take place.

So far the researchers have shown that there is diversity in the functional properties of ingredients within a cake formula. In addition, these functions are vital to the quality of the baked product.

II. BALANCING THE CAKE FORMULA

Optimum contributions by individual ingredients to the good qualities of any cake can only be achieved if their proportions within the formula are maintained (Lawson, 1970). Hunter, Briant and Personius (1950) reported the following cake formulae:

(1) Low Ratio

- The weight of sugar does not exceed that of flour
- Weight of fat does not exceed that of eggs
- Weight of liquid ingredients equals that of the flour

(2) High Ratio

- Weight of sugar exceeds that of flour
- Weight of fat does not exceed that of eggs
- Weight of liquid ingredients equals/exceeds that of sugar

III. OBJECTIVE MEASUREMENTS AND ANALYTICAL PROCEDURES

A. Objective Measurements

Objective tests are measurements that do not depend on the human senses (Vollmar and Braden, 1976). Such tests are desirable to use as opposed to sensory evaluations by the mere fact that they provide results with precision and repeatability (Funk, Zabik and Elgidaily, 1969). Some of the objective tests that qualify cakes include: apparent viscosity of batter determined by a line spread; cake height; compressibility of cake; and moisture content.

1. Apparent viscosity of batter

Apparent viscosity is the resistance of a fluid substance (non-Newtonian) to flow (Vollmar and Braden, 1976). Line-spread is a commonly used method to measure apparent viscosity of batter (Funk et al., 1969). The method is simple and inexpensive (Grawemeyer and Pfund, 1943). Line-spread measurements are obtained by placing a hollow metal cylinder on a flat glass plate. Underneath the glass plate a line-spread chart is placed (Funk et al., 1969). The cylinder is filled with batter at controlled temperature. The batter is leveled with a spatula, and the cylinder carefully lifted. The batter is allowed to spread for a preselected time, and the readings are taken at four equidistant points that mark the limits reached by the product (Vollmar and Braden, 1976; Funk et al., 1969; Grawemeyer and Pfund, 1943). The average of the four readings is reported as line-spread value for that particular sample of batter.

2. Cake height

Standing height has been used to estimate the volume of baked products (Vollmar and Braden, 1976). This is determined by measuring the height of a specified slice at the outer edges, at the center, and at points one-half of the distance from the center to the edges. The average of these measurements is a value for index to volume (Funk et al., 1969). In case of a cake, standing height can also be determined by measuring the variable at designated points, such as 2 cm off the edge of the corner on diagonal lines, and where the diagonal lines cross each other at the center (Smith and Hawrysh, 1978).

3. Compressibility

Methods used to measure compressibility of a baked product are based on the same principle; that is, subjecting a sample of a product to a specified weight for a given time (Funk et al., 1969). Paul, Batcher and Fulde (1954) determined compressibility of cake using a Precision Universal Penetrometer fitted with a flat disc. This was done by measuring the distance the crumb was flattened by the known weight of the disc over a specified period. The flat disc used weighed 25.5 grams, cake sample was 6.4 cm in diameter, cut from the center of a previously designated slice. The sample was compressed for 30 seconds. The results from these tests indicated highly significant differences among cakes baked at different temperatures. It was concluded that a penetrometer fitted with a flat disc could be used to measure differences in compressibility of the cake crumb. Correlation coefficient computations for sensory evaluations for texture with penetrometer readings were found to be highly significant ($r = 0.87$). The correlation suggested that as the size of the cake cells increased, compressibility of cake increased. Compression values as measured with the penetrometer were also found to be highly correlated with the tenderness of cakes, since compressibility increased as the scores for cake tenderness increased ($r = 0.93$).

4. Moisture content

Moisture content of a cake can be measured by drying a sample of known weight for a specific time in a constant temperature vacuum or air-drying oven (Funk et al., 1969). Moisture determination by

Brabender moisture tester is a method where the sample of known weight is oven dried. The technique/instrument combines into one unit a forced draft temperature controlled oven, and a precision balance with illuminated scale, graduated to read directly in percentage moisture or volatiles (Anonymous, 1966).

B. Analytical Procedures

1. Lipid extraction

Fisher, Broughton and Peel (1964) defined lipids as biologically utilizable compounds related to the naturally occurring fatty acids which are soluble in solvents such as chloroform, benzene and butanol. They are insoluble or sparingly soluble in water. Early work dealing with lipid extraction was conducted by Folch, Ascolis, Lees, Meath and LeBaron (1951). These researchers used chloroform and methanol to extract lipids from brain tissues. The method developed by the above mentioned researchers was modified by Folch, Lees and Sloanestanely (1957) for use with brain, liver and muscle tissues. The methods developed by above mentioned researchers were regarded as time consuming and requiring large amounts of solvent by other researchers (Bligh and Dyer, 1959). The method developed by Folch et al. (1951) for extraction of lipids was adapted by Bligh and Dyer (1959) to use methanol and chloroform which when mixed with water yield a monophasic solution. The homogenate when diluted with water or chloroform forms a biphasic system. The advantage of this adaptation is the use of smaller amounts of solvents. The procedure described by Bligh and Dyer (1959) was modified by Phillips (1966) who used methanol, chloroform and water as solvents to extract crude lipids from 50 gram samples of unbaked and baked: pastry, biscuits, cookies, chocolate and plain cakes. The method was simple and easy to use and produced highly reproducible results.

2. Preparation of methyl esters and saponification

Quantitative analysis of fatty acids requires the cleaving of the fatty acids from extracted crude lipid, and saponification is one such process (James, 1960). The crude lipid is reacted with a base (KOH) in methanol to form a potassium soap of the fatty acids under warm conditions. Water is added during the process as a solvent for the soap, and the mixture is heated to remove the methanol (Ast, 1963). The potassium is cleaved from the soaps by a strong acid (HCl) to release free fatty acids. These free fatty acids are collected in petroleum ether to separate them from nonsaponifiable material (James, 1960). It is advised that the conditions for saponification be mild to prevent isomerization of the fatty acids (Ast, 1960).

The determination of free fatty acids by gas chromatography is preferably done through their methyl esters (Rogozinski, 1964). The fatty acids collected in petroleum ether are subjected to heat to evaporate the ether. Aliquots of methanol and sulfuric acid are added and the mixture is brought to a boil for the methylation of the fatty acids (Rogozinski, 1964). The methyl esters are collected in hexane which is injected into the gas chromatograph (Rogozinski, 1964).

3. Gas chromatographic analyses

Gas liquid chromatography (GLC) is widely used to separate long chain fatty acids (Jamieson and Reid, 1965: Horning, Ahrens, Lipsky, Mattson, Mead, Turner and Goldwater, 1964). The above researchers have indicated that accuracy of quantitative determination of the instrument depends on the proper combination of columns and detectors.

a. Columns

Polyester columns coated with 10 to 15 percent liquid phase are the most commonly used, compared to those of thick film apiezon, thin film silicone and nonpolar phase ones (Jamieson and Reid, 1965; Horning *et al.*, 1964). Horning *et al.* (1964) indicated that nonpolar phases have higher thermal stabilities than do polyester phases.

b. Detectors

The detection system of a chromatograph is dependent on its intrinsic properties and the way it is used (Horning *et al.*, 1964). Alanjones (1970) described the function of the detector as that of: "sensing differences in the composition of the effluent gases from the column and translating the column's separation process into an electrical signal which is communicated via an amplifier to a recorder." Detection systems include those that are based on thermal conductivity, ionization, or electron capture (Alanjones, 1970; Horning *et al.*, 1964). Ionization detection systems are based on the partial ionization of an organic substance contained in a gas stream (Horning *et al.*, 1964).

Quantitation of fatty acids (methyl esters) following gas chromatography may be done in several ways. Horning *et al.* (1964)

indicated: "multiplication of peak height by width at half height; multiplication of peak height by half base width; multiplication of peak height by adjusted retention time; measurement of peak area by planimetry; and measurement of area by integrators", as methods commonly used to calculate area under a peak on a chromatograph. These researchers have also reported that all the above mentioned methods give satisfactory results, and that the choice of one depends on ease and experience with the particular method by the user.

CHAPTER THREE

PROCEDURE

I. MATERIALS

Cake flour (Swans Down), salt (Watkins, iodized), SAS-phosphate baking powder (Calumet), nonfat dry milk (Kroger), hydrogenated vegetable shortening (Crisco), corn oil (Mazola), soybean oil (Crisco), and peanut oil (Planters) were obtained from nearby supermarkets in Blacksburg. Sugar was obtained in one lot from the departmental supply.

These products were stored in a closed cabinet under ambient conditions. Egg Beaters, Scramblers and fresh whole eggs (medium size) were bought from nearby supermarkets in Blacksburg. The first two products were stored frozen until used, and the last was bought bi-weekly and refrigerated. Tap water was used to hydrate the dry ingredients.

II. METHOD

Twelve different cakes (Table 2) were made from four types of fat (slightly melted hydrogenated vegetable shortening, corn oil, soybean oil, and peanut oil), and three types of egg (fresh whole eggs, Egg Beaters, and Scramblers). Love's (1955) formula I was modified by increasing the fat 20 percent (Table 3), and the ingredients were mixed using the emulsion method. The twelve cakes were replicated four times. Four cakes, randomly selected were prepared in a day (Table 4).

Table 2: Design of experiment.

	Hydrogenated shortening	Corn oil	Soybean oil	Peanut oil
	Cake	Cake	Cake	Cake
Fresh whole egg	1, 2, 3, 4	1, 2, 3, 4	1, 2, 3, 4	1, 2, 3, 4
	Cake	Cake	Cake	Cake
Egg Beaters	1, 2, 3, 4	1, 2, 3, 4	1, 2, 3, 4	1, 2, 3, 4
	Cake	Cake	Cake	Cake
Scramblers	1, 2, 3, 4	1, 2, 3, 4	1, 2, 3, 4	1, 2, 3, 4

Table 3: Basic cake formula.

Ingredients	Amount (grams)
Egg*	96
Fat**	112
Sugar	300
Flour, cake	300
Baking powder (SAS phosphate)	10
Salt	3
Milk (reconstituted nonfat dry milk)	244

*Egg includes medium size fresh whole egg, or Egg-Beaters, or Scramblers.

**Fat includes slightly melted hydrogenated vegetable shortening, or corn oil, or soybean oil, or peanut oil.

Table 4: Schedule: Cake making.

Day Number	Ingredient: Fat	Egg
1	Peanut oil with Egg Beaters	
	Soybean oil with Scramblers	
	Soybean oil with fresh whole eggs	
	Corn oil with Egg Beaters	
2	Corn oil with Egg Beaters	
	Corn oil with fresh whole eggs	
	Peanut oil with Scramblers	
	Hydrogenated vegetable shortening with Scramblers	
3	Soybean oil with Egg Beaters	
	Peanut oil with fresh whole egg	
	Hydrogenated vegetable shortening with Scramblers	
	Soybean oil with Egg Beaters	
4	Peanut oil with fresh whole eggs (two cakes)	
	Soybean oil with fresh whole eggs	
	Corn oil with fresh whole eggs	
5	Hydrogenated vegetable shortening with Egg Beaters	
	Peanut oil with Egg Beaters	
	Hydrogenated vegetable shortening with fresh whole eggs	
	Peanut oil with Scramblers	
6	Soybean oil with fresh whole eggs	
	Corn oil with fresh whole eggs	
	Peanut oil with fresh whole eggs	
	Hydrogenated vegetable shortening with Egg Beaters	
7	Hydrogenated vegetable shortening with fresh whole eggs	
	Corn oil with Scramblers	
	Hydrogenated vegetable shortening with Egg Beaters	
	Corn oil with fresh whole eggs	

Table 4: continued.

Day Number	Ingredient: Fat	Egg
8	Hydrogenated vegetable shortening	with fresh whole eggs
	Soybean oil	with Scramblers
	Hydrogenated vegetable shortening	with Scramblers
	Soybean oil	with Egg Beaters
9	Hydrogenated vegetable shortening	with Scramblers
	Corn oil	with Scramblers
	Corn oil	with Egg Beaters
	Corn oil	with Scramblers
10	Soybean oil	with Scramblers (two cakes)
	Peanut oil	with Egg Beaters
	Peanut oil	with Scramblers
11	Peanut oil	with Scramblers
	Hydrogenated vegetable shortening	with Egg Beaters
	Peanut oil	with Egg Beaters
	Hydrogenated vegetable shortening	with fresh whole eggs
12	Soybean oil	with fresh whole eggs
	Soybean oil	with Egg Beaters
	Corn oil	with Scramblers
	Corn oil	with Egg Beaters

A Kitchenaid mixer model K5, with wire whip attachment, was linked through a timer to the power source. The ingredients were combined in one bowl as indicated below:

1. Ninety-six grams of eggs, beat 10 seconds, speed 10, scrape bowl and beater
2. A few drops of fat, beat until emulsion forms, speed 10, scrape bowl and beater
3. Remaining fat, gradually, beat continuously, speed 10, scrape bowl and beater
4. Three hundred grams sugar, gradually, beat continuously, speed 10, scrape bowl and beater
5. Beat, 10 seconds, speed 1
6. One-third of the milk, beat 15 seconds, speed 1, scrape bowl and beater
7. One-third of the dry ingredients (flour, baking powder, salt), beat 15 seconds, speed 1, scrape bowl and beater
8. One-third of the milk, beat 10 seconds, speed 1, scrape bowl and beater
9. One-third of the dry ingredients, beat 20 seconds, speed 1, scrape bowl and beater
10. One-third of the milk, beat 10 seconds, speed 1, scrape bowl and beater
11. One-third of the dry ingredients, beat 30 seconds, speed 1, scrape bowl and beater
12. Beat 30 seconds, speed 1, scale 700 g batter into a tared oiled pan (aluminum, 20 x 20 x 5 cm) using a Mettler P1000

balance. The pan was tapped on the counter top two times, to remove large air bubbles in the batter before baking. The cakes were baked in a Frigidaire self-cleaning oven, model RSE 3-36 W at 375°F for 35 minutes except for cakes made with hydrogenated vegetable shortening with fresh whole eggs which were baked for 40 minutes. Each cake was prepared and baked separately in the center of the oven, to ensure enough space and even heat distribution per cake. Time when a particular cake was prepared during the day was randomly selected.

Lowe's (1955) emulsion mixing method was chosen over the meringue method by Zabik and Lang (1978), because the former was simple and straight forward. The user did not have to use two mixer bowls during the cake preparation, as would be the case when the latter method is followed.

III. APPARENT VISCOSITY OF BATTER: LINE-SPREAD

The line-spread method was used to determine apparent viscosity of batter (Vollmar and Braden, 1976). Batter from each cake was used to determine apparent viscosity of the batter for that particular cake. The line-spread chart (Figure 1) was placed on a counter top and covered with a flat glass pie plate (23 cm diameter). Using a Celsius thermometer, the temperature of the batter was measured and recorded. Following this, a brass cylinder (inner dimensions, 3.5 cm high x 3.8 cm in diameter) was filled with the batter and leveled using a metal spatula. The ring was quickly lifted from the glass plate, and

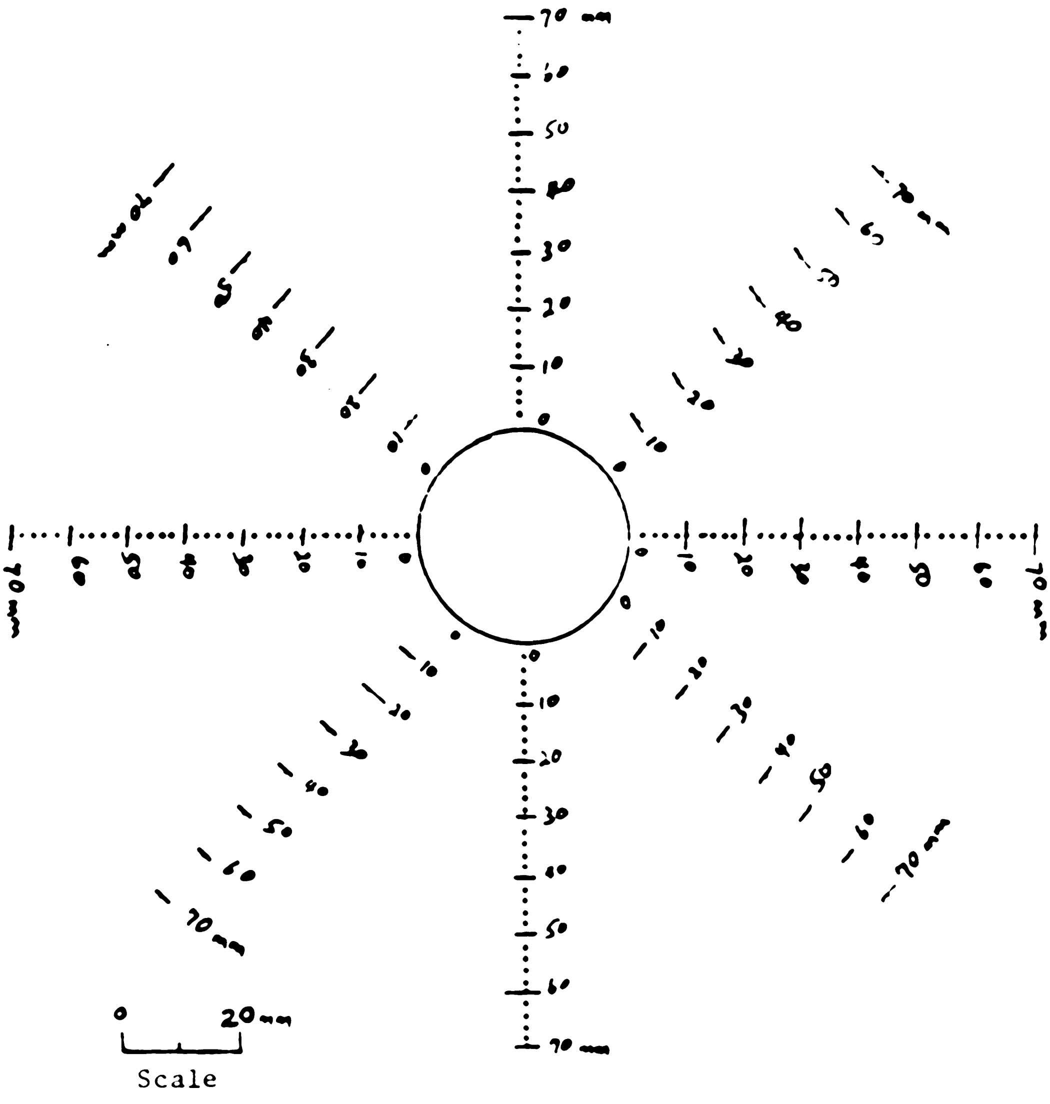


Figure 1: Mat for line spread.

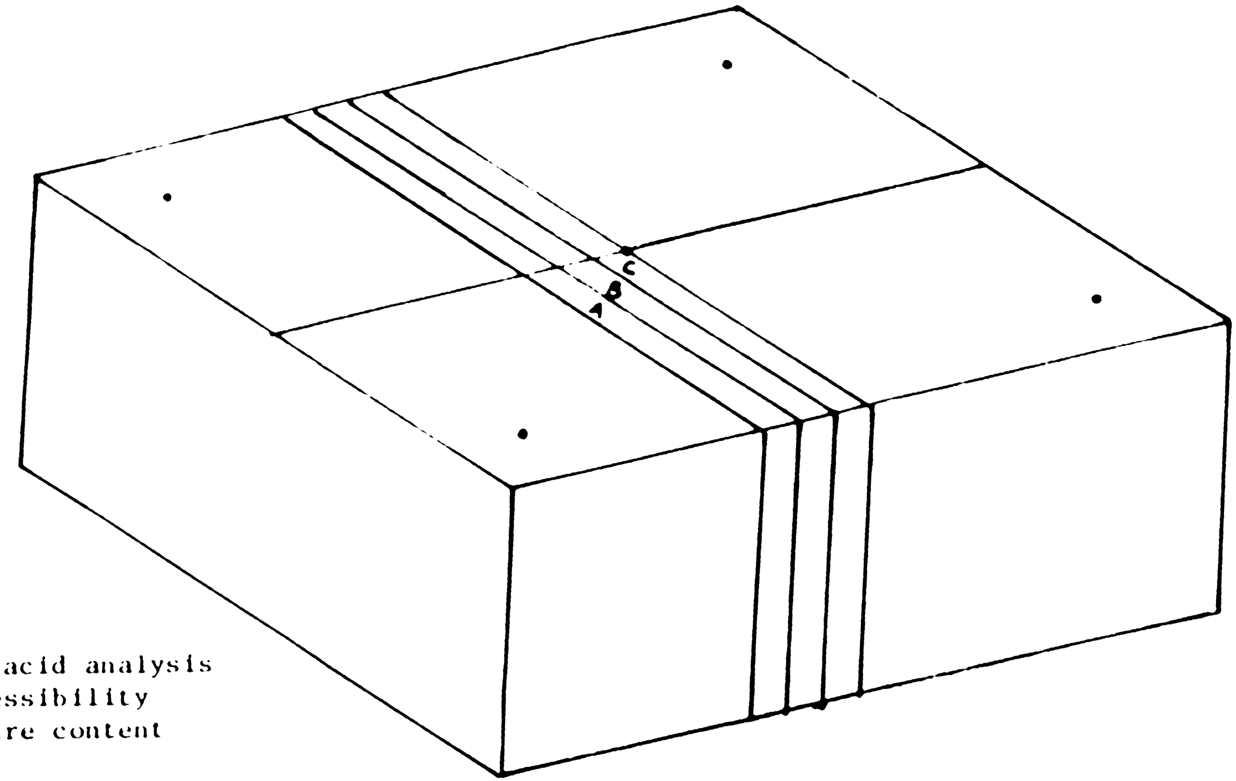
batter was allowed to flow for two minutes after the ring was lifted. At the end of the two minutes flow, the numbers visible at four equidistant points on the outer edges of the batter were recorded. The line spread of the sample was determined by averaging the four readings recorded.

IV. CAKE HEIGHT

Height measurements were taken at five points of the cake, on diagonal lines two centimeters from each corner edge, and where the diagonal lines met at the center (Figure 2). A whole baked cake was placed on a counter top, top side up. Using a ruler (graduated in centimeters) diagonal lines were marked on the surface of the cake, and the points where height measurements were to be taken were marked with wooden toothpicks. The height measurements were taken by pressing the extension bar of a vernier caliper through the cake, then the graduated bar was lowered until the bar just touched the top of the cake. The caliper was then removed from the cake and the height recorded to the nearest hundredth of a centimeter.

V. COMPRESSIBILITY OF CAKES

A Precision Universal penetrometer fitted with a flat disc (14.7 g) was used to determine the compressibility of the cake (Slice B, Figure 2). The side crusts of slice B, Figure 2, were removed and the remaining cake was cut into 3 cm x 3 cm squares. The penetrometer was leveled; the sample was placed on wax paper on the platform. The



• Height
A = Fatty acid analysis
B = Compressibility
C = Moisture content

Figure 2: Diagramatic representation of where objective measurements were taken from the cake.

recorder was dialed to the zero mark, the disc was lowered, until it just touched the top surface of the sample, the disc was released and allowed to press for 30 seconds and then a reading was taken and depth of penetration recorded. The metal rods were then pulled up, the disc raised. The procedure was repeated for another sample.

VI. MOISTURE CONTENT

Percentage moisture in the baked cake sample was determined using a Brabender moisture/volatiles tester, type SAS. A whole slice (C) previously designated (Figure 2) was chopped on a wooden board using a French knife, then 10 g samples were weighed from the chopped cake into a drying tray. Tongs were used to hold/handle the drying tray. The 10 g sample in the tray was placed in the drying oven which was preheated to 105°C for an hour. At intervals of five minutes the blowing fan was turned off and the percentage moisture lost was recorded from the direct read-out dial. The shelf in the drying oven was rotated to allow assay of the percentage moisture for each sample. Recordings were continued at five-minute intervals, until a constant value was found for each sample. This was recorded as the percentage moisture content for each sample. The mean of five samples dried per designated slice of each cake was recorded as the percentage moisture content for a particular cake.

VII. LIPID EXTRACTION

Lipid extraction (Phillips, 1966) was based on a sample containing 80 percent moisture; therefore 15 ml of water was added with the first solvent mixture to bring the cake samples to an 80 percent moisture level. The cake slice (A) previously designated for fatty acid analysis (Figure 2) was defrosted. A 50 g sample was weighed from the defrosted cake on a Mettler P1000 balance, to the nearest 0.1 gram. This was transferred to a homogenizer (Sorrall Omni Mixer), the reaction reagents (water, methanol and chloroform) were added in the following order:

1. 15 ml. water, 100 ml. methanol, 50 ml. chloroform, homogenize three minutes, speed 30
2. 50 ml. chloroform, homogenize 30 seconds, speed 30
3. 50 ml. water, homogenize 30 seconds, speed 30
4. Filter homogenate through Whatman number 541 paper on a Buchner funnel with suction into a flask
5. Rinse homogenizer with two 10 ml. portions of chloroform, and 20 ml. methanol
6. Pour rinsings through the filter; then pour the filtrate into a separatory funnel with teflon stopcock
7. Rinse suction flask with 10 ml. methanol and 10 ml. chloroform
8. Pour rinsings into the separatory funnel; allow the filtrate to separate into two phases
9. Return the residue and filter paper to the homogenizer and repeat the procedure

The crude lipid in the chloroform layer (lower phase) formed in the separatory funnel was drained into a 500 ml. round bottom evaporating flask. The solvent (chloroform) in the evaporating flask was evaporated with a Buchler flash evaporator over a water bath, maintained at 35 to 40°C. When all the solvent was evaporated the crude lipid in the evaporating flask was transferred using a dropper into a vial with a screw top. The evaporating flask was rinsed with hexane and the rinsings transferred into the vial. The crude lipid was blanketed with hexane, 3 to 5 mm above the crude lipid solution and the cap fastened. The vial was stored in a freezer (-18°C).

VIII. PREPARATION OF METHYL ESTERS AND SAPONIFICATION

An electric laboratory hot plate was connected to the power source through a voltage regulator that was maintained on setting medium or 40. An aluminum bowl (21 cm diameter) filled to a depth of five centimeters with clean sand was placed on the hot plate to warm the sand. The processes during saponification and methylation that required warming were carried out with glass vessels placed on top of the sand; those that required quick evaporation or boiling were carried out by pushing the glass vessel down into the heated sand until the bottom of the glass vessel touched the bottom of the aluminum bowl.

IX. SAPONIFICATION AND METHYLATION

A method by Phillips (1966) was used to saponify and methylate the fatty acids from the crude lipid. The frozen crude lipids stored in the vials were defrosted, the hexane evaporated, and the contents of a vial thoroughly mixed before saponification and methylation. One pellet (about 130 mg) of potassium hydroxide was dissolved in 5 ml anhydrous methanol in a clean, dry, 25 ml beaker with gentle warming. Four to five drops of crude fat (about 0.5 g) were added to the beaker and stirred with a glass rod until all the fat globules disappeared. To this, 0.5 ml of water was added and the mixture evaporated to 2 ml volume. When a 2 ml volume was achieved, one ml of water was added and the mixture evaporated to 2 ml volume. The beaker was then removed from the heat and another one ml of water was added immediately. To this, concentrated hydrochloric acid was added dropwise until the lower phase of the mixture was below a pH of 3, detected using litmus pH paper. Free fatty acids appeared on the surface. The contents of the beaker were cooled below the boiling point of petroleum ether (about room temperature). When the beaker was cold, two portions 2 ml each of petroleum ether were added to extract the fatty acids. The contents of the beaker were stirred until the fatty acids dissolved in the petroleum ether, then the contents of the beaker were transferred into a small test tube and allowed to separate into two phases. The petroleum ether extract, top phase of the test tube, was transferred to a 10 ml volumetric flask (glass stoppered) using a dropper. The petroleum ether was quickly evaporated on the sand bath. Rising vapors from the ether excluded air and prevented fatty acid oxidation. Upon evaporation of the petroleum ether, the contents were cooled. Immediately, 2 ml of methanol was added and the flask was swirled. Following this 0.5 ml of concentrated sulfuric acid was added dropwise.

The volumetric flask was replaced onto the sand bath and the contents brought to a boil. The flask was then immediately cooled to room temperature and 4 ml of hexane, then 2 ml of water were added. The flask was stoppered and shaken vigorously to mix the contents. The contents of the flask were allowed to stand, and the two layers to separate. The top phase was carefully removed using a dropper to a 15 ml tapered centrifuge tube. The contents were let to stand for one to two minutes, in order to be certain that any of the lower phase from the volumetric flask settled to the bottom. The hexane solution was transferred to a screw topped glass vial using a dropper. Care was taken to omit any of the sulfuric acid phase which might have been carried over in the first transfer. The glass vials were stored in a refrigerator at 1°C until an aliquot could be injected into the gas chromatograph.

X. GAS LIQUID CHROMATOGRAPHY

Twelve batches of fatty acid methyl esters, previously prepared, were randomly selected from the 48, representing the 48 cakes made with four fats and three egg products for gas chromatographic analyses. Each of the 12 batches was randomly selected from four batches of the same fat egg combination shown in Table 2. Duplicate samples (one microliter each) from each of the 12 batches of fatty acid methyl esters were injected through a Bendix 2600 gas chromatograph with a flame ionization detector.

The gas chromatograph was operated on the conditions outlined below:

(1)	Column:	
	length	121.9 cm
	inner diameter	0.4 cm
	outer diameter	0.6 cm
(2)	Packing:	5 percent SE-30 on 80/100 chromsorb WHP
(3)	Temperature:	
	Column	150°C
	Detector	250°C
(4)	Carrier gas	Helium
	Carrier gas flow rate	50 ml/min
	Hydrogen gas flow rate	50 ml/min
	Air flow rate	500 ml/min
(5)	Attenuation	100K
(6)	Speed of recorder	1.3 cm/min

One sample was injected at a time through the injection port of the gas chromatograph. The area of peaks obtained from the gas chromatograph, representing the different fatty acids was calculated using the formula: height x width at half height. The areas under all peaks were summed and the percentage of the total represented by each peak was calculated.

The fatty acids corresponding to the peaks on the chromatograph were identified using a standard. The standard contained myristate ($C_{14:0}$), palmitate ($C_{16:0}$), stearate ($C_{18:0}$), oleate ($C_{18:1}$), linoleate ($C_{18:2}$) and linolenate ($C_{18:3}$). A minor peak that followed $C_{18:3}$ was assumed to be a longer chain, probably a C_{20}.

XI. DATA ANALYSIS

Data for the experiment for the characteristics measured: apparent viscosity of batter; and height, compressibility (tenderness), and moisture content of baked cakes were analyzed statistically using Analysis of Variance (ANOVA), factorial with nesting design. Fat and egg comprised the two factors in the factorial ANOVA with the cakes nested within each replicate. The Duncan's Multiple Range Test was conducted on means to distinguish which fats or egg products produced significant effects on the characteristics measured. All analyses were carried out at the 0.05 level of significance. Means were calculated for percentage of fatty acid composition for the cakes made with the 12 different fat/egg combinations.

CHAPTER FOUR

RESULTS AND DISCUSSION

Cakes were made using four fats and three egg products (Table 3). Apparent viscosity of batter, and four characteristics of baked cake: height, compressibility, moisture content, and fatty acid composition were evaluated.

I. APPARENT VISCOSITY, BATTER

Apparent viscosity of batter has been defined as the resistance to flow of a cake batter (Vollmar and Braden, 1976). The characteristic was determined by a measure of spread (line-spread). The higher the line spread value, the thinner the batter, and the lower the value, the thicker the batter.

Mean values of line spread (Table 5) are an indication of the thickness and/or thinness of batters made with the four fats and the three egg products listed in Table 3. Cake batters made with hydrogenated shortening and any of the egg products were found to be significantly different from those made with corn oil, or soybean oil or peanut oil ($P \leq 0.05$). In addition cake batters made with Scramblers and any of the fats were found to be significantly different from those made with fresh whole eggs or Egg Beaters ($P \leq 0.05$). Both sets of batters, those made with hydrogenated vegetable shortening, and the other made with Scramblers were more thick, compared to those made with other fats or other egg products listed (Table 5).

Table 5: Mean* values for apparent viscosity of batter for cakes made with four fats and three egg products, overall mean**, and standard deviation.

	Hydro-genated vegetable shortening	Corn oil	Soybean oil	Peanut oil
	(mm)	(mm)	(mm)	(mm)
Fresh whole eggs	9.8	34.5	33.0	32.5
	8.2	31.2	31.2	33.2
	10.2	31.2	31.0	32.2
	11.5	32.0	31.8	31.0
Overall mean**	9.9[a]	32.3[b]	31.8[b]	32.2[b]
Standard deviation	±1.7	±1.5	±1.1	±1.0
Egg Beaters	9.5	32.8	33.0	33.0
	8.0	33.0	34.0	31.8
	10.5	34.5	31.0	33.2
	11.5	32.5	33.5	33.0
Overall mean**	9.9[a]	33.2[b]	32.9[b]	32.8[b]
Standard deviation	±1.7	±1.0	±1.5	±1.3
Scramblers	9.0	30.2	31.5	33.0
	11.5	33.5	29.2	28.8
	8.8	31.8	30.0	30.2
	9.0	29.9	31.0	31.0
Overall mean**	9.6[c]	31.1[d]	30.4[d]	30.8[d]
Standard deviation	±1.4	±2.5	±1.8	±1.8

*n = 2
**n = 8
a,b,c,d
Overall mean values with different alphabetic superscripts were significantly different ($P \leq 0.05$).

Funk et al. (1969) indicated that batters with low line spread values had their incorporated air evenly distributed in small units. Such batters are therefore expected to produce cakes that are fine grained and tender. Harnett and Thalheimer (1979) reported that plastic fats aerated a batter more than did liquid fats. The results for the present experiment (Table 5) agree with those reported by Hood and Lowe (1948) who found that batter made with an oil (type of oil not indicated) was the least viscous compared to batter made with butter or hydrogenated lard.

In case of egg as a major factor, the results do not agree with those reported by Zabik and Lang (1978) who reported that batters made with fresh whole eggs were significantly more viscous than those made with Egg Beaters.

II. CAKE HEIGHT

Cake height was determined, using a vernier caliper, at five points on the cake: on the diagonal lines two centimeters from each corner edge and where the diagonal lines crossed (Figure 2). The mean values, presented in Table 6, show how well the cakes expanded during baking. Cakes made with hydrogenated vegetable shortening and fresh whole eggs were found to be significantly higher than those made with corn oil or soybean oil, or peanut oil and fresh whole eggs ($P \leq 0.05$). Further, cakes made with fresh whole eggs and hydrogenated vegetable shortening were found to be significantly higher than those made with Egg Beaters or Scramblers and hydrogenated vegetable shortening

Table 6: Mean* values for height of baked cakes made with four fats and three egg products, overall mean** and standard deviation.

	Hydro-genated vegetable shortening	Corn oil	Soybean oil	Peanut oil
	(cm)	(cm)	(cm)	(cm)
Fresh whole eggs	4.9	4.2	4.2	4.5
	5.0	4.4	4.5	4.3
	5.0	4.5	4.4	4.5
	4.6	4.6	4.3	4.6
Overall mean**	4.9[a]	4.4[b]	4.4[b]	4.5[b]
Standard deviation	±0.4	±0.8	±0.7	±0.6
Egg Beaters	4.6	3.3	3.5	3.2
	4.6	3.4	3.7	3.6
	4.5	3.8	3.6	3.5
	4.5	3.4	3.4	3.4
Overall mean**	4.6[c]	3.5[d]	3.5[d]	3.4[d]
Standard deviation	±0.4	±0.3	±0.3	±0.2
Scramblers	4.5	3.4	3.2	3.3
	4.5	3.6	3.3	3.4
	4.5	3.7	3.7	3.6
	4.4	3.6	3.6	3.5
Overall mean**	4.4[c]	3.6[d]	3.4[d]	3.4[d]
Standard deviation	±0.2	±0.2	±0.2	±0.2

*n = 5
**n = 20
a,b,c,d
Overall mean values with different alphabetic superscripts were significantly different ($P \leq 0.05$).

($P \leq 0.05$). These results (considering fat as major variable) seem to agree with those for apparent viscosity. Batters made with hydrogenated shortening were found the most viscous, compared to those made with corn oil, soybean oil, or peanut oil. A more viscous batter meant that more air was incorporated and was distributed finely.

In case of egg as an individual factor, the results do not agree with those for apparent viscosity. Batters made with Scramblers were found to be significantly more viscous than those made with fresh whole eggs or Egg Beaters. It could be that the proprietory formula for Egg Beaters has been changed since the product was used by Zabik and Lang (1978).

Cakes made with hydrogenated vegetable shortening and fresh whole eggs were slightly humped at the center. Those cakes made with any oil and Egg Beaters or Scramblers had slightly sunken centers or were level. Zabik and Lang (1978) indicated in their report that generally cakes prepared with fresh whole eggs had a convex shape. On the other hand, those made with egg substitutes: Second Nature, Egg Beaters and Eggstra had sunken centers.

III. COMPRESSIBILITY OF CAKES

Compressibility of cakes was determined using a Precision Universal penetrometer fitted with a flat disc. The mean values reported in Table 7 are an indication of the relative tenderness of the cakes. The bigger the value the more tender the cake, and the smaller the mean value, the tougher the cake. Cakes made with hydrogenated vegetable shortening and any of the egg products were found to be significantly different from those made with corn oil, or soybean oil or peanut oil ($P \leq 0.05$). In addition cakes made with fresh whole eggs and any of the fats were found to be significantly different from those made with Egg Beaters or Scramblers ($P \leq 0.05$). Based on these mean values (Table 7), cakes made with hydrogenated vegetable shortening, of the fats used, or fresh whole eggs, of the egg products used, were more tender than the other cakes made with the fats or egg products listed (Table 3) respectively.

Considering fat as a major factor the present results agree with those reported by Harnett and Thalheimer (1979). The researchers found cakes made with plastic fat to be more tender than those made with vegetable oils. In addition the findings for the present study, on compressibility, agree with those for apparent viscosity, batter. One would expect cakes baked from more viscous, hence well aerated batter, to be more tender than those made from a thin, less aerated one. In case of egg as a major variable, the results agree with those for height. As was the case for cakes made with hydrogenated vegetable shortening, one would expect cakes that were well expanded during baking to be more tender than those that did not rise as much. Zabik and Lang (1978) however, did not find significant differences for compressibility among cakes made with fresh whole egg, and Egg Beaters.

Table 7: Mean* values for compressibility of baked cakes made with four fats and three egg products, overall mean** and standard deviation.

	Hydro-genated vegetable shortening	Corn oil	Soybean oil	Peanut oil
	(mm)	(mm)	(mm)	(mm)
Fresh whole eggs	6.5	5.1	5.2	5.1
	8.2	7.6	5.4	6.7
	7.1	5.2	6.4	5.9
	8.1	6.4	7.8	5.3
Overall mean*	7.5[a]	6.1[b]	6.1[b]	5.8[b]
Standard deviation	±2.5	±2.2	±1.6	±1.4
Egg Beaters	5.5	3.6	2.3	3.8
	6.4	4.0	3.5	2.5
	7.9	2.7	5.6	3.5
	7.0	2.3	2.9	4.5
Overall mean**	6.7[c]	3.2[d]	3.6[d]	3.6[d]
Standard deviation	±3.2	±1.8	±2.2	±2.0
Scramblers	4.7	3.9	1.3	4.1
	4.5	4.8	3.5	3.3
	9.4	5.4	4.1	3.7
	11.2	3.2	4.1	5.4
Overall mean**	7.4[c]	4.3[d]	3.3[d]	4.1[d]
Standard deviation	±4.6	±2.5	±2.0	±2.5

*n = 5
**n = 20
a,b,c,d
Overall mean values with different alphabetic superscripts were significantly different ($P \leq 0.05$).

IV. MOISTURE CONTENT

Moisture content in cakes was determined using a Brabender moisture/volatiles tester. The mean values, presented in Table 8, are representative of the amount of moisture present in baked cakes (as a percentage). Cakes made with Egg Beaters and any fat were found to be significantly more moist than those made with fresh whole eggs or Scramblers and any fat ($P \leq 0.05$). The results agree with those by Zabik and Lang (1978) who found cakes made with Egg Beaters, significantly more moist than those made with fresh whole eggs. No significant differences were found for the present study on the moisture content between cakes made with hydrogenated vegetable shortening, or corn oil or soybean oil, or peanut oil ($P \leq 0.05$).

V. FATTY ACID COMPOSITION

Fatty acids are hydrocarbon compounds with a terminal carboxyl group. These may be saturated (with no double bonds along the carbon skeleton) or unsaturated (with one or more double bonds along the carbon skeleton) (Lehninger, 1975). Quantitative determination of fatty acids present in the cakes was done through gas liquid chromatographic analyses. The area under each peak was determined using height x width at half height. A standard was used to determine identity of the fatty acids.

Mean values shown in Table 9 represent one cake from each egg-fat combination and are an estimate of the fatty acids present in cakes made with various combinations of the four fats, and the three egg

Table 8: Mean* values for moisture content of baked cakes made with four fats and three egg products, overall mean** and standard deviation.

	Hydro-genated vegetable shortening	Corn oil	Soybean oil	Peanut oil
	(%)	(%)	(%)	(%)
Fresh whole eggs	22.9	23.9	22.1	24.5
	22.0	23.7	23.3	24.1
	22.5	23.6	24.0	24.4
	23.3	23.3	25.2	23.5
Overall mean**	22.7[a]	23.6[a]	23.6[a]	24.1[a]
Standard deviation	±0.6	±0.5	±1.2	±0.7
Egg Beaters	24.4	22.6	25.5	24.3
	24.2	23.9	25.2	24.9
	23.7	23.1	22.6	25.1
	25.3	24.2	24.7	24.5
Overall mean**	24.5[b]	23.4[b]	24.5[b]	24.7[b]
Standard deviation	±0.9	±0.8	±1.2	±0.4
Scramblers	22.8	23.5	22.5	23.3
	23.8	23.7	2..9	22.7
	22.4	23.4	24.0	23.3
	23.2	24.2	23.9	24.4
Overall mean**	23.0[a]	23.7[a]	23.3[a]	23.4[a]
Standard deviation	±0.7	±0.5	±0.7	±0.7

*n = 5
**n = 20
a,b,c,d
Overall mean values with different alphabetic superscripts were significantly different ($P \leq 0.05$).

Table 9: Mean* percentage values of fatty acid composition (methyl esters) of baked cakes made with four fats and three egg products.

Fat/egg used to make cake	Fatty Acids*					
	Palmitate ($C_{16:0}$)	Stearate ($C_{18:0}$)	Oleate ($C_{18:1}$)	Linoleate ($C_{18:2}$)	Linolenate ($C_{18:3}$)	Arachidate** ($C_{20:0}$)
	%	%	%	%	%	%
Hydrogenated vegetable shortening with:						
- Fresh whole eggs	16.4	12.6	44.4	24.4	2.2	-
- Egg Beaters	16.2	14.1	41.2	27.3	1.4	-
- Scramblers	15.1	12.7	41.6	29.1	1.6	-
Corn oil with:						
- Fresh whole eggs	13.2	3.9	29.2	53.8	Trace	-
- Egg Beaters	11.2	3.4	25.8	59.6	Trace	-
- Scramblers	13.1	3.4	25.3	58.3	Trace	-
Soybean oil with:						
- Fresh whole eggs	11.5	4.8	41.2	39.3	3.2	-
- Egg Beaters	11.4	6.1	45.0	34.2	3.6	-
- Scramblers	13.3	7.0	39.6	37.6	2.6	-
Peanut oil with:						
- Fresh whole eggs	14.6	3.8	46.6	32.7	1.0	1.3
- Egg Beaters	12.9	3.8	53.0	28.4	0.9	1.0
- Scramblers	13.1	4.2	50.0	31.0	1.9	Trace

*Mean of duplicate determination for one cake from each fat-egg product combination.
**No positive identification, may be C_{20} or something.

products listed (Table 2). The pattern of fatty acids as determined is a reflection of the composition of the fat used. This would be expected since the formula included 112 g of fat per se and 96 g of egg (12 percent fat) which is only 11.5 g of fat. Those cakes made from oils, higher in polyunsaturated fatty acids, contained a similar pattern.

From these data (Table 10), a more thick batter does not necessarily yield a cake with greater height, or tenderness (measured by compressibility), or higher moisture content. Considering the baked cake, the height of the product seems to have a bearing on its tenderness, but not on the moisture content. Fresh whole eggs seemed to have more effect on the baked cake qualities, as determined by height and tenderness (measured by compressibility). However, it did not have any effect on the moisture content. It is possible, with the mixing method used in this study, to use a vegetable oil with fresh whole eggs and get an acceptable product. With egg substitutes, a less tender cake with less height was obtained. If cholesterol level is of concern, it is possible to produce cakes made with egg substitutes that approach volume and tenderness of cakes made with fresh whole eggs. Moisture content was similar regardless of egg form used except for Egg Beaters.

VI. SUMMARY

The tests for apparent viscosity of batters, and for height, texture (compressibility), and moisture content of baked cakes revealed the following:

Table 10: Summary of overall mean values for apparent viscosity, batter; height; compressibility and moisture content of cake.

	Apparent* viscosity	Height**	Compres- sibility**	Moisture** content
	(mm)	(cm)	(mm)	(%)
Hydrogenated vegetable shortening				
- Fresh whole eggs	9.9^{a}	4.9^{a}	7.5^{a}	22.7^{a}
- Egg Beaters	9.9^{a}	4.6^{c}	6.7^{c}	24.5^{b}
- Scramblers	9.6^{c}	4.4^{c}	7.4^{c}	23.0^{a}
Corn oil				
- Fresh whole eggs	32.3^{b}	4.4^{b}	6.1^{b}	23.6^{a}
- Egg Beaters	33.2^{b}	3.5^{d}	3.2^{d}	23.4^{b}
- Scramblers	31.1^{d}	3.6^{d}	4.3^{d}	23.7^{a}
Soybean oil				
- Fresh whole eggs	31.8^{b}	4.4^{b}	6.1^{b}	23.6^{a}
- Egg Beaters	32.9^{b}	3.5^{d}	3.6^{d}	24.5^{b}
- Scramblers	31.0^{d}	3.4^{d}	3.3^{d}	23.3^{a}
Peanut oil				
- Fresh whole eggs	32.2^{b}	4.5^{b}	5.8^{b}	24.1^{a}
- Egg Beaters	32.8^{b}	3.4^{d}	3.6^{d}	24.7^{b}
- Scramblers	30.8^{d}	3.4^{d}	4.1^{d}	23.4^{a}

*n = 8
**n = 20
^{a,b,c,d}Overall mean values with different alphabetic superscripts were significantly different ($P \leq 0.05$).

A. Apparent Viscosity, Batter

Cake batters made with hydrogenated vegetable shortening and any of the egg products were found significantly thicker than those made with corn oil, or soybean oil, or peanut oil ($P \leq 0.05$). In case of egg product as a major factor, batters made with Scramblers and any of the fats (Table 3) were found significantly more viscous than those made with fresh whole eggs or Egg Beaters ($P \leq 0.05$).

B. Cake Height

Cakes made with hydrogenated vegetable shortening and any of the egg products used were significantly higher ($P \leq 0.05$) than those made with corn oil or soybean oil or peanut oil. This could be attributed to the more air incorporated in the batter made with plastic fat, compared to the batters made with oils. In addition cakes made with fresh whole eggs and any of the fats (Table 3) expanded significantly more than those made with Egg Beaters or Scramblers ($P \leq 0.05$).

C. Texture - Compressibility

Cakes made with hydrogenated vegetable shortening and any of the egg products were found significantly more compressible, hence more tender, than those made with corn oil, or soybean oil, or peanut oil ($P \leq 0.05$). Further, cakes made with fresh whole eggs and any of the fats were found significantly more tender than those made with Egg Beaters or Scramblers ($P \leq 0.05$).

D. Moisture Content

Cakes made with Egg Beaters and any of the fats (Table 3) were found significantly more moist than those made with fresh whole eggs, or Scramblers ($P \leq 0.05$).

Fatty acids were determined in cakes made with one of the four fats (hydrogenated vegetable shortening, corn oil, soybean oil, or peanut oil) and one of three egg products (fresh whole eggs, Egg Beaters, or Scramblers). These fatty acids were measured using GLC analysis of methyl esters of the fatty acids.

Considering the results found on the characteristics, height and compressibility of baked cakes, it can be concluded that cakes that expanded well during baking were more tender than those that did not. Cakes made with hydrogenated vegetable shortening and any of the egg products used expanded more during baking and were found more tender than those made with corn oil, or soybean oil, or peanut oil. Considering egg products, cakes made with fresh whole eggs and any of the fats (Table 3) expanded more during baking and were more tender than those made with Egg Beaters or Scramblers.

With the findings of this experiment, not all characteristics of baked cakes (including batter) can be used alone to determine quality of cakes. Apparent viscosity, batter does not seem to be a good determinant of quality of cakes. Cake height and compressibility have proved to be consistent with each other as a measurement of quality of cakes.

The desired fatty acid composition of cakes may be used in selecting the type of ingredient to make cakes by interested parties.

Substituting a liquid fat for a solid fat or egg substitute for fresh whole eggs might mean giving up some of the characteristics for good quality cakes. However, these differences are not so pronounced that egg substitutes cannot be used to make cakes. More research needs to be done to find out why Scramblers produced a more viscous batter than fresh whole eggs, while the cakes made from such batter (made with Scramblers), are less tender and expand less during baking compared to those with fresh whole eggs.

REFERENCES

Alanjones, R. 1970. An introduction to gas-liquid chromatography. pp. 202. Academic Press, London.

Anonymous. 1966. Brabender moisture/volatiles tester manual. pp. 24. C. W. Brabender Instrument, Inc., New Jersey.

Ast, H. J. 1963. Inadvertent isomerization of polyunsaturated acids during ester preparation. Anal. Chem. 35(10): 1539.

Baldi, V., Little, L. and Hester, E. E. 1965. Effect of the kind and proportion of flour components and of sucrose level on cake structure. Cereal Chem. 42: 462.

Bligh, E. G. and Dyer, W. J. 1959. A rapid method of total lipid extractionand purification. Can. J. Biochem. Physiol. 37: 911.

Campbell, A. M., Penfield, M. P. and Griswold, R. M. 1979. The experimental study of food. Second edition. pp. 513. Houghton Mifflin Company, Boston.

Childs, M. T. and Ostrander, J. 1976. Egg substitutes: chemical and biologic evaluations. J. Am. Dietet. Assn. 68: 229.

Fisher, N., Broughton, M. E. and Peel, D. J. 1964. The lipids of wheat II: lipids of flour from single wheat varieties of widely varying baking quality. J. Sci. Food Agric. 15: 325.

Folch, J., Ascoli, I., Lees, M., Meath, J. A. and LeBaron, F. N. 1951. Preparation of lipids extracts from brain tissue. J. Biol. Chem. 191: 833.

Folch, J., Lees, M. and Sloanestanley. 1957. A simple method for the isolation and purification of total lipids from animal tissues. J. Biol. Chem. 226: 497.

Funk, K., Zabik, M. E. and Elgidaily, D. O. 1969. Objective measurements for baked products. J. Home Econ. 61(2): 119.

Grawemeyer, E. A. and Pfund, M. C. 1943. Line-spread as an objective test for consistency. Food Res. 8: 105.

Halliday, E. G. and Noble, I. T. 1946. Hows and whys of cooking. pp. 328. The University of Chicago Press, Chicago.

Harnett, D. I. and Thalheimer, W. G. 1979. Use of oil in baked products. II: Sweet goods and cakes. J. Amer. Oil Chem. Soc. 56: 948.

Hindman, M. S. and Marbut, M. J. 1962. Interchangeability of shortenings in baked products. S. C. Agr. Expt. Sta. Bull. Number 502.

Hoerr, C. W. 1960. Morphology of fats, oils and shortenings. J. Amer. Oil Chem. Soc. 37: 539.

Hood, M. P. and Lowe, B. 1948. Air, water vapor and carbon dioxide as leavening gases in cakes made with different types of fats. Cereal Chem. 24: 244.

Horning, E. C., Ahrens, E. H., Lipsky, S. R., Mattson, F. H., Mead, J. F., Turner, D. A. and Goldwater, W. H. 1964. Quantitative analysis of fatty acids by gas liquid chromatography. J. Lipid Res. 5: 20.

Hoseney, R. C., Finney, K. F. and Pomeranz, Y. 1970. Functional (breadmaking) and biochemical properties of wheat flour components. VI. gliadin-lipid-glutenin interaction in wheat gluten. Cereal Chem. 47: 135.

Howard, N. B., Hughes, D. H. and Strobel, R. G. K. 1979. Function of the starch granule in the formation of layer cake structure. Cereal Chem. 45: 329.

Hunter, M. B., Briant, A. M. and Personius, C. J. 1950. Cake quality and batter structure: Effects of formula, temperature of ingredients, kind of fat and method of mixing. pp. 59. Bulletin number 860. New York State College of Agric., a unit of the State University of New York at Cornell University, Ithaca, New York.

James, A. T. 1960. Qualitative and quantitative determination of the fatty acids by gas liquid chromatography. Methods of Biochem. Anal. 8: 1.

Jamieson, G. R. and Reid, E. H. 1965. The analysis of oils and fats by gas chromatography. J. Chromatog. 17: 230.

Jooste, M. E. and Mackey, A. O. 1951. Cake structure and palatability as affected by emulsifying agents and baking temperatures. Technical Paper No. 694. pp. 11. Oregon Agric. Exp. Sta.

Kamat, V. B., Lawrence, G. A., Hart, C. J. and Yoell, R. 1973. Contribution of egg yolk lipoproteins to cake structure. J. Sci. Food Agric. 24: 77.

Kasarda, D. D., Bernardin, J. E. and Nimmo, C. C. 1976. Wheat proteins. Advances in Cereal Sci. and Tech. 1: 158.

Lawson, H. W. 1970. Functions and applications of ingredients for cake. Bakers Digest 44: 36.

Lehninger, A. L. 1975. Biochemistry. Second edition. pp. 1104. Worth Publishers, Inc., New York.

Lowe, B. 1955. Experimental cookery. Fourth edition. pp. 553. John Wiley and Sons, New York.

MacRitchie, F. 1978. Differences in baking quality between wheat flours. J. Food Technol. 13: 187.

Mathews, R. H. and Dawson, E. H. 1966. Performance of fats in wheat cake. Cereal Chem. 43: 538.

Mecham, D. K. 1972. Flour proteins and their behavior in doughs. Cereal Sci. Today 17: 208.

Moss, H. J. 1980. Strength requirements of doughs destined for repeated sheeting compared with those of normal doughs. Cereal Chem. 53(3): 195.

Ohlrogge, H. B. and Sunderlin, G. 1948. Factors affecting the quality of cakes made with oil. J. Amer. Dietet. Assn. 24: 213.

Paul, P., Batcher, O. M. and Fulde, L. 1954. Dry mix and frozen baked products. I. Dry mix and frozen cakes. J. Home Econ. 46: 249.

Peckham, G. C. and Graves, J. H. F. 1979. Foundations of food preparation. Fourth edition. pp. 616. Macmillan Publishing Company, Inc., New York.

Phillips, J. A. 1966. Fatty acid composition of crude lipid extracted from five flour mixtures before and after baking. Unpublished dissertation. Purdue University.

Rogozinski, M. 1964. A rapid quantitative esterification technique for carboxylic acids. J. Gas Chromatog. 2: 136.

Smith, D. A. and Hawrysh, Z. J. 1978. Quality characteristics of wheat-bran chiffon cakes. J. Am. Dietet. Assn. 72: 599.

Turpeinen, O. 1979. Effects of cholesterol lowering diet on mortality from coronary heart disease and other causes. Circulation 59(1): 1.

USDA. 1981. Fatty acid composition of American foods. USDA Handbook Number 8. pp. 231. U.S. Government Printing Office, Washington, D.C.

Vail, G. E., Phillips, J. A., Rust, L. O., Griswold, R. M. and Justin, M. M. 1978. Foods. Seventh edition. pp. 528. Houghton Mifflin Company, Boston.

Vollmar, E. K. and Braden, R. A. 1976. A laboratory manual for selected objective measurements used in foods research. pp. 33. Department of Human Nutrition and Foods, Virginia Polytechnic Institute and State University, Blacksburg.

Yamakazi, W. T. and Kissell, L. T. 1978. Cake flour and baking research. Cereal Foods World 23(3): 114.

Zabik, M. E. and Lang, P. 1978. Note on performance of low cholesterol egg substitutes in layer cakes. Cereal Chem. 55: 524.

APPENDIX

Table 11. Values for apparent viscosity of batter for cakes made with four fats and three egg products, mean*, overall mean** and range (mm).

	Fat															
	Hydrogenated vegetable shortening				Corn oil				Soybean oil				Peanut oil			
Fresh whole eggs	11.5	7.0	9.5	11.5	35.0	31.0	30.5	32.0	32.0	30.5	31.0	31.5	33.5	33.5	32.5	31.0
	8.0	9.5	11.0	11.5	34.0	31.5	32.5	32.0	34.0	32.0	31.0	32.0	31.5	33.0	32.0	31.0
Mean*	9.8	8.2	10.2	11.5	34.5	31.2	31.2	32.0	33.0	31.2	31.0	31.8	32.5	33.2	32.2	31.0
Overall mean**	9.9^{a}				32.3^{b}				31.8^{b}				32.2^{b}			
Range	7.0 - 11.5				30.5 - 35.0				30.5 - 34.0				31.0 - 33.5			
Egg Beaters	9.0	9.0	9.0	12.0	33.0	33.0	34.0	31.5	34.0	33.0	31.0	33.0	32.5	31.5	33.0	35.0
	10.0	7.0	12.0	11.0	32.5	33.0	35.0	33.5	32.0	35.0	31.0	34.0	33.5	32.0	33.5	31.0
Mean*	9.5	8.0	10.5	11.5	32.8	33.0	34.5	32.5	33.0	34.0	31.0	33.5	33.0	31.8	33.2	33.0
Overall mean**	9.9^{a}				33.2^{b}				32.9^{b}				32.8^{b}			
Range	7.0 - 12.0				31.5 - 35.0				31.5 - 35.0				31.0 - 35.0			
Scramblers	9.0	10.5	8.0	8.5	27.0	33.5	32.0	28.5	31.5	30.5	27.5	30.5	32.5	29.0	29.0	30.5
	9.0	12.5	9.5	9.5	33.5	33.5	31.5	29.5	31.5	28.0	32.5	31.5	33.5	28.5	31.5	31.5
Mean*	9.0	11.5	8.8	9.0	30.2	33.5	31.8	29.0	31.5	29.2	30.0	31.0	33.0	28.8	30.2	31.0
Overall mean**	9.6^{c}				31.1^{d}				30.4^{d}				30.8^{d}			
Range	8.0 - 12.5				27.0 - 33.5				27.5 - 32.5				28.5 - 33.0			

*n = 2
**n = 8
a,b,c,d
Overall mean values with different alphabetic superscripts were significantly different ($P \leq 0.05$).

Table 12: Values for height of baked cakes made with four fats and three egg products, mean*, overall mean**, and range (cm).

	Fat															
	Hydrogenated vegetable shortening				Corn oil				Soybean oil				Peanut oil			
Fresh whole eggs	5.2	5.1	4.6	4.5	4.0	4.2	4.2	4.2	3.8	4.1	4.1	4.2	4.2	4.3	4.2	4.3
	5.0	4.9	4.6	4.7	4.1	4.1	4.2	4.1	3.9	4.2	4.1	4.1	4.3	4.1	4.4	4.2
	5.2	4.9	4.7	4.6	3.9	4.1	4.1	4.2	3.7	4.2	3.9	3.8	4.1	4.2	4.3	4.2
	4.8	4.9	4.7	4.6	3.8	3.8	4.1	4.1	4.1	4.2	4.2	3.9	4.1	4.1	4.1	4.2
	4.3	5.1	6.4	4.6	5.4	5.8	6.1	6.2	5.6	5.7	5.9	5.6	5.8	5.0	5.3	6.2
Mean*	4.9	5.0	5.0	4.6	4.2	4.4	4.5	4.6	4.2	4.5	4.4	4.3	4.5	4.3	4.5	4.6
Overall mean**	4.9[a]				4.4[b]				4.4[b]				4.5[b]			
Range	4.3 - 6.4				3.8 - 6.2				3.7 - 5.9				4.1 - 6.2			
Egg Beaters	4.3	4.5	4.2	4.3	3.4	3.4	3.6	3.3	3.3	3.8	3.4	3.3	3.3	3.3	3.4	3.4
	4.4	4.6	4.4	4.5	3.4	3.5	3.4	3.4	3.5	3.6	3.5	3.6	3.4	3.6	3.4	3.4
	4.4	4.4	4.3	4.4	3.2	3.2	3.7	3.3	3.3	3.8	3.5	3.3	3.1	3.6	3.5	3.4
	4.5	4.3	4.3	4.3	3.2	3.4	3.8	3.2	3.5	3.2	3.4	3.4	3.2	3.6	3.4	3.4
	5.2	5.4	5.5	5.2	3.4	3.4	4.3	3.6	3.8	4.2	4.1	3.3	3.2	3.9	3.7	3.5
Mean*	4.6	4.6	4.5	4.5	3.3	3.4	3.8	3.4	3.5	3.7	3.6	3.4	3.2	3.6	3.5	3.4
Overall mean**	4.6[c]				3.5[d]				3.5[d]				3.4[d]			
Range	4.3 - 5.5				3.2 - 4.3				3.3 - 4.2				3.1 - 3.9			
Scramblers	4.4	4.6	4.4	4.5	3.3	3.6	3.7	3.6	3.2	3.4	3.4	3.5	3.2	3.2	3.6	3.4
	4.5	4.6	4.3	4.4	3.3	3.6	3.7	3.6	3.2	3.2	3.7	3.6	3.1	3.5	3.6	3.6
	4.3	4.4	4.4	4.4	3.4	3.5	3.6	3.4	3.3	3.3	3.6	3.4	3.2	3.2	3.6	3.3
	4.4	4.3	4.4	4.2	3.4	3.7	3.8	3.5	3.3	3.2	3.7	3.6	3.2	3.3	3.5	3.6
	4.8	4.5	4.9	4.3	3.6	3.5	3.9	3.9	3.0	3.6	4.0	3.7	3.7	3.6	3.8	3.6
Mean*	4.5	4.5	4.5	4.4	3.4	3.6	3.7	3.6	3.2	3.3	3.7	3.6	3.3	3.4	3.6	3.5
Overall mean**	4.4[c]				3.6[d]				3.4[d]				3.4[d]			
Range	4.2 - 4.9				3.3 - 3.9				3.0 - 4.0				3.1 - 3.8			

*n = 5
**n = 20
a,b,c,d
Overall mean values with different alphabetic superscripts were significantly different ($P \leq 0.05$).

Table 13. Values for compressibility of baked cakes made with four fats and three egg products, mean*, overall mean** and range (mm).

	Fat															
	Hydrogenated vegetable shortening				Corn oil				Soybean oil				Peanut oil			
Fresh whole eggs	5.8	7.1	9.8	7.4	3.8	4.5	4.9	6.4	4.0	4.4	6.6	8.1	3.9	6.1	6.1	5.1
	6.9	6.1	6.9	8.2	5.1	8.6	5.5	5.4	6.0	5.9	8.6	6.1	4.2	7.2	5.0	6.7
	9.7	6.4	7.5	6.4	4.0	12.6	6.1	8.8	5.6	5.0	4.6	6.4	5.6	8.6	9.3	6.2
	2.7	15.3	5.8	8.8	4.0	6.7	4.7	5.3	5.0	5.1	4.7	10.5	6.7	5.9	5.8	4.6
	7.5	5.9	5.7	9.8	8.8	5.5	4.9	6.1	5.6	6.4	7.7	5.0	4.9	5.5	3.5	3.8
Mean*	6.5	8.2	7.1	8.1	5.1	7.6	5.2	6.4	5.2	5.4	6.4	7.2	5.1	6.7	5.9	5.3
Overall mean**		7.5[a]				6.1[b]				6.1[b]				5.8[b]		
Range		2.7 - 15.3				3.8 - 8.8				4.0 - 8.6				3.5 - 9.3		
Egg Beaters	5.0	3.5	17.7	6.1	3.1	5.5	4.0	1.6	2.5	8.2	7.6	3.4	9.9	3.2	1.9	4.2
	3.9	7.7	4.5	7.3	3.0	7.3	2.8	2.3	1.6	2.5	3.2	2.3	3.6	1.8	4.0	5.7
	4.0	7.7	6.0	5.1	1.8	2.7	1.5	4.5	3.5	4.0	7.7	3.8	3.3	1.5	4.0	4.4
	9.7	5.4	4.2	6.6	3.1	1.8	2.5	1.0	1.5	0.8	3.0	2.9	2.2	2.0	4.0	2.8
	4.9	7.6	7.2	10.0	7.2	2.5	2.7	2.0	2.6	1.8	6.3	2.1	0.2	4.2	3.4	5.4
Mean*	5.5	6.4	7.9	7.0	3.6	4.0	2.7	2.3	2.3	3.5	5.6	2.9	3.8	2.5	3.5	4.5
Overall mean**		6.7[c]				3.2[d]				3.6[d]				3.6[d]		
Range		3.5 - 17.7				1.0 - 7.3				0.8 - 8.2				0.2 - 9.9		
Scramblers	3.8	4.0	12.0	18.5	1.8	8.0	2.4	1.5	2.5	3.6	1.4	3.0	3.6	3.7	2.9	5.0
	4.5	4.4	6.0	12.5	6.9	4.9	4.0	5.2	0.6	3.0	2.1	4.0	1.3	2.2	2.1	4.3
	8.8	3.9	4.9	6.2	1.3	1.8	8.0	2.7	1.1	2.9	7.0	4.7	7.5	6.5	0.6	4.2
	2.5	6.9	12.7	14.6	7.0	6.1	2.6	4.2	2.0	5.4	3.4	6.7	3.6	1.3	8.2	2.9
	4.0	3.3	11.4	4.4	1.6	3.4	9.8	2.2	0.4	2.8	6.6	2.3	4.5	2.6	4.6	10.4
Mean*	4.7	4.5	9.4	11.2	3.9	4.8	5.4	3.2	1.3	3.5	4.1	4.1	4.1	3.3	3.7	5.4
Overall mean**		7.4[c]				4.3[d]				3.3[d]				4.1[d]		
Range		2.5 - 18.5				1.6 - 9.8				0.4 - 7.0				0.6 - 10.4		

*n = 5
**n = 20
a,b,c,d
Overall mean values with different alphabetic superscripts were significantly different ($P \leq 0.05$).

Table 14. Values for moisture content of baked cakes made with four fats and three egg products, mean*, overall mean**, range (percent).

	Fat															
	Hydrogenated vegetable shortening				Corn oil				Soybean oil				Peanut oil			
Fresh whole eggs	22.7	21.8	23.2	23.0	23.8	25.0	23.2	24.0	22.5	23.4	24.4	25.4	25.0	24.6	25.4	23.8
	23.2	22.4	22.6	23.4	24.1	23.5	23.2	23.9	21.6	23.4	23.9	25.5	24.5	23.7	24.6	23.8
	22.7	23.2	22.5	23.5	23.6	23.8	24.5	23.0	22.1	22.4	23.4	24.9	23.3	24.2	23.9	23.7
	22.7	21.6	22.1	23.2	24.0	23.1	23.3	22.8	22.0	23.8	23.9	25.2	25.1	23.4	24.3	23.2
	23.0	21.2	22.0	23.3	23.9	23.3	23.8	23.0	22.1	23.5	24.5	24.9	24.4	24.4	23.8	22.9
Mean*	22.9	22.0	22.5	23.3	23.9	23.7	23.6	23.3	22.1	23.3	24.0	25.2	24.5	24.1	24.4	23.5
Overall mean**		22.7[a]				23.6[a]				23.6[a]				24.1[a]		
Range		21.2 - 23.5				23.2 - 24.5				21.6 - 25.4				22.9 - 25.4		
Egg Beaters	25.3	23.5	22.2	26.1	23.5	24.5	22.8	24.5	25.5	25.3	23.0	25.4	24.3	25.0	25.5	24.5
	24.3	25.0	24.4	25.4	23.3	23.9	23.3	23.9	25.5	25.6	22.8	24.7	24.6	25.0	24.7	24.6
	25.6	24.8	24.8	25.5	21.9	23.4	22.8	24.0	25.9	25.2	22.6	24.4	24.5	25.0	25.4	24.5
	24.7	24.7	24.0	24.6	22.7	24.0	23.4	24.2	25.7	25.0	22.2	24.4	24.0	25.0	25.1	24.2
	24.7	23.2	23.3	24.8	21.5	23.7	23.1	24.3	25.0	24.8	22.6	24.6	24.3	24.6	24.7	24.8
Mean*	24.9	24.2	23.7	25.3	22.6	23.9	23.1	24.2	25.5	25.2	22.6	24.7	24.3	24.9	25.1	24.5
Overall mean**		24.5[b]				23.4[b]				24.5[b]				24.7[b]		
Range		22.2 - 25.6				21.5 - 24.5				22.2 - 25.9				24.0 - 25.5		
Scramblers	23.1	24.9	22.6	23.4	23.9	24.2	23.0	25.0	22.5	23.1	24.2	24.0	23.2	22.7	23.5	25.0
	23.4	23.9	22.3	23.1	23.8	23.6	24.3	23.4	22.7	23.2	24.3	23.9	23.5	22.3	23.4	24.0
	22.7	23.5	22.0	22.9	23.5	23.6	23.1	24.0	22.1	22.6	24.2	24.1	23.5	22.6	23.3	24.5
	22.1	23.3	22.1	23.1	23.6	23.4	23.4	24.1	22.5	22.8	23.5	23.8	23.0	22.8	23.4	24.3
	22.6	23.3	23.2	23.6	22.7	23.5	23.2	24.3	22.7	22.9	24.0	23.5	23.3	22.9	22.9	24.0
Mean*	22.8	23.8	22.4	23.2	23.5	23.7	23.4	24.2	22.5	22.9	24.0	23.9	23.3	22.7	23.3	24.4
Overall mean**		23.0[a]				23.7[a]				23.3[a]				23.4[a]		
Range		22.0 - 24.9				22.7 - 25.0				22.1 - 24.3				22.3 - 25.0		

*n = 5
**n = 20
a,b,c,d
Overall mean values with different alphabetic superscripts were significantly different ($P \leq 0.05$).

The vita has been removed from the scanned document

FATTY ACID COMPOSITION AND

OTHER CHARACTERISTICS OF SHORTENED CAKES

by

Mercy Mnyembezi Nafuleka

(ABSTRACT)

Data on characteristics of cakes is desirable to have for use by interested parties in making decisions about use of the product. Measurements on apparent viscosity, batter and cake characteristics: height, compressibility and moisture content were determined for cakes made with four fats and three egg products.

Apparent viscosity of batter prepared did not predict the kind of cake that was produced. However, a viscous batter was obtained from cakes made with hydrogenated vegetable shortening and any of the egg products used. In addition, a thick batter was produced with Scramblers and any of the fats used.

Considering the baked cake, height measurements were in agreement with those of compressibility. These characteristics (height and compressibility) were influenced by fresh whole eggs and hydrogenated vegetable shortening. However, fresh whole eggs did not have any effect on moisture content. In addition, it was concluded that using Lowe's (1955) mixing method, it was possible to use a vegetable oil with fresh whole eggs and get an acceptable cake. With egg substitutes, it was observed that a less tender cake with less height was obtained, but that the cakes were generally acceptable.

Though not so much as a characteristic of cakes, but a measurement that was taken on the baked cakes, fatty acids were determined using gas liquid chromatography.