EVALUATION OF DIFFERENT TYPES OF FATS FOR USE IN HIGH-RATIO
LAYER CAKES

by

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Abstract

Shortening is a major ingredient used in high-ratio layer cakes. Plastic shortenings are most commonly used by the U.S. baking industry, but high levels of trans- or saturated fats cause health concerns. Compared to plastic shortenings, liquid shortenings could significantly reduce the dependence on high melting point fats and the emulsifiers used would enhance the shortening's functionality.

The objective of this research was to compare the influence of different types of fats on the texture and shelf-life of high-ratio layer cakes. Cakes were baked with soybean oil to evaluate the function of three emulsifiers (PGMS, GMS, and Lecithin) on layer cake quality, including volume, cake score, interior visual texture (C-Cell), and firmness (Voland-Stevens). An optimum emulsifier combination was chosen (PGMS 1.8%, GMS 1.0% and Lecithin 0.8%) for addition to the liquid oil. Four groups of layer cakes were baked using: plastic shortening, liquid shortening, liquid oil, or liquid oil plus emulsifier combination. Cake performance and firming over-time were evaluated. The liquid shortening provided the best fresh cake characteristics and cake firmness performance. Liquid oil combined with a combination of added emulsifiers performed very similar in terms of firmness, as did the liquid shortening. This indicated that emulsifiers played an important role on the improvement of cake firmness shelf-life.

Table of Contents

List of Figures

List of Tables

Acknowledgements

CHAPTER 1 - INTRODUCTION

Shortening is a major ingredient in high-ratio layer cakes, i.e., those in which there is more sugar than flour in the formula. Shortening performs three basic functions in high ratio cake production: (a) it entraps air during the creaming process to aid in the proper aeration or leavening of the batter and the finished cake; (b) it coats the protein and starch particles, thereby disrupting the continuity of the gluten and starch to provide tenderization and lubrication to the texture and mouth-feel; (c) it emulsifies large amounts of liquid thereby contributing to increased crumb moisture and softness in the product (Pyler, 1988).

Plastic shortenings are the type most commonly used in the U.S. baking industry. They can be used in most types of cakes. In the USA, plastic shortening is often made from partially hydrogenated soybean oil. However, the consumption of trans- fats formed during hydrogenation increases the risk of coronary heart disease by raising the levels of LDL bad cholesterol and lowering levels of HDL good cholesterol (Juttelstad, 2004). With more and more people concerned about health problems and the FDA's finding that there is no safe level of trans fat consumption, many companies began to use palm oil instead of hydrogenated soybean oil to make zero-trans shortenings. Ironically, the high levels of saturated fatty acids in palm oil result in the same cardiovascular problem as trans fats do (List, 2004).

Liquid shortening has been developed for bulk handling and metering at room temperature. The designation "liquid" covers all fluid suspensions that consist of a small amount of hard fat, usually the beta-tending crystal form, and emulsifiers dispersed in liquid oil (O'Brien, 1998). Few publications have assessed the performance of liquid shortenings in cake baking systems. In general, liquid cake shortenings function much like solid shortening in baking systems, but they offer the user certain advantages. First, as a liquid shortening is a fluid- like material at room temperature, it is pumpable, which leads to great savings in labor cost. It is easier to handle and there are no boxes or liners to unpack or dispose of (McGill, 1973). Second, it has no trans fatty acids and much lower saturated fatty acids content.

Compared to plastic shortening, liquid shortening would significantly reduce the dependence on solid fats for their performance. Further, it is possible that additives, for example emulsifiers, could supplement the functionality previously performed solely by the fats and oils.

Consequently, the overall objective of this research was to compare the influence of different types of oils and fats on the texture and stability of high ratio layer cakes. The expectation is that the results will expand the applications for liquid cake shortening in the baking industry.

The specific objectives of this research were: (a) compare the effects of different types of fats (plastic shortening, liquid cake shortening, and liquid oil) on the texture and other properties of high-ratio layer cakes; (b) determine the effects of those fats on cake texture and storage stability; (c) examine the abilities of different combinations of emulsifiers to contribute positively to cake texture and storage stability.

CHAPTER 2 - LITERATURE REVIEW

2.1 High-ratio layer cakes

Cake has been defined as a semi-dry foam produced by the setting of a fluid medium that has been expanded by gas resulting from chemicals dissolved in the medium (Zelch, 2001). Starting with a few basic formulas, changes in the cake ingredients and/ or processing techniques have resulted in the development of many products having a wide range of characteristics. These can range from light angel food cakes to dense, rich, cheese cakes. Cakes can generally be classified into one of three categories: foam cakes, batter cakes, or chiffon cakes. The aeration properties of batter cakes are based on the shortening/ oil included in the formula. Batter cakes include two subdivisions: layer cake and pound cake, based on the forms of leavening that are used. Layer cake contains chemical leavening agents in the formula and pound cakes are leavened only by air incorporated and entrapped during the mixing process. The original pound cakes were so named because they were made with one pound each of sugar, flour, lard, and eggs. High ratio cakes are those in which the weight of the sugar is equal to or greater than that of the flour (Pyler, 1988 and Zelch, 2001).

Incorporating air into a cake batter can be accomplished by three methods: creaming mixing, single stage mixing, or continuous mixing. In the creaming mixing, shortening and sugar are mixed vigorously to incorporate air into the shortening; this is followed by the incorporation of the eggs, while the creaming action is continued. The last stage is mixing the milk and flour into the batter. In the single-stage method, all the ingredients are introduced into the mixing bowl at one time and mixed into a homogeneous mass. This method requires surfactants to facilitate air incorporation. In continuous mixing, the batter is homogenized and emulsified by a high speed rotor and aerated by the incorporation of pressurized air (Plyer, 1988 and Bath et al, 1992).

Cake quality is governed by three major factors: the suitability of the individual ingredients for the specific type of cake being made, a properly balanced formula, and the optimum mixing and baking procedures (Pyler, 1988).

There are many publications about the functionality of various layer cake components (Howard, 1972; Johnson and Hoseney, 1979; Brooker, 1993; Donelson, et al 2000; Zelch, 2001). In general, cake ingredients may be classified as tougheners, tenderizers, moisteners, or driers. In order to make a satisfactory cake, tougheners and tenderizers must be properly balanced (Pyler, 1988; Mizukoshi, 1985). Flour is classed as a structure builder as it is involved in establishing the crumb structure of most types of cake and is considered a toughener. Chlorination is generally used on those soft wheat flours that are intended for cake production in order to produce better cakes. The functional effect of chlorination is on the flour starch, partially de-polymerizing and oxidizing it (Pyler, 1988). Oxidized starch granules are able to swell more rapidly after the starch reaches the gelatinization temperature and the resulting batter system will be sufficiently viscous to support the cake's structure without collapsing (Pyler, 1988). Kissell and Yamazaki (1979) tested the effect of 14 different levels of chlorination on baking performance. They found batter expansion was greater for treated flours, even at the lowest chlorination rate, than for untreated flour. Due to safety concerns, a number of researchers including Donelson et al (2000) have tried to replace chlorine treatment of cake flour. They found that replacement of non-chlorine-treated flour with up to 43% starch produced a pasting curve with curve areas that were equivalent to those produced by chlorine-treated flours. Increasing the concentration of dried egg albumen plus adding soya lecithin and xanthan gum produced a new basic ingredient set capable of producing cakes of very similar cake quality to those produced using chlorinated flour (Donelson et al, 2000).

Johnson and Hoseney (1979) measured the effect of different cake ingredients on the baking properties of chlorine-treated and untreated flours. They found that untreated cake flours gave lower volumes as the shortening content in the formula increased. Egg whites improved both the volume and grain of cakes baked from untreated flour, but did not materially improve the baking properties of chlorine-treated flours. Whole eggs affected the baking properties of untreated flour but did not significantly affect the baking properties of chlorine-treated flours. Wheat or corn starch improved cake volume but did not improve cake grain.

Although much research has been conducted on the staling of bread, little has been reported on the problem of the staling of cakes (Hodge, 1977; Walker et al, 1988; Lahtinen et al, 1998 and Gelinas et al, 1999). Hodge (1977) found a rapid increase in crumb firmness during the first few hours after baking and that the crumb continues to firm at a reduced rate in storage

even in the absence of any moisture loss. Walker et al (1988) found that the firmness testing method approved for bread is also applicable to cakes and can be used to differentiate cakes of different formulations and ages. Staling is much slower in cake than in breads, partly because cakes contain more fat and less flour. Therefore, lower concentrations of starch might slow the staling rates.   Lahtinen et al (1998) studied the factors affecting cake firmness and cake moisture content by Response Surface Methodology. They found that cake firmness increased notably with increasing initial fat temperature; increasing the mass ratio of fat to sucrose (F/S ratio) increased cake firmness at each of the fat temperatures. Mixing time and size of sucrose granules either did not affect cake firmness and cake moisture or their influence on them was weak.

2.2 Fats and Oils

Fats and oils are principal and essential constituents of the human diet. Fats and oils are major energy sources, supplying 9 calories per gram, as compared with 4 calories per gram for protein and carbohydrates. They also enhance many foods by providing texture, mouth feel, and imparting or covering flavor.

2.2.1 Structure and properties

The fats and oils of commerce are mixtures of lipids. They are comprised mainly of triacylglycerols (commonly referred to as triglycerides) accompanied by lower levels of diacylglycerols (diglycerides), monoacylglycerols (monoglycerides) and free fatty acids, and with other minor components such as sterols, triterpene alcohols, tocols, hydrocarbons, and the fat soluble vitamins (Gunstone, 1999).

Figure 2-1. Diagram of triglycerides

$$
\begin{array}{l}
H_2C\!-\!O\!-\!\overset{\displaystyle O}{\overset{\|}{C}}\!-\!\!-R_1 \quad \text{Fatty acid}_1 \\[4pt]
HC\!-\!O\!-\!\overset{\displaystyle O}{\overset{\|}{C}}\!-\!\!-R_2 \quad \text{Fatty acid}_2 \\[4pt]
H_2C\!-\!O\!-\!\overset{\displaystyle O}{\overset{\|}{C}}\!-\!\!-R_3 \quad \text{Fatty acid}_3
\end{array}
$$
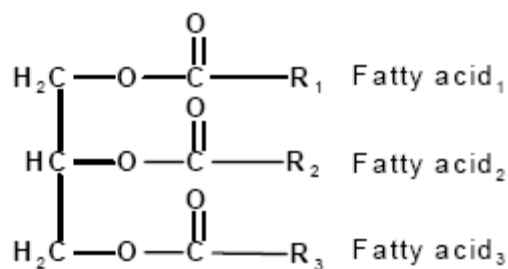
(Adapted from Anon, 2006)

A triglyceride (Figure 2-1) consists of three fatty acids attached to one glycerol molecule. The three fatty acids can be identical or different. The fatty acids in a triglyceride define its properties and characteristics. They are classified by their degree of saturation. Saturated fatty acids contain only single carbon-to-carbon bonds. The melting point of fatty acids increases with chain length. Unsaturated fatty acids (Figure 2-2) contain one or more double carbon-to-carbon bonds. Oleic acid (cis-9- octadecenoic acid) is the unsaturated fatty acid that occurs most frequently in nature. Polyunsaturated fatty acids, for example, Linoleic and Linolenic, are the most important polyunsaturated fatty acids as they are essential fatty acids, required by humans but not synthesized by the body, and therefore must be obtained through the diet (Anon, 2006).

Figure 2-2. Diagrams of saturated and unsaturated bonds
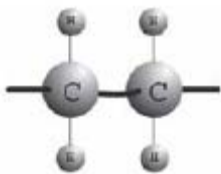
Saturated Bond
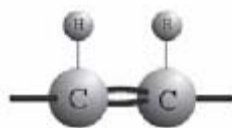
Unsaturated Bond

(Adapted from Anon, 2006)

2.2.2 Trans fatty acids

Trans, in Latin, means "on opposite sides". In this context, it refers to the locations of hydrogen atoms attached to carbons involved in double bonds. A cis-fatty acid has two hydrogen atoms that attached to carbons in double bonds on the same side. The principal trans-fatty acid source in the U.S. is partially hydrogenated fats used as food ingredients, such as plastic shortening and deep-frying oil. However, small amounts of trans fats also occur naturally in foods such as milk, butter, cheese, beef, and tallow (2-5%) as a result of biohydrogenation in ruminant animals (List, 2004).

Trans- fatty acids have a very different biological function than do the "cis" fatty acids. Some research (Moon et al, 2009; Bhattacharya et al, 2006; Juttelstad, 2004; Ramli, et al, 2008) showed that trans fatty acids could raise the bad (LDL) cholesterol, lower the good blood lipids (HDL), and increased the risk of heart disease. On July 2003, the U.S. Food and Drug Administration published final rules that required trans acid content to be included on food labels by January 1, 2006 (List, 2004). Consequently, food companies have had to change their formulas to reduce the trans fat contents in their food products.

Figure 2-3. Diagram of cis- and trans fatty acids

cis

Trans

(Adapted from Anon, 2006)

7
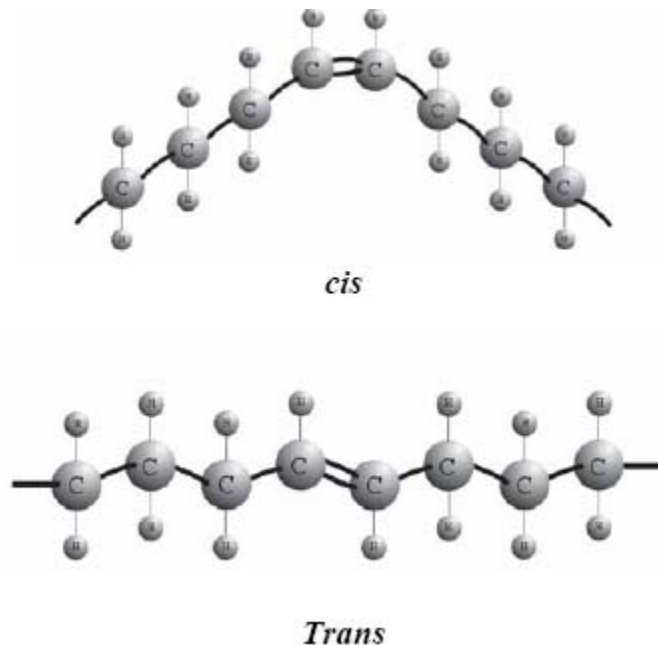
2.2.3. Shortenings

Crystal structure

The application of fats in bakery products depends on their fats' crystallization and melting properties. The crystal structure of a shortening is determined by source oil composition, processing, and tempering. Fatty acid triglycerides are polymorphic, exhibiting four crystal forms as follows: Alpha form (α), Beta prime form (ß'), intermediate, and Beta form (ß) (Birnbaum 1978). Crystal melting points increase from the alpha to the beta form. Crystals in the alpha form are fragile, small (about 5 microns in size), and are readily transformed to higher melting forms. Beta-prime crystal forms are up to 1 micron in length, delicate, needle-like shapes that can pack together to dense fine-grained structures. Beta crystal forms are on average 25-50 microns in length and can grow to over 100 microns. They have the highest melting point and they are large and coarse. Intermediate crystal forms may exist in a mixture of several different crystals forms (O'Brien, 1998). Upon rapid cooling, melted fat crystallizes in the alpha form, which is the least stable type. This transitory crystalline phase undergoes an irreversible transformation from alpha to beta prime to intermediate to beta. Of these four forms, Beta prime is the most suitable for cake making (Birnbaum, 1978 and Gunstone, 1999).

The crystal form of the solidified fat product has a major influence upon its textural properties (Heertje and Leunis 1997). Fats in the stable ß' form appear smooth, provide good aeration, and have excellent creaming properties. On the other hand, the ß form crystal shortening is waxy and grainy and provides poor aeration. Consequently in cake baking, the ß' crystal is preferred (Gunstone, 1999).

Berger et al. (1979) found that air bubbles in creamed batters were entirely within the fat phase and that their surface was lined with oil which was stabilized by an underlying layer of packed fat crystals. The small ß' crystals could arrange themselves around the interface of small bubbles more easily than could the larger ß polymorph, and could incorporate air very well. Brooker (1993) showed the role of fat crystals in the stabilization of air bubbles in cake batters. Specifically the adsorption of fat crystals helps to stabilize large numbers of small bubbles, which must expand without rupturing during baking if the batter is not to collapse. This model also explains why oils cannot produce the same degree of cake aeration as the same weight of crystalline fats.

Plastic shortening

The term "Shortening" comes from shortens. Fat tenderizes (shortens the texture of) baked goods by preventing cohesion of gluten strands during mixing and baking (O'Brien, 1998). Plastic shortenings are composed of a solid phase of fat crystals intimately mixed with a liquid phase of fluid oil. They are semi-solid in room temperature.

Shortenings are a very important ingredient in the baking industry because they can comprise up to 30% of baked products' composition. They contribute to baked products in a number of ways, such as imparting shortness, richness, and tenderness, improving flavor and eating characteristics, providing flakiness, providing lubrication, retarding staling, and providing structure for icing and fillings (O'Brien, 1998).

The role of shortening in the cake baking process has been described as the aeration of batters for the incorporation of air into the plastic shortening phase during batter-mixing. Photographs of batters show the air cells to be associated with fat. The stability of these cells during mixing and in the early stages of baking is, therefore, associated with certain characteristics of the shortening (Wootton et al, 1967).

Shortening and oils serve a variety of functions in the processing of batter cakes. Their main function is as a tenderizer, in that they provide lubrication and a crumb softening effect. Shortenings also aid in the aeration process during leavening. During mixing, fat crystals become coated with an interfacial layer of adsorbed protein (crystal-water interface). An oil-in-water emulsion is thus formed, with the fat being well distributed. These irregularly shaped fat regions contain the nucleating or initial air cells (Zelch, 2001). During baking, the fat crystals melt and the oil exposed over the internal surface of the cells, providing an extra interface during its expansion. This activity combined with the effect of moisture vapor expansion, and the CO_2 from leavening causes the cake to rise.

Most cake shortenings contain emulsifiers. These assist in maintaining the oil-in-water emulsion that is necessary for processing cakes.

Liquid shortenings

Liquid shortenings are distinguished from liquid oils by their compositions and properties. Both are pourable, but liquid oils are clear while liquid shortenings are opaque due to

9

their suspended solids. Liquid shortening has been defined as "a stable dispersion of crystalline solids in a liquid oil matrix that is fluid and pumpable at room temperature" (Pyler, 1988). The liquid oil phase may or may not be hydrogenated, depending on the finished product's consistency and oxidative stability requirement. Low –IV (Iodine value is defined as the grams of iodine that can add to 100 gram fat or oil, which measures the fat saturation degree) ß crystal hard fats are used as seeds for crystallization. Their concentration in liquid shortening varies from 1% or higher to usually no more than 10%. ß crystal hard fats are used for liquid shortening products to convert the whole system to a stable crystal form so that the liquid phase and solid phase will not separate. For use in cakes, liquid shortenings require balanced emulsifier systems, generally consisting of several components. They also must contain a minimum of about 10% of either solid emulsifiers or crystalline triglycerides (O'Brien, 1996).

Even with the addition of emulsifiers and antioxidants, the crystal form and saturation levels of the base oils are still important. Emulsifiers have significantly reduced the dependence on solid fats solely for their performance. This, in turn, led to the development and introduction of liquid shortenings for use in both yeast-raised and chemically-leavened baked products. Liquid shortenings combine the highly functional characteristics exhibited by plastic shortening with the bulk handling characteristics of liquid oil. A liquid shortening is a stable dispersion of solids with proper polymorphic form in a continuous oil phase that is both flowable and pumpable over a temperature range of 60 to 90 ℉ (O'Brien, 1998).

Liquid shortenings are dependent upon a balanced emulsifier system and are designed to provide most of the functionality necessary for cakes. Therefore, different combinations of emulsifiers will have significant effects on the performance of liquid shortening. A variety of emulsifiers, including glyceryl lacto esters, propylene glycol monoester, and mono-and diglycerides etc. could provide aeration, tenderizing, and moisture retention properties to liquid shortening (O'Brien, 1998).

The processing of liquid shortening is much different from that of plastic shortening. Liquid shortenings need a special crystallization process. Many different crystallization procedures for liquid shortenings have been patented. The most popular crystallization procedure is "gradual cooling of melted product to form large ß crystals with gentle agitation. This procedure normally requires 3-4 days elapsed time." (O'Brien, 1996). The other procedures still in use include: gradual cooling followed by comminution with a homogenizer or colloid

mill; rapid cooling with a swept-surface heat exchanger followed by a holding period of at least 16 hours with gentle agitation; suspension of finely ground hard fat or emulsifier in a cooling liquid oil with subsequent comminution using a homogenizer, colloid mill or shear pump.

McGill (1973) discussed the advantages and economy of liquid shortening. Liquid shortenings are easy to handle and there are no boxes or liners to unpack or dispose of. There is a saving in labor. However, their distribution cost is higher than that of plastic products because they must be held at a constant temperature. Storage temperatures are critical with liquid shortenings. Storage below 65 ℉ will cause the liquid shortening to solidify and lose pumpability. Storage above 95 ℉ will cause melting or partial melting of the suspended solids. None of the damage caused by temperature changes can be reversed (O'Brien, 1996). Because of their very high content of liquid oil, the trans- and saturated fatty acid contents are much lower than those of normal plastic shortening. This can help the baked products meet the FDA's trans-free requirement (Anon, 2007).

2.3 Emulsifiers

A "surfactant" is a surface active agent. The term is applied to "molecules that migrate to interfaces between two physical phases, and thus are more concentrated in the interfacial region than in the bulk solution phase" (Stauffer, 1990). The key molecular characteristic of a surfactant is that it is amphiphilic in nature, the lipophilic (or hydrophobic) part of the molecule preferring to be in a lipid (nonpolar) environment, and the hydrophilic part preferring to be in an aqueous (polar) environment.

Emulsifiers, a subset of surfactants, are commonly used in many food products. The bakery industry is the largest user of food emulsifiers (Schuster and Adams, 1984). Emulsifiers are made up of molecules that have a non-polar (fatty acid) end, which carries no charge and has an affinity for oil, and a polar (glycerol) end, which carries a charge and has an affinity for water. Such a molecule can situate itself at the interface between oil and water. The polar end will immerse itself in the aqueous phase and the non-polar end will immerse itself in the lipid phase and prevent coalescence of the oil droplets. This helps the two phases to stay intimately mixed and form a stable emulsion (Schuster and Adams, 1984).

Figure 2-4. Structure of emulsifiers

lipophilic area

hydrophilic area

CH₃

hydrocarbon chain
nonpolar group
impossible or hard to hydrate
"hydrophobic tail"

glycerol - residue
polar group
easy to hydrate
"hydrophilic head"
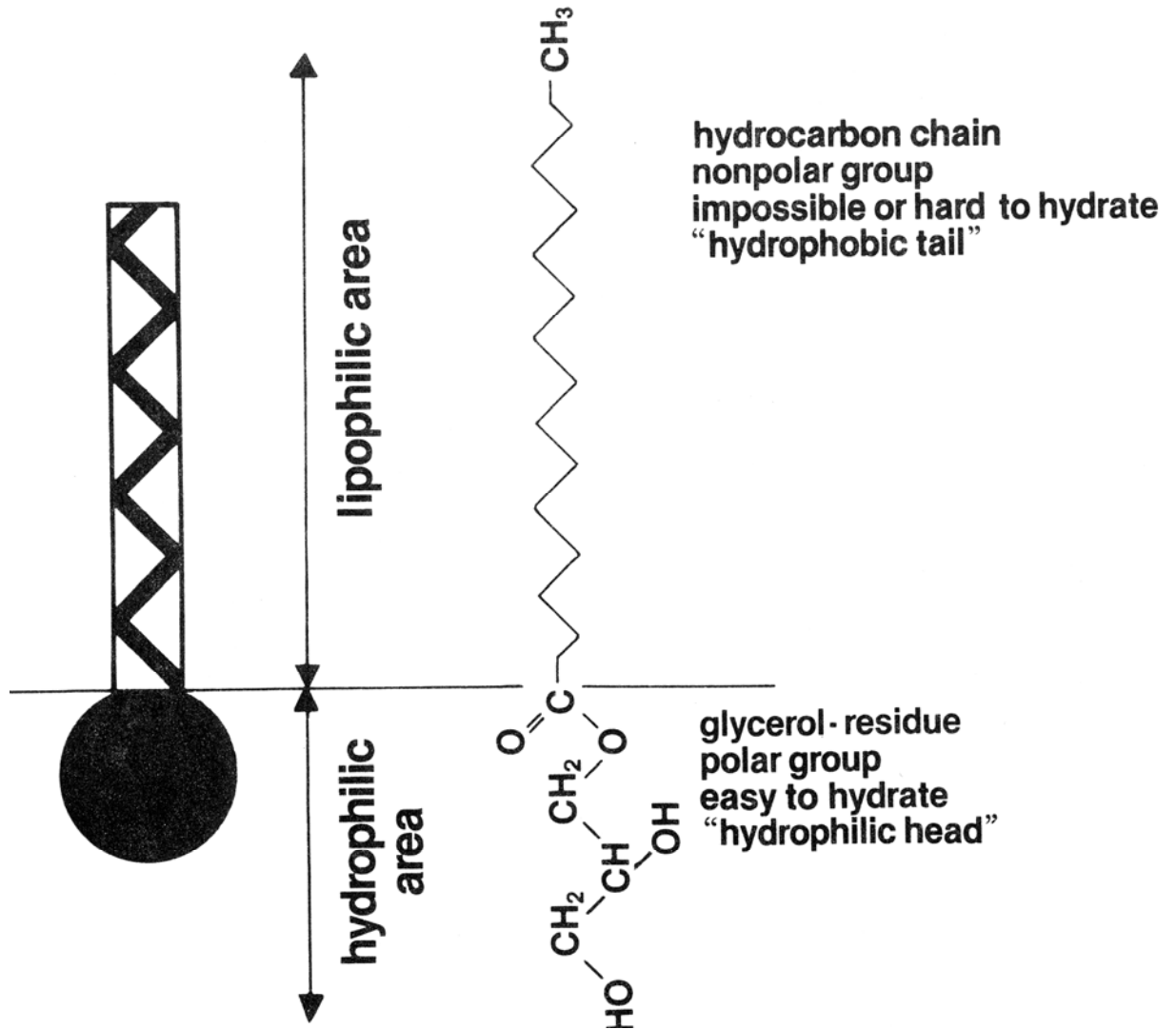
(Adapted from Schuster and Adams, 1984)

2.3.1 Classification

There are several methods for classification of emulsifiers, such as the charge of the hydrophilic groups in water, the lipophilic groups, the solubility in various substances, the ratio of hydrophilic to lipophilic groups, the crystal form, and the arrangement of the emulsifier molecule during interaction with water (Del Vecchio, 1975; Schuster and Adams, 1984). One of the best-known criteria is classification by HLB. HLB stands for hydrophilic-lipophilic balance

and theoretically relates the ratio of the molecular weight of the hydrophilic portion of the surfactant molecule to the total molecular weight. The range set for HLB is 0-20. This scale indicates attraction to either oil or water. Emulsifiers that are predominantly lipophilic will have low HLB values and tend to form water-in-oil emulsions. The neutral point between lipophilic and hydrophilic properties in this HLB scale is 10. While this system has some drawbacks, HLB does offer a starting point for emulsifier selection in products such as cakes where emulsification is important (Duxbury, 1992a).

2.3.2 Emulsifier functions

Emulsification:

One of the main properties of emulsifiers is the stabilization of emulsions by reducing the surface tension at the interface between immiscible liquids or phases (Schuster and Adams, 1984). Cake batter is an oil-in-water emulsion, with shortening or oil as the dispersed phase and water as the continuous phase (Pohl, 1968). An emulsifier reduces the interfacial tension between oil and water and, therefore, facilitates the disruption of emulsion droplets during homogenization. The emulsifier adsorbs on the surfaces of emulsion droplets to form a protective coating that prevents the droplets from aggregating with each other. The integrity of the foam walls, formed by proteins, determines cake volume and uniform appearance (Brooker, 1993). Shortening is an antifoam agent that tends to disrupt the foam cells. Emulsifiers coat the fat particles' exterior surface, providing protection to the protein film cell walls and eliminating film disruption. Because of this protection, bakers can incorporate shortenings (or vegetable oils) in their formulation (Wootton et al., 1967; Rusch, 1981).

Crumb softening:

Emulsifiers were first used in bread to extend shelf life, i.e., to retard staling. The mechanisms behind this include the formation of a starch-emulsifier complex on the surface of the starch granule, stabilizing the granule, and retarding water penetration and swelling, as temperature is raised. The complex also reduces the percentage of starch solubilized or dissolved, mainly by retarding recrystallization of the amylose fraction (Matz, 1987; Stauffer, 1990). The amylose in a dough containing an emulsifier coils is like a piece of twine wrapped

around a nail. The result is that less amylose is free to bind with itself to form the rigid gel (Rusch, 1981). Stauffer (1999) mentioned that starch could form a helical structure, a hollow cylinder that has a hydrophilic outer surface and a hydrophobic inner surface. The straight chain alkyl molecules of emulsifiers such as glycol monostearate (GMS) could fit into the helix and form a starch-emulsifier complex. Some of the practical implications of this behavior follow. Some emulsifiers like GMS, affect starch gelatinization and leavener distribution in a cake system during baking, assuring that rising takes place longer in the outer edges, giving a more symmetrical cake, with homogeneous grain, softer crumb and extended shelf life (Gorton, 1977).

Aeration/foam stability:

Cake batter is an aerated emulsion. The integrity of the air cells determines cake volume and uniformity. Emulsifiers coat the exterior of the fat particles protecting the integrity of the air cell (Wooten et al., 1967). In addition, emulsifiers increase the amount of air that can be whipped into the batter by decreasing the surface tension of the aqueous phase, thereby increasing the whipping rate of batters (Rusch, 1981). Carbon dioxide gas, a leavener, can not spontaneously create bubbles in cake batters. Rather, it diffuses into and fills the existing air cells, expanding the cake batter. By adding emulsifiers, more uniform sized air cells are generated during mixing and these act as nucleation sites for the dissolved gas. The result is a cake with improved grain, more even cell structure, and increased volume (Handleman, 1961). The emulsifiers adsorb on the surfaces of emulsion droplets to form a protective coating that prevents the droplets from aggregating, and thus stabilize the foam (Sakiyan et al, 2004).

Crystal modification:

The emulsifiers used in food systems are fat derivatives, because their lipophilic parts are fatty acids. Fats (fatty acid triglycerides) are polymorphic. Emulsifiers exhibit varying degrees of similarity to triglycerides and, thus, varying degrees of polymorphism. The crystal form and crystal size of emulsifiers play important roles in their functionality and improving effect (Wootton et al., 1967; Howard, 1972; Schuster and Adams, 1984). For many applications, the alpha or alpha-tending forms of emulsifiers exhibit particularly advantageous effects, e.g., increased emulsifying activity, easier dispersibility, and improved aerating properties, all because of their crystal modification capabilities. The fat crystal transition (from crystal form α transfer to β' and finally transfer to β) could be retarded by the incorporation of emulsifiers to

stabilize the crystal form in the more active alpha or beta prime form, resulting in improved functionality (O'Brien, 1998). That result makes it possible for liquid shortenings to be used in cake-making. Richardson et al. (2002) noted that in the cake batter, all the α-gel (α-tending emulsifiers melted with water and liquid oil) emulsifiers decreased batter density, thus increasing the incorporation of air and cake volume. The ß-crystalline emulsifier did not have any effect on the density.

2.3.3 Emulsifier combinations

Each individual emulsifier has specific properties, but in food systems, emulsifiers may be required to perform several functions at the same time. Therefore, combinations of emulsifiers are very important for development of food formulations, and in fact are commonly used. It is well known that combinations of emulsifiers have synergistic effects, improving on their individual properties (Schuster and Adams 1984; Del Vecchio 1975). Different mechanisms have been proposed to explain the synergistic effects of emulsifier combinations. One is that the fat surface, if it is an oil/water emulsion, is covered better by a combination of various emulsifiers with different structures, forming a better protective layer with fewer gaps (Gonzalez-Juarez 1994). Lee and Hoseney (1982a) studied the single-stage cake mix and found that even though a lot of emulsifiers can form α-gels, interfacial viscoelastic properties are often improved by blending two emulsifiers in specific proportions.

Although many types of emulsifiers can function effectively in cakes, several are predominant because of their cost and their excellent performance. In cakes, the most commonly used emulsifier is PGMS at 10-15% of shortening weight, and incorporated into the shortening (Rusch, 1981). The behavior of cake crumb softening involves retention of moisture, efficiency of shortening action, and starch complexing. The starch-complexing phenomenon in cakes is the same as it is in breads (Rusch, 1981). Distilled monoglyceride (GMS) is the primary antistaling additive used today for baking foods (Stauffer, 1999). It is very common to compound monoglycerides with other α-tending surfactants such as PGMS for use in cake making (Birnhaum, 1978).

Lecithin has been used in bread and other baked goods for a long time. It can delay staling and reduce the amount of shortening required. A synergistic effect on baked goods volume and crumb grain occurs between lecithin and monoglycerides (Orthoefer, 2008). A cake

emulsifier system is usually a blend of two or three emulsifiers such as GMS, PGMS, and Lecithin (Orthoefer, 2008).

The patent WO 03/079802 (Rajiv et al, 2003) discussed a shortening-based emulsifying formulation for the preparation of cakes. The emulsifier combination of distilled glycerol monostearate (GMS), sodium stearoyl-2-lactylate (SSL), sorbitan monostearate (SMS), poly glycerol monostearate (PGMS), and polysorbate (PS-60) was claimed to produce lower specific gravity, higher cake volume, and more uniform cake cells than using individual emulsifiers.

Duxbury (1992b) suggested that combinations of emulsifiers including lecithin, mono- and diglycerides, polyglycerol esters, polyoxyethylene sorbitan esters, propylene glycol monoesters, and glycerolacto palmitate might work synergistically to yield a cake with improved eating quality. In his research, four cake mixes were prepared and baked with different shortening/emulsifier systems. One contained a regular commercial shortening, one contained 73% soybean oil-based powdered vegetable shortening, one contained 73% shortening with a blend of mono-and diglycerides, and one contained liquid oil with propylene glycol esters and mono- and diglycerides. Results showed that the last combination had the closest, most even texture, and the greatest volume (Duxbury, 1992b). The results also indicated that propylene glycol esters and mono-and diglycerides work synergistically to produce better cakes than does adding them separately. Liquid oil with propylene glycol esters and mono- and diglycerides worked better than did plastic shortening in cakes.

In Lee and Hoseney's (1982b) research, 4.0% propylene glycol monostearate (PGMS), 3.0% mono- and diglycerides, and 0.81% lecithin were used in the formula. More results showed that the combinations were more effective than the single components.

Gonzalez-Juarez (1994) studied several different emulsifiers used in the cakes. He had tested PGMS at 1.0%, 2.0% and 3.0% (flour weight basis) levels and GMS at 1.0%, 1.5% and 2.0% levels. For PGMS, it was found that between 1.0% to1.5% (flour weight basis) was the optimum when combined with PS-60. GMS at 1.0% produced cakes with highest volume, but when the GMS level increased, cake volume decreased.

CHAPTER 3 - MATERIALS AND METHODS

3.1 Materials

Flour: Purasnow® Bakers Hi-ratio cake flour from General Mills (Minneapolis, MN). (Protein content 9.12%, ash 0.46%, moisture 13.81% and pH 4.6)

Liquid Shortening: NUTEX Z® high ratio liquid cake shortening from ACH Food companies (Memphis, TN). This product was made from soybean oil with Mono- and Diglycerides, Propylene Glycol Mono- and Diesters of Fatty acids, and Glyceryl-Lacto Esters of Fatty acids.

Plastic Cake shortening: HYMO® emulsified vegetable shortening from ACH Food companies (Memphis, TN). This product was made from palm oil, with Mono- and Diglycerides.

Liquid oil: Soybean oil from Cargill (Minneapolis, MS). Citric acid was added to protect freshness.

Baking Powder: AB Mauri Double-acting baking powder from Fleischmann's Yeast Company. (Ingredients: sodium acid pyrophosphate, sodium bicarbonate, corn starch, monocalcium phosphate) (Chesterfield, MO).

Dry Whole Eggs: dried whole eggs from Michael Foods (Minnetonka, MN). It was a spray dried, pasteurized whole egg product.

Salt: Purex® salt from the Hutchinson, KS plant.

Sorbic Acid: from Fleischmann's Yeast company (Chesterfield, MO).

Lecithin: Yelkin® soy lecithin from ADM (Decatur, IL).

Distilled glycerol Monostearate (GMS): DIMODAN® HP K-A from Danisco (Kansas City, KS). Total monoglyceride content was over 90% and melting point of this monoglyceride was about 64℃.

Propylene glycol monostearate (PGMS): Stepan ® PGMS from Stepan company (Northfield, IL). It contained 45-60% propylene glycol monosterate and 40-55% propylene glycol disterate. Propylene glycol content was less than 1.5%.

3.2 Methods

3.2.1 High Ratio Yellow Cake Formulation

Modification of standard AACC formula

The basic cake formula was based on AACC method 10-90 (AACC, 1999). In order to meet the requirements for our study, i.e., produce acceptable cakes, we found it necessary to modify the AACC method slightly. This included a series of preliminary experiments to adjust the ingredient ratios and procedures.

Table 1. AACC standard formula

Ingredients	Flour Weight Basis (%)
Flour	100
Sugar	140
Shortening	50
NFDM	12
Dried Egg Whites	9
Salt	3
Baking Powder	6
Water	125, 135 or 145

Sugar content

The standard formula is used for evaluating the cake-baking potential of a flour. Its sugar content is higher than in a common commercial formula. Consequently, it was necessary to try different sugar contents for our flour in order to get high quality cakes. Plastic shortening was used for these tests.

Table 2. Sugar content test

Sugar[1]	140%	130%	120%
Cake volume[2]	110	117	123
Cake texture	tender, surface sticky	tender	Slightly dry

[1]Flour weight basis; [2] Cake volumes were measured by plastic template according to AACC10-91

Comparing cake textures, 130% was chosen as the sugar content for the subsequent tests.

Egg

The AACC standard formula is for a high-ratio white layer cake. However, the high-ratio yellow layer cake formula is more common in the market place and we wanted our study to more closely follow commercial baking practice. Consequently, dried whole eggs were used instead of dried egg whites in the formula. The ratio of whole eggs was increased to 15% (flour weight) because soluble protein (egg white) is known to be the key aerating ingredient (Howard, 1972) and this change maintains the same amount of egg whites in the formula.

Fat content

Fat is an important ingredient in this study. The intent was tried to keep fat contents as high as possible in the formula in order to see functional differences in the fats. Plastic shortening was used in this test. Table 3 shows the cake volume and texture that resulted with different fat contents. It was found that reducing fat content by 10% caused the cakes' surfaces to no longer be sticky and to be easy to handle.

Table 3. Fat content test

Fat[1]	50%	40%
Cake volume[2]	116	121
Cake texture	tender, sticky, and fragile	tender

[1]Flour weight basis; [2] Cake volume was measured by plastic template according to AACC10-91

Mixing procedures

The mixing procedure suggested in AACC method 10-90 is: scale all dry ingredients and sift well; put all the dry ingredients and shortening into the mixing bowl, add 60 % of the water and mix at low speed for 30 seconds and scrape down; mix at medium speed for 4 minutes and scrape down; add 20% water and mix at low speed for 30 seconds, scrape down; mix at medium speed for two minutes, scrape down; add remaining water, mix at low speed for 30 seconds, scrape down; mix at medium speed for two minutes.

Using this mixing sequence resulted in large air cells in the cake batter and cakes with high volume but tunneling in the crumb. Tests were carried out which reduced mixing time and consequently the amount of air incorporated into the batter. Changing the last mixing step from medium speed to low speed positively affected batter viscosity and dispersed the big air cells in the batter, resulting in cakes with improved crumb grain quality.

A modified mixing procedure, using a paddle instead of a whip was adopted as follows: scale all dry ingredients and sift well; put all the dry ingredients and shortening or oil into the mixing bowl of a Hobart N-50 mixer, (a) mix at low speed for 2 min; add 60 % of the water; (b) mix at low speed for 30 seconds and scrape down; (c) mix at medium speed for 4 minutes and scrape down; (d) add remaining water and mix at low speed for 30 seconds, scrape down; (e) mix at medium speed for two minutes, scrape down; (f) mix at low speed for one minute.

Water absorption

A series of water absorption tests were run to select the optimum for the final research tests. In this study, liquid oil, liquid shortening, and plastic shortening were tested in the high-ratio yellow cake formulas developed previously. Liquid shortening and plastic shortening contain emulsifiers and they have higher solid fat contents at room temperature than does liquid oil. Because liquid and plastic shortening held more water during mixing, it was necessary to test water absorption with different fats.

Liquid shortening:

Table 4. Liquid shortening with different water content

Water[1]	125%	135%	145%
Cake volume[2]	131	133	127
Cake texture	Uniform, tender	Uniform, tender	Gummy

[1]Flour weight basis; [2] Cake volume was measured by plastic template according to AACC 10-91

Plastic shortening:

Table 5. Plastic shortening with different water content

Water[1]	125%	135%	145%
Cake volume[2]	117	123	123
Cake texture	Uniform, tender	Uniform, tender	Gummy

[1]Flour weight basis; [2] Cake volume was measured by plastic template according to AACC10-91

Liquid oil:

Table 6. Liquid oil with different water content

Water[1]	125%	130%	135%
Cake volume[2]	124	116	116
Cake texture	Coarse	Coarse, big holes	Coarse, big holes

[1]Flour weight basis; [2] Cake volume was measured by plastic template according to AACC10-91

Based on all these tests, the final water absorptions were chosen as: liquid oil-125%, liquid shortening-135%, and plastic shortening-135%. For the emulsifier combination tests, water absorption was set at 135% to allow comparison with liquid shortening.

The final cake formula used in this study was as follow:

Table 7. Cake formula

Ingredients	**Flour Weight Basis (%)**
Flour	100
Sugar	130
Shortening	40
NFDM	12
Dried Whole Eggs	15
Salt	3
Baking Powder	6
Water	135 or 125

Final details

Because the cakes needed to be stored for a long time to test firmness changes in this study, it was necessary to add sorbic acid (0.15% batter wt.) to the batter as a preservative to retard mold growth. Batter temperature was controlled at 72-73 ℉ (22.2-22.8 ℃) by controlling the water and room temperatures. Eight inch (inside diameters 20.3cm, depth 3.8cm) layer cake pans with cake bottom liner were used in the baking test. Each pan contained 400g of batter. The reel over was used in this study. The oven temperature used was 350 ℉ (177 ℃) and baking time was 25 min.

After baking, cakes were cooled for 30 minutes at room temperature, depanned, and dusted with cake flour. After cooling for 1 hour, cakes were packaged in double Ziploc plastic bags and stored at room temperature (22-25℃).

3.2.2 Cake analysis

Batter Specific Gravity

Cake batter specific gravity was calculated by dividing the weight of the batter by the weight of an equal volume of water.

Cake measurement

Cake volume, symmetry, and contour were determined by AACC method 10-91 (AACC, 1999). Crumb (internal texture) was graded according to AACC method 10-90. Cells, grain, texture, crumb color, and flavor were scored on the next day after baking.

Moisture content

The cake moisture content was determined by the single-stage air-oven method (AACC 44-15A). The outer surfaces of the cake were removed and the crumb was used for analysis.

Water activity

Water activity was measured with a DECAGON (Decagon devices Inc., Pullman, WA) CX-1 water activity meter.

Viscosity

The cake batter viscosity was measured by using a Bostwick consistometer (Christison Particle Technologies Limited, Gateshead, UK). The batter was poured into the sample reservoir sufficient to reach the top of the product gate, and then released by pressing down on the lever arm. The batter was allowed to run along the trough for 30 seconds before measuring the distance traveled in cm. The results were reported as distance per 30 seconds batter flow. Thus, higher values indicate lower viscosities.

Texture analysis

Cake crumb firmness was measured using a Voland-Stevens texture analyzer (Voland Crop., Hawthorne, NY currently sold by Brookfield Engineering Laboratories Inc. Middleboro, MA). The cake was sliced in half across its diameter, and then a 25 mm wide longitudinal slice was taken from one of the halves. The measurements were taken at three different slice points (left, center, and right) with a one inch (25.4 mm) diameter cylinder probe. Operating conditions were at a crosshead speed of 2 mm/sec and 10 mm penetration distance (40% compression) based on AACC method 74-09.

C-cell analysis

A cake was sliced in half across the diameter, and then a 25 mm wide longitudinal slice was taken from one of the halves. The slices were scanned in a C-cell instrument (Calibre Control Internal Ltd., WARRINGTON, UK) using the standard method for collecting images and the standard C-cell software for data analysis. Average crumb brightness, the number of cells, and cell diameter were calculated and recorded.

3.3 Experimental design

Emulsifier combination tests

Based on previous literature and preliminary tests, three emulsifiers (PGMS, GMS, and Lecithin) were selected for testing as combinations. In order to obtain the maximum information with a minimum number of experimental points, a three-way Response Surface Methodology (RSM) experimental design (Walker and Parkhurst, 1984) was used. Thirteen emulsifier combination tests (table 8) (including two replications) were run which covered the 27 possible combinations presented by utilizing the low, medium, and high levels of each emulsifier (table 9). The control cake used liquid oil without any emulsifiers and a water content of 125 % (flour weight basis). The emulsifiers were scaled and heated with liquid oil and stirred uniformly until all the emulsifiers were melted. These emulsifiers and liquid oil were prepared the day before baking and stored at room temperature.

The results were analyzed and plotted by software, RSM plus (AEW consulting, version date: 1992) using the model, STD 3_ VAR.

Table 8. Response Surface Methodology (RSM) design

	X	Y	Z
1	-1	-1	-1
2	0	-1	1
3	1	-1	0
4	-1	0	1
5	0	0	-1
6	0	0	0
7	0	0	1
8	1	0	-1
9	-1	1	0
10	0	1	-1
11	1	1	1
12	0	0	0
13	0	0	0

Table 9. Variables and levels

		L(-1)	M(0)	H(1)
X	PGMS	1	2	3
Y	GMS	0.5	1	1.5
Z	Lecithin	0	0.5	1

The level is based on the flour weight.

Cake storage tests

Four groups of cakes were baked. The first group was the control that used plastic shortening. The second group used liquid oil only. The third group used liquid shortening and the fourth group used liquid oil plus combinations of emulsifiers. Eight cakes were baked for each group. Batter specific gravity, batter temperature, and viscosity were measured before baking. Cakes were packaged in double Ziploc bags after baking and stored at room temperature (22-25℃). The cakes were scored including volume, symmetry, and contour on the second day.

Moisture analysis, water activity, c-cell, and texture analysis were analyzed at the same time. Texture analysis (cake firmness) was run after 1 day, 5 days, 12 days, and 21 days storage. Triplicate batter tests were done in this research. One-way ANOVA was used to analyze the data.

CHAPTER 4 - RESULTS AND DISCUSSION

4.1 EMULSIFIER COMBINATION

The emulsifier combination test was to determine which of the emulsifier combinations produced the best final cakes. The results for the 11 different combination tests are shown in Table 10. Based on comparisons with the plastic shortening, the criteria for the best cake combination were: cake score 80-100, cake volume >120, one day firmness 150-200. Contour maps for two variable combinations were run, keeping the third as a stepping variable, and this was repeated for each variable in turn.

First, GMS was kept as a stepping variable, and three contour maps with PGMS and Lecithin were plotted (Figure 4-1, 4-2, 4-3). Figure 4-4 presents an example of how to determine the optimum point from the contour maps. In the GMS 1.0 % map, the area between the firmness curve means cake first day firmness was 150-200; the area above the score curve means cake score was 80-100; the area under the volume curve means cake volume was over 120. The intersection of these areas was the optimum area for obtaining acceptable cakes. The center of this area was picked as the optimum point and that optimum combination was: PGMS 1.8%/GMS 1.0%/Lecithin 0.78% (Figure 4-4). In the GMS 1.5% map, another optimum combination was found as; PGMS 2.85%/GMS 1.5%/Lecithin 0.85% (Appendix A).

Second, PGMS was kept as a stepping variable, and three contour maps with GMS and Lecithin were plotted, for each of the response parameters described above. The optimum combinations shown were: PGMS 2%/GMS 1.05%/Lecithin 0.75% and PGMS 3.0%/GMS 1.4%/Lecithin 0.375% (Appendix A).

Third, Lecithin was kept as the stepping variable, and three contour maps with PGMS and GMS were plotted, for each of the response parameters described above. The optimum combinations shown were: PGMS 2.3%/GMS 1.2%/Lecithin 0.5% and PGMS1.5%/GMS 1.075%/Lecithin 1.0% (Appendix A).

The different stepping variables identified a very similar combination (PGMS 2%/GMS 1.05%/Lecithin 0.75%, PGMS 1.8%/GMS 1.0%/Lecithin 0.78%, and PGMS1.5%/GMS 1.075%/Lecithin 1.0%). So the best emulsifier combination was selected as: PGMS1.8%/ GMS 1.0%/ Lecithin 0.8%.

Table 10. Effect of different emulsifier combinations on cake quality

	Specific Gravity (g/ml)	Batter temp. (°F)	cake volume	cake score	moisture content (%)	water activity	Firmness		
							1st day	5th day	12thday
Control	0.988± 0. 009	70.9 ± 2.8	120.7 ± 7.2	67 ± 13.8	28.42 ± 1.25	0.858 ± 0.009	323 ± 28.5	403.7± 28.9	448.3 ± 18.8
1	1.025 ± 0.048	71.3 ± 0.9	112.3 ± 1.5	62.7 ± 12.5	29.67 ± 0.86	0.876 ± 0.009	361.7 ± 89.6	418 ± 72.5	442.3 ± 64.8
2	0.893 ± 0.01	73.2 ± 0.3	122.3 ± 2.5	88 ± 3	29.79 ± 1.13	0.873 ± 0.012	230 ± 7.5	272 ± 26.9	312 ± 38.7
3	0.789 ± 0.012	72.7 ± 0.6	117.3 ± 3.5	83.3 ± 4.6	29.94 ± 0.86	0.878 ± 0.012	211.3 ± 32.7	230.7 ± 5.5	266 ± 43.5
4	0.91 ± 0.085	71.2 ± 1.5	121.7 ± 4.0	81 ± 11.1	29.54 ± 1.15	0.879 ± 0.01	228.3 ± 39.2	262.7 ± 41.5	299.7 ± 54.1
5	0.826 ± 0.09	71.3 ± 1.1	120.0 ± 6.2	86.7 ± 6.8	31.35 ± 0.36	0.881 ± 0.011	185 ± 39.5	218 ± 31.6	238.3 ± 52.5
6	0.787± 0.012	71.0 ± 0.6	118.7 ± 7.4	82.7 ± 5.5	29.98 ± 0.82	0.878 ± 0.008	212.3 ± 32.7	237.7 ± 15.6	273.3 ± 69.4
7	0.806 ± 0.023	71.8 ± 0.7	125.0 ± 1.4	91.5 ± 0.7	30.21 ± 0.71	0.877 ± 0.008	174.7 ± 11.5	215.5 ± 33.2	235.5 ± 0.7
8	0.803 ± 0.022	72.1 ± 1.0	117.7 ± 4.7	77.7 ± 11.6	28.92 ± 1.56	0.882 ± 0.006	198.3 ± 21.6	242.7 ± 11.9	269.3 ± 27.5
9	1.037 ± 0.046	71.8 ± 0.8	114.3 ± 3.1	71.7 ± 8.1	30.24 ± 0.64	0.877 ± 0.01	277.3 ± 35.0	305 ± 50.7	359.7 ± 48.3
10	0.99 ± 0.026	72.9 ± 0.7	117.3 ± 7.1	73 ± 1	29.58 ± 0.96	0.878 ± 0.012	269.3 ± 46.9	305.7 ± 15.4	332.7 ± 53.2
11	0.701 ± 0.021	72.7 ± 1.1	129.7 ± 2.5	90 ± 5.3	30.35 ± 1.15	0.879 ± 0.013	153.3 ± 22.4	172.0 ± 16.5	198.7 ± 54.6
12	0.773 ± 0.006	72	121.3 ± 4.7	84.3 ± 4.0	30.31 ± 0.71	0.881 ± 0.008	193.3 ± 33.3	229.3 ± 11.6	252.1 ± 43.7
13	0.784 ± 0.023	72.3 ± 0.6	120.3 ± 3.5	83 ± 1	30.14 ± 0.82	0.875 ± 0.005	201.3 ± 13.7	232.7 ± 28.0	259.7 ± 14.0

Control: liquid oil without any emulsifier.

Emulsifier combination 1: PGMS 1.0%/ GMS 0.5%/ Lecithin 0

2: PGMS 2.0%/ GMS 0.5% / Lecithin 1.0%

3: PGMS 3.0%/ GMS 0.5% / Lecithin 0.5%

4: PGMS 1.0%/ GMS 1.0% / Lecithin 1.0%

5: PGMS 2.0%/ GMS 1.0% / Lecithin 0

6: PGMS 2.0%/ GMS 1.0% / Lecithin 0.5%

7: PGMS 2.0%/ GMS 1.0% / Lecithin 1.0%

8: PGMS 3.0%/ GMS 1.0% / Lecithin 0%

9: PGMS 1.0%/ GMS 1.5% / Lecithin 0.5%

10: PGMS 2.0%/ GMS 1.5% / Lecithin 0

11: PGMS 3.0%/ GMS 1.5% / Lecithin 1.0%

12: PGMS 2.0%/ GMS 1.0% / Lecithin 0.5%

13: PGMS 2.0%/ GMS 1.0% / Lecithin 0.5%

```
                          Response in FIRM-1
                      (Stepping Variable: GMS = 1)

     +3.000 |           BBBBBBBBBBB              AAAAAAAAAAAAAAAAAAAAAAAAAA
     +2.950 |            BBBBBBBBBBBB             AAAAAAAAAAAAAAAAAAAAAAAAA
     +2.900 |             BBBBBBBBBBBB            AAAAAAAAAAAAAAAAAAAAAAAAA
     +2.850 |              BBBBBBBBBBBB           AAAAAAAAAAAAAAAAAAAAAAAA
     +2.800 |               BBBBBBBBBBBB          AAAAAAAAAAAAAAAAAAAAAA
     +2.750 |CC              BBBBBBBBBBBBB        AAAAAAAAAAAAAAAAAAAA
     +2.700 |CCC              BBBBBBBBBBBBB       AAAAAAAAAAAAAAAAAA
     +2.650 |CCCCC             BBBBBBBBBBBBB      AAAAAAAAAAAAAAAA
     +2.600 |CCCCCCC            BBBBBBBBBBBBB     AAAAAAAAAA
     +2.550 |CCCCCCCC            BBBBBBBBBBBBBB      AAAAAAAA
     +2.500 |CCCCCCCCCC           BBBBBBBBBBBBBB       AAAAA
     +2.450 |CCCCCCCCCCCC          BBBBBBBBBBBBBB        AAA
     +2.400 |CCCCCCCCCCCCCC         BBBBBBBBBBBBBB         A
     +2.350 |CCCCCCCCCCCCCCCC        BBBBBBBBBBBBBB
     +2.300 |CCCCCCCCCCCCCCCCCC       BBBBBBBBBBBBBB
     +2.250 |CCCCCCCCCCCCCCCCCCCC      BBBBBBBBBBBBBB
     +2.200 |CCCCCCCCCCCCCCCCCCCCCC     BBBBBBBBBBBBBB
     +2.150 |CCCCCCCCCCCCCCCCCCCCCCCC    BBBBBBBBBBBBBBB
     +2.100 |CCCCCCCCCCCCCCCCCCCCCCCCCC   BBBBBBBBBBBB
     +2.050 |CCCCCCCCCCCCCCCCCCCCCCCCCCCC  BBBBBBBBBB
P    +2.000 |CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC  BBBBBBB
G    +1.950 |CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC  BBBB
M    +1.900 |CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC  B
S    +1.850 |CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
     +1.800 |CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
     +1.750 |CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
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     +1.350 |CCCCCCCCCCCCCCCCCCC              CCCCCCCCCCCCCCCCCCCC
     +1.300 |CCCCCCCCCCCCCCCCCC                CCCCCCCCCCC
     +1.250 |CCCCCCCCCCCCCCCCCC                  CCCCC
     +1.200 |CCCCCCCCCCCCCCCCCC
     +1.150 |CCCCCCCCCCCCCCCCCC
     +1.100 |CCCCCCCCCCCCCCCCCC
     +1.050 |CCCCCCCCCCCCCCCCCC
     +1.000 |CCCCCCCCCCCCCCCCCC
            \+---------+---------+---------+---------+---------+---------+
            +0.000    +0.167    +0.333    +0.500    +0.667    +0.833    +1.000

                               LECITHIN

   Legend:   +100.00=A    +150.00=B    +200.00=C    +250.00=D    +300.00=E
             +350.00=F    +400.00=G    +450.00=H    +500.00=I    +550.00=J
             +600.00=K
```

Figure 4-1. RSM plots for first day firmness. GMS= 1.0

```
                          Response in SCORE
                        (Stepping Variable: GMS = 1)

      +3.000 |      GGGGG       HHHHHH       IIIIII      JJJJJJJJ          KKKK
      +2.950 |F       GGGGG       HHHHHH       IIIIIII      JJJJJJJJ          K
      +2.900 |F       GGGGG       HHHHHH       IIIIIII      JJJJJJJJ
      +2.850 |FF      GGGGG       HHHHHH       IIIIIIII     JJJJJJJJJ
      +2.800 |FF       GGGGG       HHHHHH       IIIIIIII     JJJJJJJJJ
      +2.750 |FFF      GGGGGG       HHHHHH       IIIIIIIII     JJJJJJJJJJ
      +2.700 |FFF       GGGGGG       HHHHHH       IIIIIIIII     JJJJJJJJJ
      +2.650 |FFFF      GGGGG       HHHHHHH       IIIIIIIIII      JJJJJ
      +2.600 |FFFFF     GGGGGG       HHHHHHH       IIIIIIIIII       JJJ
      +2.550 |FFFFF      GGGGGG       HHHHHHH       IIIIIIIIIII
      +2.500 |FFFFFF      GGGGGG       HHHHHHHH       IIIIIIIIII
      +2.450 | FFFFF      GGGGGGG       HHHHHHHH       IIIIIIIIIIII
      +2.400 | FFFFF      GGGGGGG       HHHHHHHH       IIIIIIIIIIIII
      +2.350 | FFFFFF      GGGGGGG       HHHHHHHHH       IIIIIIIIIIIIII
      +2.300 |  FFFFFF      GGGGGGG       HHHHHHHHH       IIIIIIIIIIII
      +2.250 |  FFFFFF      GGGGGGG       HHHHHHHHH       IIIIIIII
      +2.200 |   FFFFFF      GGGGGGG       HHHHHHHHHH          IIIII
      +2.150 |   FFFFFF      GGGGGGGG       HHHHHHHHHHH          II
      +2.100 |   FFFFFFF      GGGGGGGG       HHHHHHHHHHH
      +2.050 |    FFFFFF       GGGGGGGG       HHHHHHHHHHHH
 P    +2.000 |    FFFFFFF       GGGGGGGG       HHHHHHHHHHHHHH
 G    +1.950 |    FFFFFFF       GGGGGGGGG       HHHHHHHHHHHHHHHH
 M    +1.900 |    FFFFFFFF       GGGGGGGGG       HHHHHHHHHHHHHHHHHHH
 S    +1.850 |     FFFFFFF       GGGGGGGGGG       HHHHHHHHHHHHHHHHHHHH
      +1.800 |     FFFFFFFF       GGGGGGGGGGG       HHHHHHHHHHHHHHHHHH
      +1.750 |     FFFFFFFF       GGGGGGGGGGG       HHHHHHHHHHHHHH
      +1.700 |     FFFFFFFF       GGGGGGGGGGG       HHHHHHHHHHH
      +1.650 |     FFFFFFFFF       GGGGGGGGGGGG       HHHHHH
      +1.600 |      FFFFFFFF       GGGGGGGGGGGGG              H
      +1.550 |      FFFFFFFF       GGGGGGGGGGGGGGG
      +1.500 |      FFFFFFFFF       GGGGGGGGGGGGGGG
      +1.450 |      FFFFFFFFF       GGGGGGGGGGGGGGGGG
      +1.400 |      FFFFFFFFF       GGGGGGGGGGGGGGGGGGG
      +1.350 |      FFFFFFFFFF       GGGGGGGGGGGGGGGGGGGGG
      +1.300 |      FFFFFFFFFF       GGGGGGGGGGGGGGGGGGGGGGGGG
      +1.250 |      FFFFFFFFFFF       GGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGG
      +1.200 |      FFFFFFFFFFF       GGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGG
      +1.150 |      FFFFFFFFFFF        GGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGG
      +1.100 |      FFFFFFFFFFF        GGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGG
      +1.050 |     FFFFFFFFFFFF        GGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGG
      +1.000 |     FFFFFFFFFFFF        GGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGG
             \+---------+---------+---------+---------+---------+---------+
             +0.000     +0.167     +0.333     +0.500     +0.667     +0.833     +1.000

                                    LECITHIN

    Legend:     +50.00=A     +55.00=B     +60.00=C     +65.00=D     +70.00=E
                +75.00=F     +80.00=G     +85.00=H     +90.00=I     +95.00=J
                +100.00=K
```

Figure 4-2. RSM plots for cake score. GMS= 1.0

```
                          Response in VOLUME
                       (Stepping Variable: GMS = 1)


        +3.000 |    EEEEEEEE        DDDDDDD       CCCCCCC       BBBBB       A
        +2.950 |      EEEEEEEEE       DDDDDDDD      CCCCCCC      BBBBBBB
        +2.900 |        EEEEEEEEE       DDDDDDDDD      CCCCCCC       BBB
        +2.850 |          EEEEEEEEEE      DDDDDDDDD      CCCCCCCC
        +2.800 |F          EEEEEEEEEEE      DDDDDDDDDD      CCCCCCCC
        +2.750 |FF          EEEEEEEEEEEE      DDDDDDDDDD       CCC
        +2.700 |FFFF         EEEEEEEEEEEEE      DDDDDDDDDDD
        +2.650 |FFFFF         EEEEEEEEEEEEEEE      DDDDDDDDDDD
        +2.600 |FFFFFF         EEEEEEEEEEEEEEEE       DDDDD
        +2.550 |FFFFFFF         EEEEEEEEEEEEEEEEEEE
        +2.500 |FFFFFFF          EEEEEEEEEEEEEEEEEEEEEE
        +2.450 |FFFFFF            EEEEEEEEEEEEEEEEEEEE
        +2.400 |                                        EEEEEE
        +2.350 |
        +2.300 |
        +2.250 |              FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
        +2.200 |              FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
        +2.150 |EE            FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
        +2.100 |EEEEEEE        FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
        +2.050 |EEEEEEEEEE       FFFFFFFFFFFFFFFFFFFFFFFF
  P     +2.000 |  EEEEEEEEEEEEE       FFFFFFFFFFFFFFFFFF
  G     +1.950 |      EEEEEEEEEEE       FFFFFFFFFFFFFFF
  M     +1.900 |        EEEEEEEEEE       FFFFFFFFFFFFF
  S     +1.850 |DDD          EEEEEEEEEE       FFFFFFFFFF           GG
        +1.800 |DDDDDDD        EEEEEEEEE       FFFFFFFFFF          GGG
        +1.750 |   DDDDDDDD        EEEEEEEEE       FFFFFFFFF        GGGG
        +1.700 |       DDDDDDD        EEEEEEE        FFFFFFFFF       GGGG
        +1.650 |CCC         DDDDDDD       EEEEEEEE       FFFFFFFF     GGGG
        +1.600 |  CCCCCC        DDDDDDD       EEEEEE        FFFFFFF    GGGG
        +1.550 |    CCCCC         DDDDDDD       EEEEEE        FFFFFFF   GGG
        +1.500 |BB       CCCCC        DDDDD       EEEEEE        FFFFF    GGG
        +1.450 |BBBBBB       CCCCC       DDDDD        EEEE        FFFFFF   GG
        +1.400 |    BBBBB        CCCC       DDDD        EEEE        FFFFFF   G
        +1.350 |AAA      BBBBB       CCCC       DDDDD       EEEE        FFFFFF
        +1.300 |AAAAAA       BBBB        CCCC       DDDD        EEEE       FFFFF
        +1.250 |AAAAAAAA       BBBB        CCCCC       DDDD        EEEE      FFFFF
        +1.200 |AAAAAAAAAAAA       BBBB        CCCC        DDDD        EEE      FFFFF
        +1.150 |AAAAAAAAAAAAAA        BBBB        CCCCC       DDD        EEE      FFFF
        +1.100 |AAAAAAAAAAAAAAAAA        BBBB        CCCC       DDD        EEE      FFFF
        +1.050 |AAAAAAAAAAAAAAAAAAAA       BBBB        CCCC       DDDD       EEEEE     FF
        +1.000 |AAAAAAAAAAAAAAAAAAAAAAAA        BBBB        CCCC       DDDD        EEEE     F
               \+---------+---------+---------+---------+---------+---------+
              +0.000     +0.167     +0.333     +0.500     +0.667     +0.833     +1.000

                                      LECITHIN


    Legend:    +100.00=A    +104.00=B    +108.00=C    +112.00=D    +116.00=E
               +120.00=F    +124.00=G    +128.00=H    +132.00=I    +136.00=J
               +140.00=K
```

Figure 4-3. RSM plots for cake volume. GMS= 1.0

29

Figure 4-4. RSM plots summary. GMS= 1.0

30

4.1.1 Batters Properties

Specific gravity

Figure 4-5 compares the specific gravity of cake batters with different emulsifier combinations. Batter specific gravity is a measurement of total air-holding capacity but gives little information about bubble size or dispersion. Combinations 1 and 9 produce higher batter specific gravities than does the control. This is because the control cake uses 125 % water and the others use 135 % water. When emulsifier content is low and the batter has too much liquid, the batter cannot hold as much air after mixing. Combinations 1, 4, 9 all have 1.0 % PGMS (the low value) and high specific gravity, which indicated that PGMS is important to aerate and increase the incorporation of air of the cake batter. PGMS is an α-tending emulsifier and creates a film on the bubble surfaces. The stronger the film, the more air the bubble incorporates (Richardson et al, 2002). The Combination 10 has 2.0 % PGMS but its specific gravity is still very high. That might be because there is no lecithin in that combination and lecithin has a synergistic effect with PGMS in improving aeration (Orthoefer, 2008). Combination 11 which had 3.0% PGMS and 1.0% Lecithin in the formula produced the lowest batter specific gravity. This suggests that PGMS increases the air incorporation and that lecithin works synergistically with PGMS to do this. Further, combinations 3 and 6 have the same amount of Lecithin and the higher the PGMS is, the lower the specific gravity.

From the above results, it is possible to conclude first, that as the amount of PGMS in the blend increases, the specific gravity decreases, and secondly, Lecithin helps facilitate or potentates this effect. This study did not test higher emulsifier contents (PGMS > 3.0% or Lecithin > 1.0%), because at those levels, the cake crumb would be too tender and it would collapse after baking.

Figure 4-5. Cake batter specific gravity for different emulsifier combinations
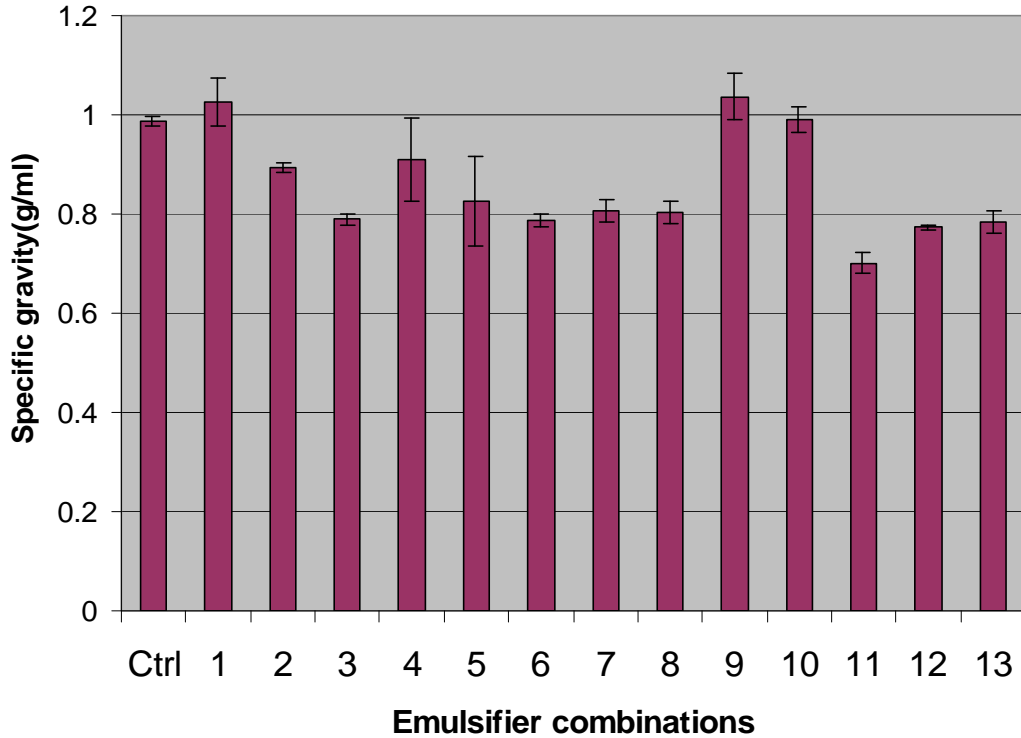
Control: liquid oil without any emulsifier

Emulsifier combination 1: PGMS 1.0%/ GMS 0.5%/ Lecithin 0

2: PGMS 2.0%/ GMS 0.5% / Lecithin 1.0%

3: PGMS 3.0%/ GMS 0.5% / Lecithin 0.5%

4: PGMS 1.0%/ GMS 1.0% / Lecithin 1.0%

5: PGMS 2.0%/ GMS 1.0% / Lecithin 0

6: PGMS 2.0%/ GMS 1.0% / Lecithin 0.5%

7: PGMS 2.0%/ GMS 1.0% / Lecithin 1.0%

8: PGMS 3.0%/ GMS 1.0% / Lecithin 0%

9: PGMS 1.0%/ GMS 1.5% / Lecithin 0.5%

10: PGMS 2.0%/ GMS 1.5% / Lecithin 0

11: PGMS 3.0%/ GMS 1.5% / Lecithin 1.0%

12: PGMS 2.0%/ GMS 1.0% / Lecithin 0.5%

13: PGMS 2.0%/ GMS 1.0% / Lecithin 0.5%

4.1.2 Baking tests

4.1.2.1 Cake Volume

Cake volume is a measure of cake size and reflects the amount of air entrapped during mixing and CO_2 expansion throughout the crumb. These gases may be dispersed in small cells throughout a fine crumb or in larger cells throughout a coarser crumb. Although high volumes do not always indicate a desirable cake, low volumes generally indicate a heavy, less desirable crumb (Brooker, 1993). Figure 4-6 shows the cake volumes (and standard deviations) for each of the combinations plus control. The lowest cake volume resulted from combination 1. This is likely due to the low emulsifier content coupled with the high water content compared to that of the control cake. Combination 3, 8, 9, and 10 resulted in lower cake volume than that of control cake. The most probable explanation is the fact that they all have low Lecithin content and thus are less able to stabilize the air cells in the cake batter during mixing and baking. Combinations 2, 4, and 7 have higher volumes compared to the control cake, which indicates that Lecithin has a synergistic effect with PGMS on improving batter aeration (Orthoefer, 2008). Combination 11 produced the highest cake volume, probably because it had the highest emulsifier content. However, cakes containing combination 11 were very fragile and very difficult to handle. Consequently, this combination and higher emulsifier content was deemed unsuitable for this research.

Figure 4-6. Cake volume with different emulsifier combinations
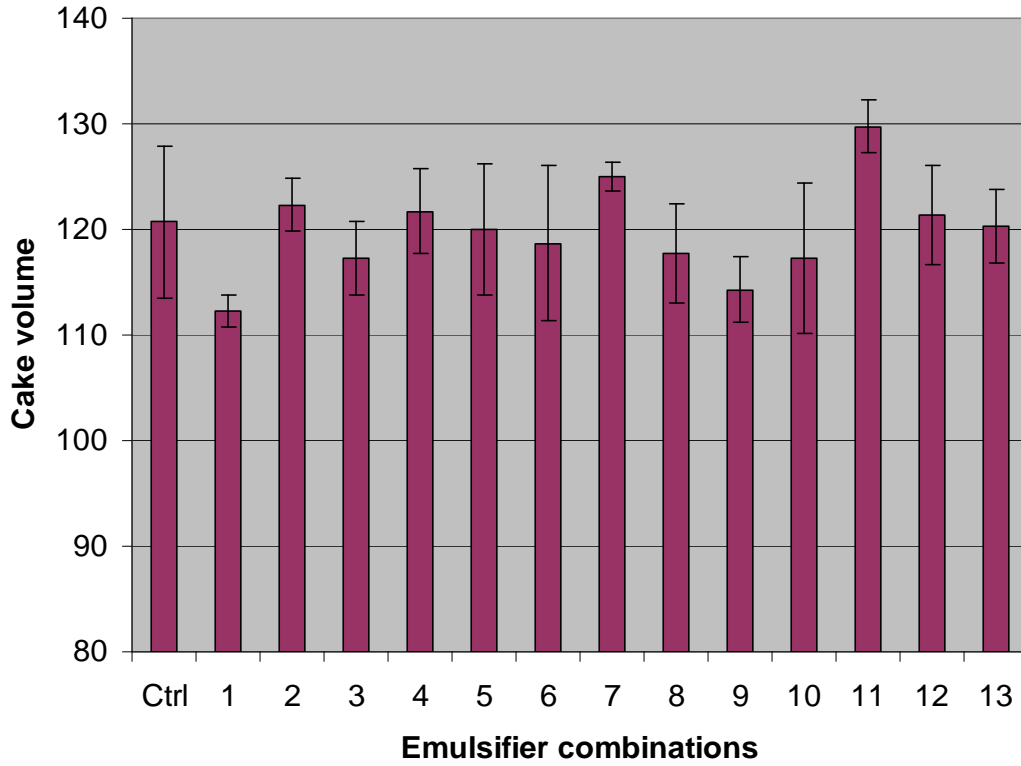
Control: liquid oil without any emulsifier

Emulsifier combination 1: PGMS 1.0%/ GMS 0.5%/ Lecithin 0

2: PGMS 2.0%/ GMS 0.5% / Lecithin 1.0%

3: PGMS 3.0%/ GMS 0.5% / Lecithin 0.5%

4: PGMS 1.0%/ GMS 1.0% / Lecithin 1.0%

5: PGMS 2.0%/ GMS 1.0% / Lecithin 0

6: PGMS 2.0%/ GMS 1.0% / Lecithin 0.5%

7: PGMS 2.0%/ GMS 1.0% / Lecithin 1.0%

8: PGMS 3.0%/ GMS 1.0% / Lecithin 0%

9: PGMS 1.0%/ GMS 1.5% / Lecithin 0.5%

10: PGMS 2.0%/ GMS 1.5% / Lecithin 0

11: PGMS 3.0%/ GMS 1.5% / Lecithin 1.0%

12: PGMS 2.0%/ GMS 1.0% / Lecithin 0.5%

13: PGMS 2.0%/ GMS 1.0% / Lecithin 0.5%

Figure 4-7. Cake volume vs. Batter specific gravity
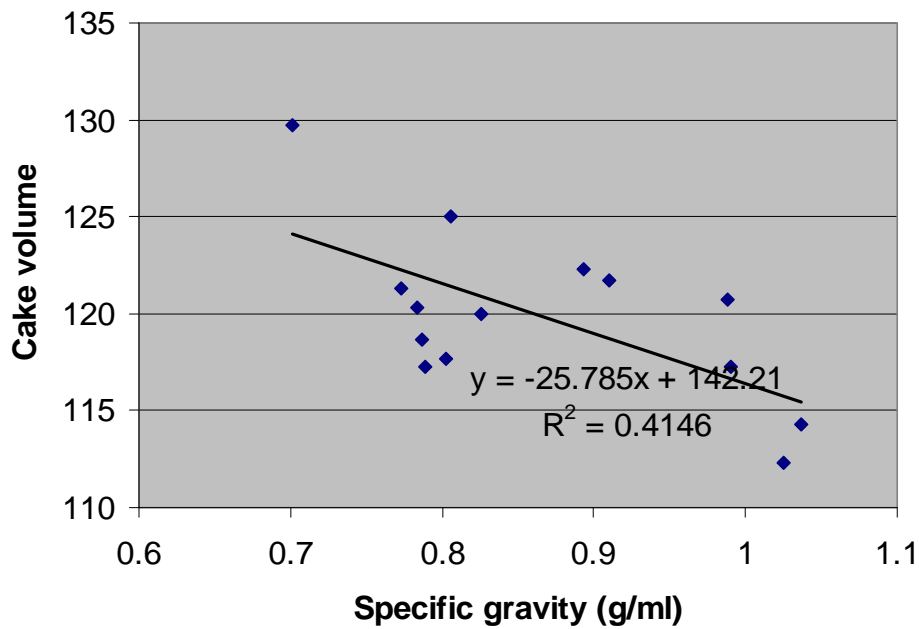
Figure 4-7 plots the relationship between cake volume and batter specific gravity. The trend, as expected, was that specific gravity decreases were associated with volume increases. However, the relationship was not a strong one. The R^2 value of 0.41 indicates that less than half the variability in the data can be attributed to variations in batter specific gravity. We can establish that the final volume of cakes was not only dependant on the initial air incorporated in the batter but also on its capacity to retain air during baking. Different emulsifier combinations have different air retaining capabilities.

4.1.2.2 *Cake Score*

Cake scores for different emulsifier combinations are shown in Figure 4-8. Cake cells, grain, texture, color, and flavor were graded separately, then summed. Cake score mainly reflects the air cell distribution in the cake crumb. The RSM relationship between the independent emulsifier variables and cake score was high (r= 0.80366). Control cake produced cakes with very open cells and coarse grain. This showed that liquid oil alone is not suitable for cake-making as in the results described by Brooker (1993) in his research. Combinations 7 and 11 produced cakes with higher scores than those of the control. They possessed more uniform texture and finer grain, compared to the control cake. This can be explained as follows: the emulsifiers aid in the transformation of big air cells in the liquid oil batter into small, uniform cells and the crumb in consequence forms finer texture. It was hard to tell an individual emulsifier's effects on the cake score. The trend was that higher Lecithin produced higher score cakes when the other two emulsifiers are the same. It is indicated that Lecithin helps to produce a better crumb grain as well as loaf volume, which was also reported by Orthoefer (2008).

Figure 4-8. Cake scores for different emulsifier combinations
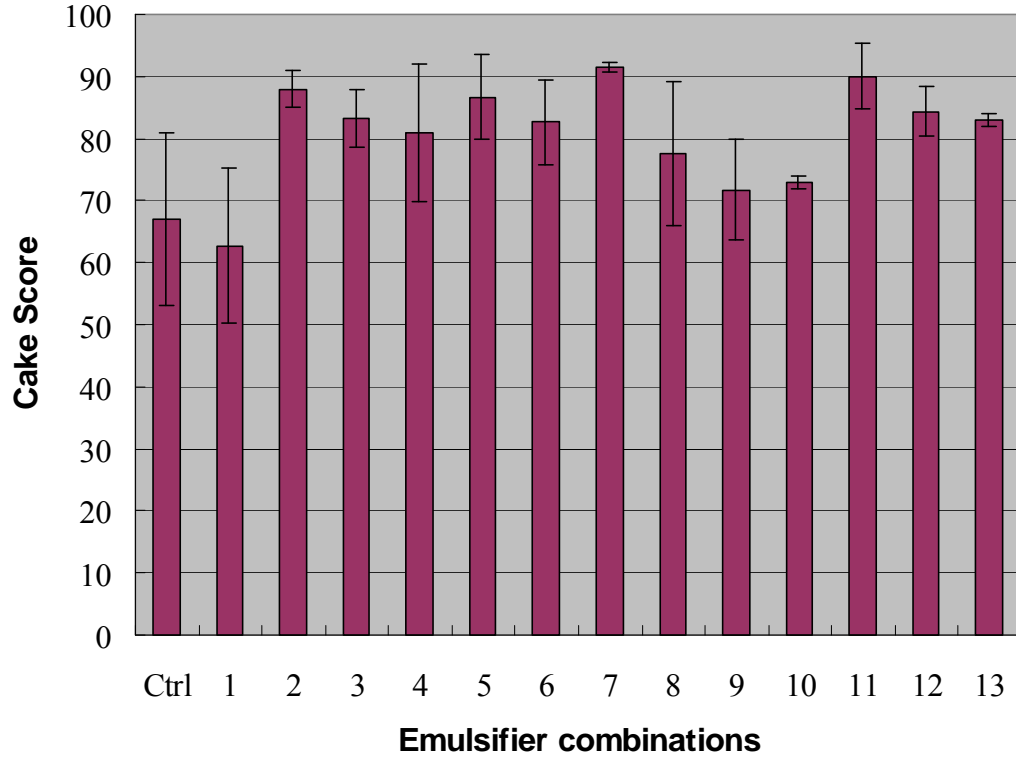
Control: liquid oil without any emulsifier

Emulsifier combination 1: PGMS 1.0%/ GMS 0.5%/ Lecithin 0

2: PGMS 2.0%/ GMS 0.5% / Lecithin 1.0%

3: PGMS 3.0%/ GMS 0.5% / Lecithin 0.5%

4: PGMS 1.0%/ GMS 1.0% / Lecithin 1.0%

5: PGMS 2.0%/ GMS 1.0% / Lecithin 0

6: PGMS 2.0%/ GMS 1.0% / Lecithin 0.5%

7: PGMS 2.0%/ GMS 1.0% / Lecithin 1.0%

8: PGMS 3.0%/ GMS 1.0% / Lecithin 0%

9: PGMS 1.0%/ GMS 1.5% / Lecithin 0.5%

10: PGMS 2.0%/ GMS 1.5% / Lecithin 0

11: PGMS 3.0%/ GMS 1.5% / Lecithin 1.0%

12: PGMS 2.0%/ GMS 1.0% / Lecithin 0.5%

13: PGMS 2.0%/ GMS 1.0% / Lecithin 0.5%

4.1.3 Cake firmness

Cake firmness increased as the storage time increased. Two important physical changes occur in cakes during storage. The first is the migration of water from the moist central crumb to the dry crust, which causes some firming. The second change is due to the intrinsic firming of the crumb caused by the retrogradation of starch. There was no clear relationship between cake water contents and its resulting firmness. The RSM relationship between the independent emulsifier variables and firmness was high (r= 0.83774). Combination 11 produced the most uniform and the softest cakes compared to the control; all the combinations except 1 all produced much softer cakes than the control. One of the reasons might be the increased moisture content of the cake crumb and the increased cake volume. The other possible explanation is that, by adding emulsifiers, the air cells tended to distribute evenly and thus soften the cakes. Figure 4-9 showed that combination 1 produced the firmest cake one day after baking. This might be because of the higher water content and lower emulsifier content of the formula. However, the curve of the combination 1 is flatter than the control curve. This indicates that the emulsifier's function in crumb softening is as an antistaling agent, and makes the firmness change more slowly than in the control cake. The highest GMS and Lecithin contents in combination 11 made the cake firmness change slower than in the other cakes. The highest emulsifier content was not used in the second part of the research, because cakes containing combination 11 were very fragile and very difficult to handle.

Figure 4-9. Cake firmness with different emulsifier combinations and storage time
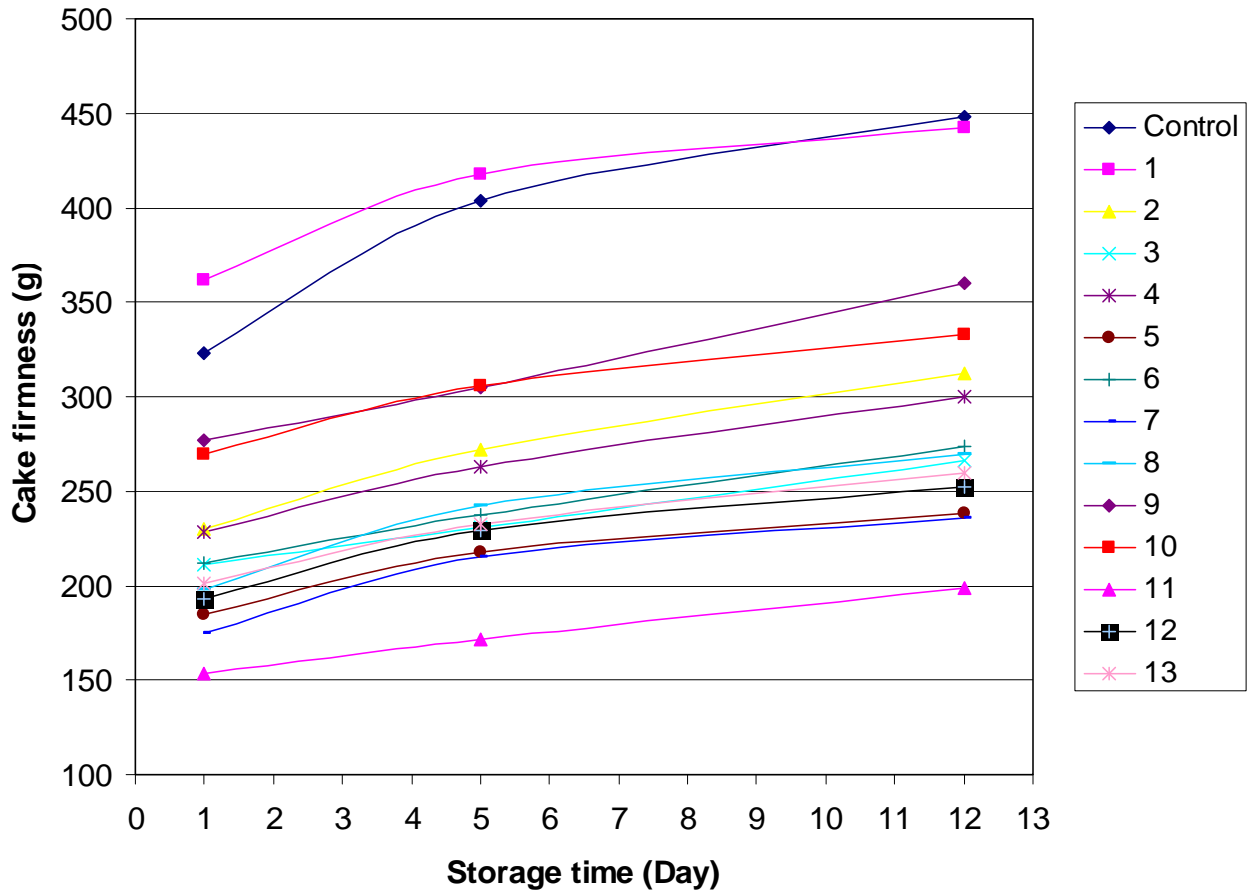
Control: liquid oil without any emulsifier

Emulsifier combination 1: PGMS 1.0%/ GMS 0.5%/ Lecithin 0

2: PGMS 2.0%/ GMS 0.5% / Lecithin 1.0%

3: PGMS 3.0%/ GMS 0.5% / Lecithin 0.5%

4: PGMS 1.0%/ GMS 1.0% / Lecithin 1.0%

5: PGMS 2.0%/ GMS 1.0% / Lecithin 0

6: PGMS 2.0%/ GMS 1.0% / Lecithin 0.5%

7: PGMS 2.0%/ GMS 1.0% / Lecithin 1.0%

8: PGMS 3.0%/ GMS 1.0% / Lecithin 0%

9: PGMS 1.0%/ GMS 1.5% / Lecithin 0.5%

10: PGMS 2.0%/ GMS 1.5% / Lecithin 0

11: PGMS 3.0%/ GMS 1.5% / Lecithin 1.0%

12: PGMS 2.0%/ GMS 1.0% / Lecithin 0.5%

13: PGMS 2.0%/ GMS 1.0% / Lecithin 0.5%

Figure 4-10. Cake firmness vs. cake volume
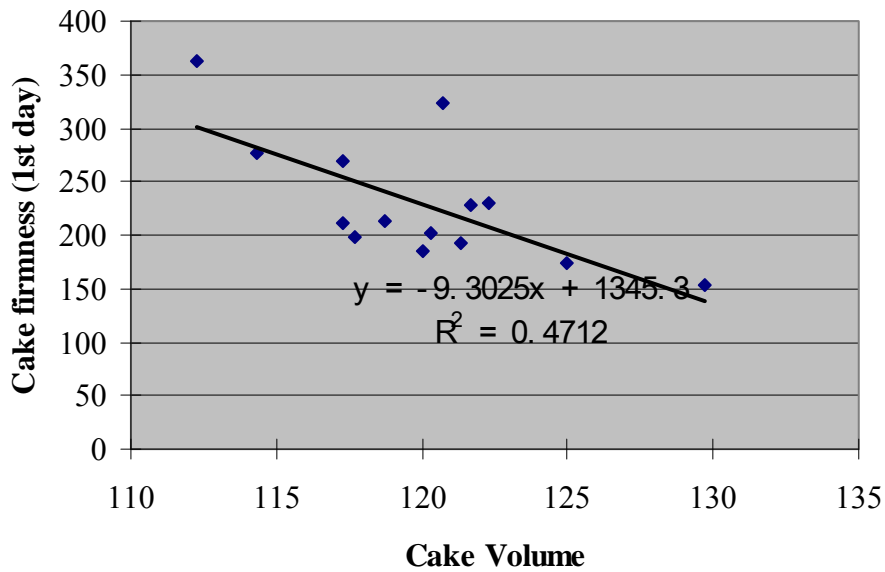
Figure 4-10 plots the relationship between cake volume and cake firmness. As Stauffer discussed (1999) in the case of bread staling, higher specific volume usually results in a lower initial firmness. The trend here was that cake firmness decreases were associated with volume increase. However, the relationship was not a strong one. The R^2 value of 0.47 indicates that less than half the variability in the data can be attributed to change in cake volume, which shows that the improvement in the softness was due both to an increase in cake volume and to an anti-firming agent.

4.2 CAKE STORAGE TEST

Experiments were conducted to study the different types of fats used in the high-ratio yellow layer cakes for their effects on cake properties, including firming over time. Four types of shortenings were used in this experiment: plastic shortening, liquid oil, liquid shortening, and liquid oil plus the emulsifier combinations identified from the results of part I: PGMS 1.8%/ GMS 1.0%/ Lecithin 0.8% (flour weight basis). Results for cake batter specific gravity, viscosity and cake properties are shown in Table 11.

Table 11. Cake properties baked with different types of fats

	Plastic shortening	Liquid oil	Liquid shortening	Liquid oil + emul.
Specific gravity(g/ml)	0.858 ± 0.012b	0.975 ± 0.01c	0.846 ± 0.004b	0.782 ± 0.019a
Viscosity (cm/30sec)[1]	9.6 ± 0.35a	15.5 ± 0.3c	13 ± 0.5b	13.3 ± 0.21b
Cake volume[2]	121.3 ± 2.52a	129.7 ± 8.39a	132.7 ± 1.53a	130.7 ± 3.51a
Cake score	85 ± 3.46b	58.7 ± 7.37a	94 ± 1.73b	87 ± 2.65b
cake firmness 1st day(g)	211 ± 32.78a	299 ± 19.47b	173 ± 16.25a	160 ± 13.12a
5th day(g)	247 ± 12.65b	362 ± 29.65c	200 ± 20.58a	184 ± 10.39a
12th day(g)	270 ± 38.25a	422 ± 17.33b	219 ± 18.02a	215 ± 17.5a
21st day(g)	296 ± 12.68b	509 ± 19.30c	249 ± 6.52a	230 ± 18.39a
Slice brightness	156.4 ± 2.51b	145.2 ± 5.08a	156.9 ± 3.48b	153.75 ± 2.40b
Wall thickness(mm)	0.473 ± 0.0064a	0.469 ± 0.0018a	0.477 ± 0.0018a	0.487 ± 0.0074a
number of cells	3674 ± 233a	3859 ± 218a	3844 ± 340a	3637 ± 201a
cell diameter (mm)	2.5757 ± 0.067a,b	2.109 ± 0.048a	2.5265 ± 0.435a,b	2.9335 ± 0.218b

[1] Viscosity was measured by Bostwich consistometer; [2] Cake volume was measured by plastic template according to AACC 10-91

Mean ± standard deviation of each analysis (n=3)

Means with the same letters within rows are not significantly different (P< 0.05).

4.2.1 Batter Properties

4.2.1.1 Specific gravity

Figure 4-11 shows the cake batter specific gravity resulting from the incorporation of different types of fats. The cakes made with liquid oil had very high specific gravities as expected. Plastic shortening and liquid shortening had similar effects on the specific gravity of the cake batters. Liquid oil plus emulsifier combinations produced significantly lower values than did the others ($p<0.05$).

Figure 4-11. Batter specific gravity from different types of fats
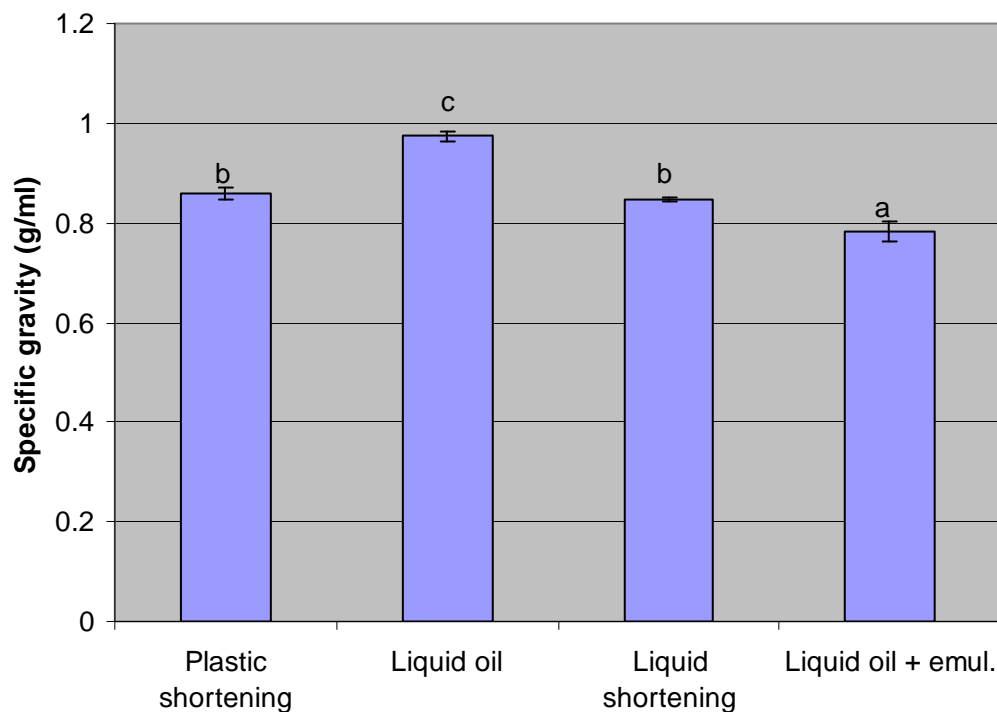
As Brooker (1993) explained, liquid oil cannot hold air bubbles because it has no crystal structure. The small ß' crystals in plastic shortening help stabilize the small bubbles, so the liquid oil had higher specific gravity than plastic shortening. Liquid shortening had high emulsifier content and could incorporate more air into the batter. As more air bubbles are incorporated into the batter, cake batter became aerated and specific gravity decreased. The

batter's viscous resistance to flow increases as the batter entrapped gas bubbles cause the fluid batter to have increased frictional resistance to moving past each other (Brooker, 1993). These bubbles tend to stay in place without coalescing or migrating out because they can only move slowly in a very viscous batter, and surface forces tend to hold them in place. PGMS is an important α-tending emulsifier and in the cake batter it can help increase the incorporation of air and decrease the cake batter specific gravity (Richardson et al, 2002). Liquid oil plus emulsifiers had high PGMS content, so a low specific gravity could be produced.

4.2.1.2 Viscosity

Because the Bostwick consistometer measures how far the batter runs in 30 seconds, the higher the result is, the lower the viscosity of the batter. Liquid oil has no solid structure and could not hold enough air in the batter, so batters made with it had significantly higher results than the others, and the viscosity is lower ($p < 0.05$) (Figure 4-12). Gas cells in the cake batter made from liquid oil tended to coalesce into larger gas cells and to be lost to the atmosphere. This could result in lower cake volume. Batters incorporating plastic shortening showed significantly less flow ($p < 0.05$) because the plastic shortening was solid at the room temperature and could not flow very well, and it incorporated more air in bubbles, further increasing viscosity. Kim and Walker (1992) have commented on air bubbles' ability to increase batter viscosity due to stearic hindrance. They also stated that an increase in batter viscosity aids the incorporation of air.

Comparing liquid shortening and liquid oil plus emulsifiers, the latter had significantly higher viscosities than did those with liquid oil only and significantly lower viscosity than batters containing plastic shortening. This can be explained by the fact that liquid shortening and liquid oil plus emulsifier batters had much less solid structure than did those with plastic shortening, but they incorporated much more air than did liquid oil batters.

Figure 4-12. Batter viscosity from different types of fats
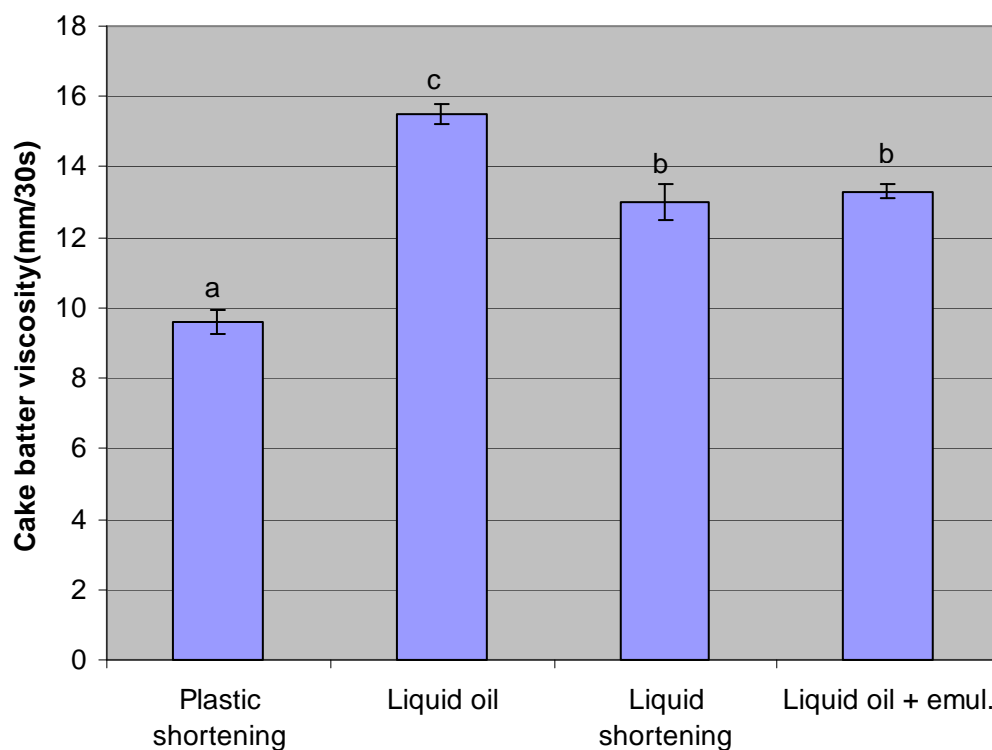
4.2.2 Baking test

4.2.2.1 Cake volume

Figure 4-13 shows cake volume as affected by different types of fats in the batters. No significant differences are shown in the results (p>0.05). The cake volumes from liquid shortening and liquid oil plus emulsifiers were similar or higher than those for plastic shortening incorporation. Liquid oil produced cake volumes similar to those of the other fats, even though the batter specific gravity of liquid oil was higher than others. Table 12 compares the cake volume index with different types of fats. A peaked cake would have a high symmetry (2C-B-D) value and a flat cake would have a low value. Liquid oil produced cakes with higher symmetry value than the others. It may be that, during baking, cake batters' viscosity from liquid oil was too low and the dispersed gas cells could move freely to coalesce into big bubbles, and float rapidly to the surface. If the cake surface were to set before the air bubbles dispersed, the big

bubbles would form tunnels in the baking cake. Such a phenomenon is shown in figure 4-15 (b).

Bath et al. (1992) noticed that by adding emulsifiers, the rate of heating would decrease. This

may indicate that the cakes made with liquid oil set earlier in the oven than did the other cakes.

Table 12. Cake volume index with different types of fats

	Plastic shortening	Liquid oil	Liquid shortening	Liquid oil+emul.
B	39.67 ± 0.58	41.33 ± 2.08	43.67 ± 1.53	42.33 ± 1.53
C	43.33 ± 2.08	47.33 ± 5.51	47.00 ± 1.0	46.67 ± 1.53
D	38.33± 0.58	41.00 ± 1.0	42.00 ± 1.73	41.67 ± 0.58
Volume(B+C+D)	121.33 ± 2.52	129.67 ± 8.33	132.67 ± 1.53	130.67 ±3.51
Symmetry(2C-B-D)	8.67 ± 4.04	12.33 ± 8.33	8.33 ± 4.51	9.33 ± 1.15
Uniformity(B-D)	1.33 ± 0.58	1.0 ± 0	1.67 ± 2.08	0.67 ± 1.15

Figure 4-13. Cake volumes baked with different types of fats
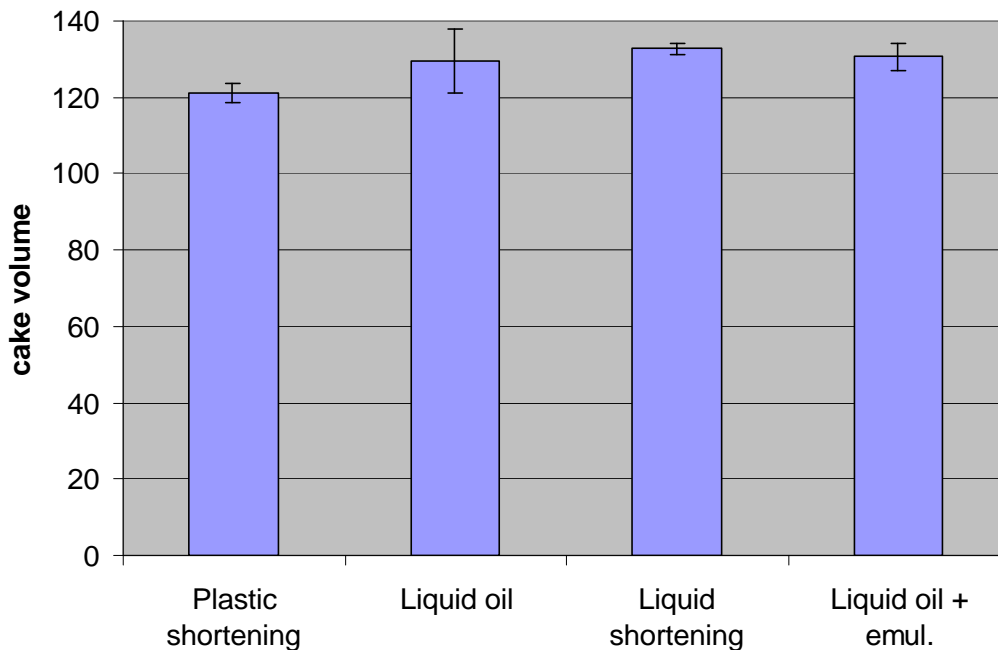
4.2.2.2 Cake score

Cake internal textures were graded according to AACC 10-90; cake cells, grain, texture,

crumb color, and flavor were graded separately, then summed (Appendix B Tables16, 17, 18).

Figure 4-14 shows that liquid oil based cakes have significantly lower scores than do the others (p<0.05). There are no significant differences in cake scores (p>0.05) between plastic shortening, liquid shortening and liquid oil plus emulsifiers based batters.

Figure 4-14. Cake score with different types of fats
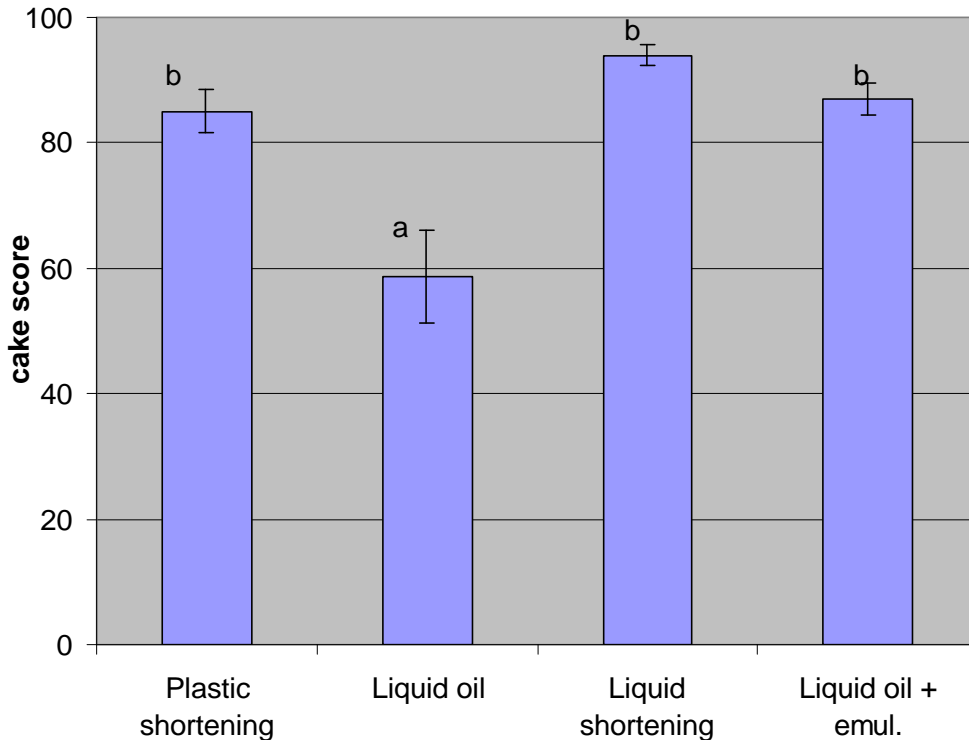
Figure 4-15 presents the crumb portions of cakes made with four different types of fats. Clearly cake b (liquid oil) has some bigger holes than do the other three cakes. That is the tunneling problems caused by less emulsifiers in the formula of the liquid oil cake. Compared to plastic shortening, liquid oil produced cakes with uneven and open cells, very thick cell walls, harsh grain, and a slightly dry, firm texture. One explanation for this is that the liquid oil based batters cannot hold the bubbles because they have no crystal structure. The pressure inside a bubble is inversely proportional to its radius, so during baking large air bubbles can easily coalesce together and form very big and buoyant cells. During baking, as the temperature of the batter rises, the air inside the bubbles begins to expand. In the batters made from plastic shortening, at the same time as the air starts expanding, the absorbed fat crystals approach their melting point. Eventually, all of the fat crystals melt and the resulting oil runs over the inside

surface of the bubble and forms a uniform layer. The large number of adsorbed crystals create sufficient interface to allow the bubbles to expand without rupturing (Brooker, 1993). With liquid oil, the oil droplets inside the batter are big and thus produce cakes with very open cells. Liquid shortening and liquid oil plus emulsifiers produce cakes with dense cells, thin cell walls, silky grain, and very tender, moist, soft texture. The emulsifiers inside the liquid shortening and liquid oil plus emulsifiers help to decrease the bubble size and stabilize the bubbles. Brooker (1993) explained that the addition of emulsifiers could replace the interfacial properties conferred by adsorbed fat crystals, thereby allowing bubble expansion without rupture during baking. Wootton et al. (1967) noticed that in cake batters made with liquid shortening, the emulsifiers made it possible for the air to be incorporated throughout the aqueous phase of the batter.
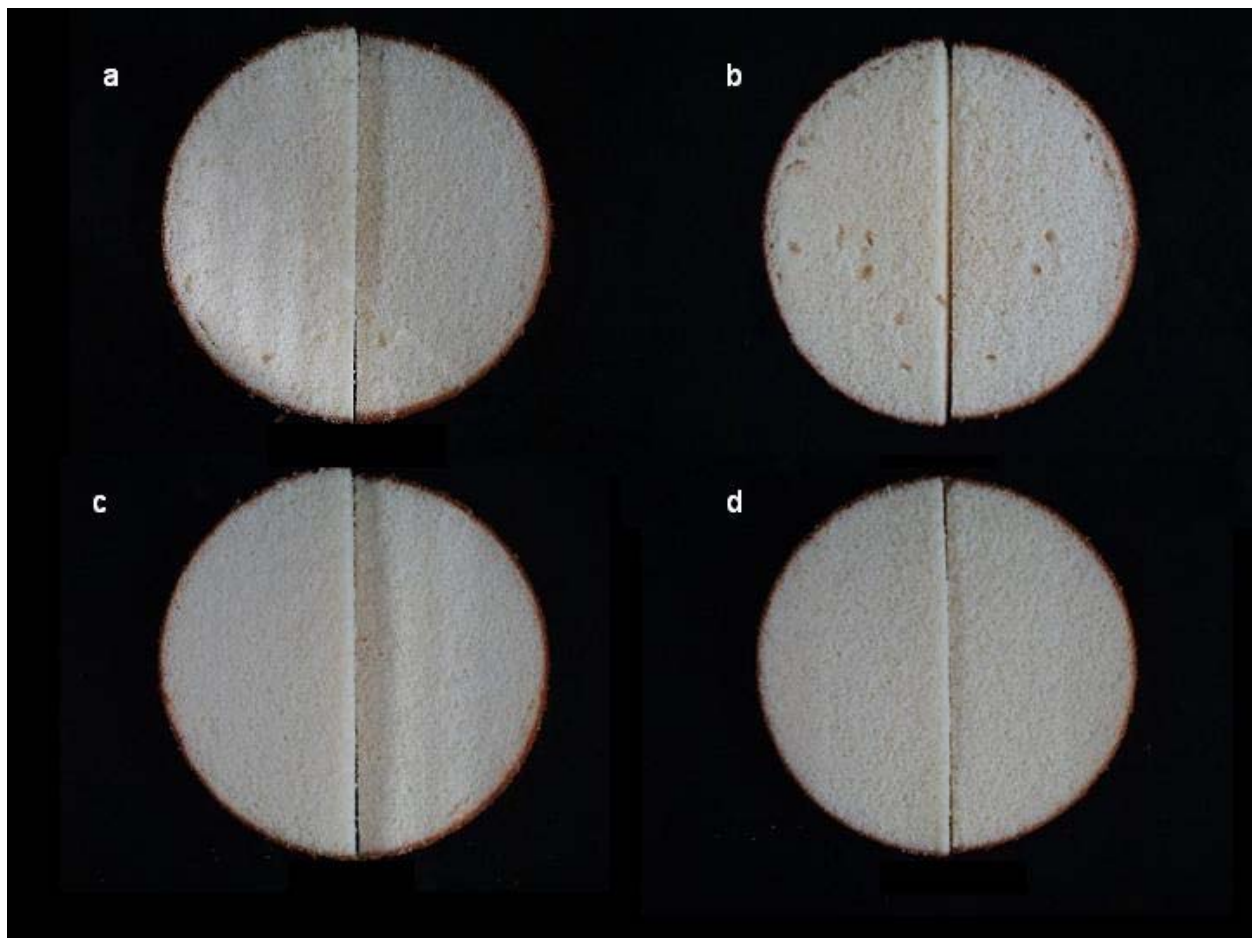
Figure 4-15. Cake crumb (a. plastic shortening; b. liquid oil; c. liquid shortening; d. liquid oil plus emulsifiers)

4.2.2.3. C-cell results:

Slice brightness

The slice brightness of the cakes (Figure 4-16) made with liquid oil was significantly lower than that of the others (p<0.05). There was no significant difference in slice brightness (p>0.05) among cakes produced with plastic shortening, liquid shortening, or liquid oil plus emulsifiers. This can be explained as that liquid oil cannot form a uniform emulsion and the cake batter had a very high specific gravity. Low air content in the cakes made with liquid oil cause the crumb to look yellowish.

Figure 4-16. Slice brightness made with different types of fats
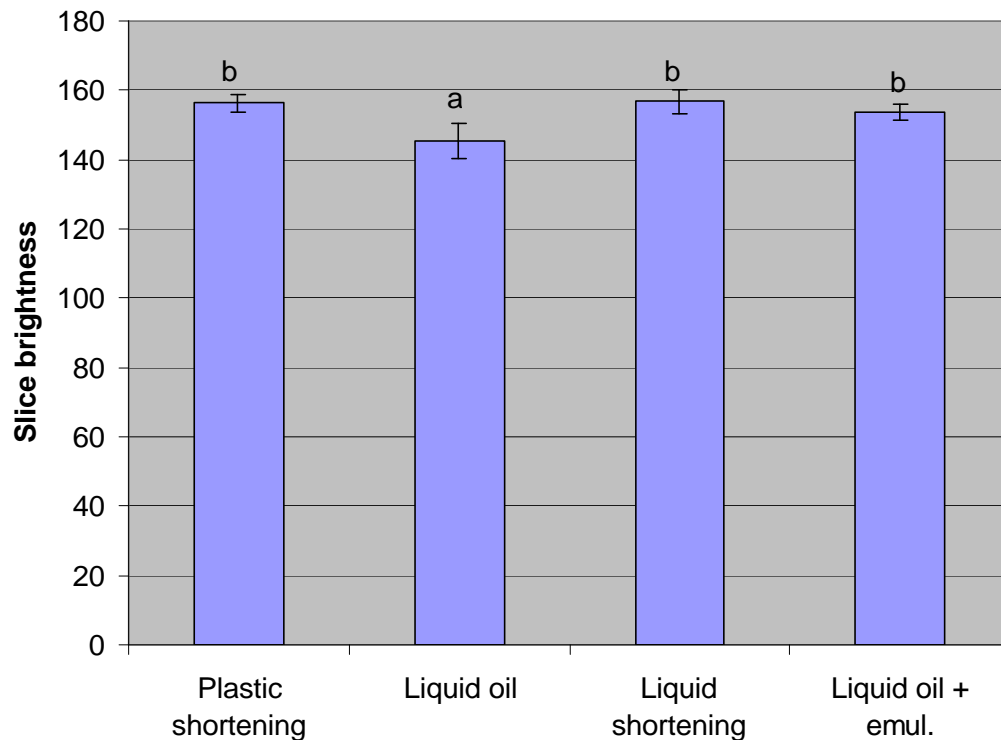
Cell wall thickness

There were no significant differences in cake cell wall thicknesses (Figure 4-17) among all kinds of fats (p>0.05). From visual observation, liquid oil produced cakes which appeared to have much thicker cell walls than the others. However, the C-Cell data didn't show the differences. This might be because, in the cakes made with liquid oil, some big cells were considered as "holes" instead of cells (Cauvain, 2003). The results were the averages of all "cells" in the measurement field. When the big holes are removed from the analysis, all the results had no significant difference.

Figure 4-17. Cell wall thickness of cakes made with different types of fats
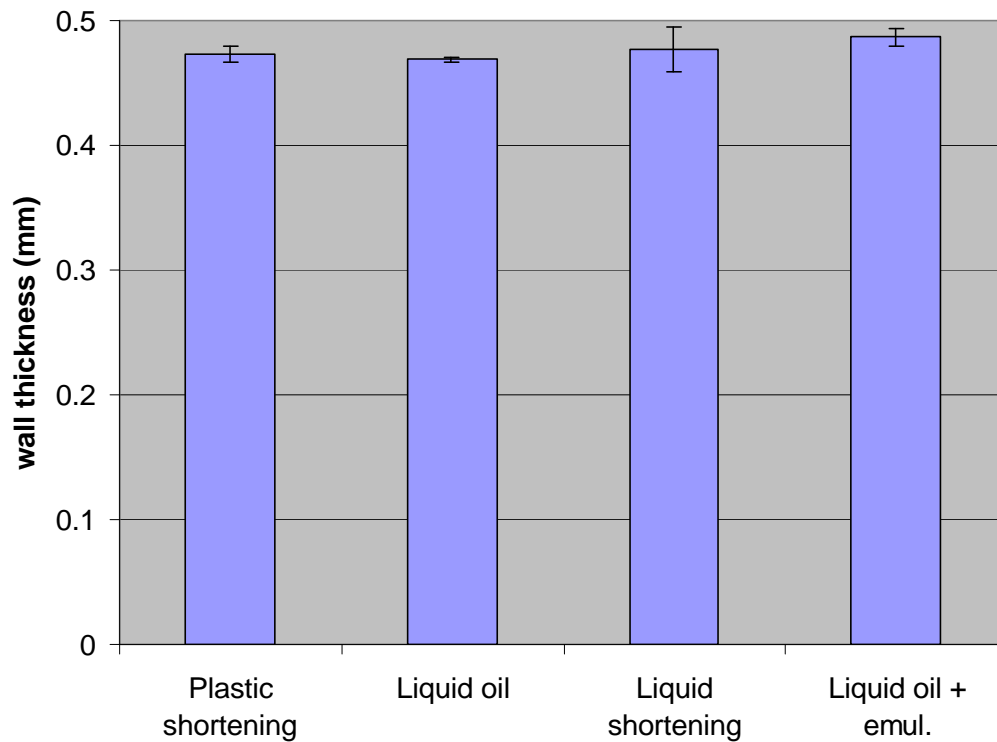
Numbers of cells

The numbers of cells (Figure 4-18) in the crumbs of cakes made using different fats did not show any significant differences ($p > 0.05$). A lower number of cells would indicate either that fewer air bubbles were incorporated into the cake batter or that there was more coalescence in the batter. When the batter viscosity is low, the gas cells would tend to coalesce more readily into large cells. In this study, we expected that cakes made from liquid oil would have fewer cells than the other groups. However, that was not confirmed by the C-cell results. This might be because, when cutting the cakes, cakes made from liquid oil are dryer than others, so the surface of the cake is smooth and it was easier to resolve cells. So those results showed higher values than did the others.

Figure 4-18. Numbers of cells in cakes made with different types of fats
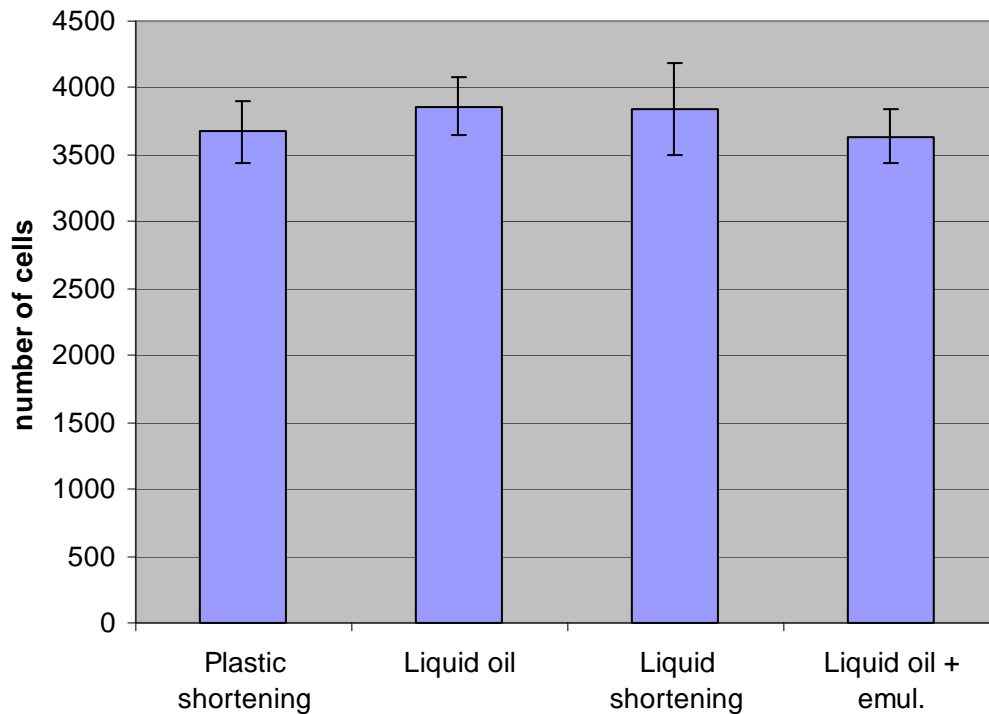
Cell diameters

Cell diameters (Figure 4-19) in cakes made with liquid oil were significantly lower than for those made with liquid oil plus emulsifiers ($p<0.05$). Liquid oil, plastic shortening, and liquid shortening produced cakes did not show significant differences in cell diameter ($p>0.05$). Plastic shortening, liquid shortening, and liquid oil plus emulsifiers produced cakes that were not significantly different in cell diameter ($p>0.05$). The size of air bubbles is important to cake volume and crumb grain. The small cell diameter in cakes made from liquid oil indicates less expansion of air bubbles during cake baking, which is reflected in the low cake volume. For the liquid oil plus emulsifiers' cakes, the large diameter of cells comprising the cake crumb may reflect the greater expansion of air bubbles, which helped improve the cake volume.

Figure 4-19. Cell diameters in cakes made with different types of fats
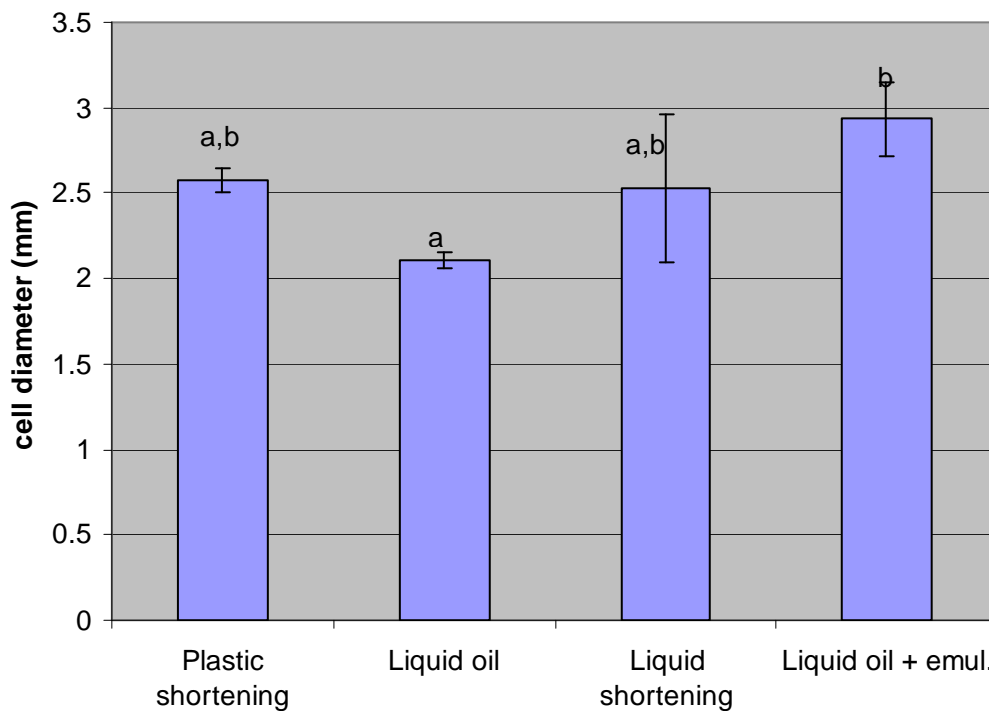
4.2.3 Cake firmness

Figure 4-20 shows the changes in firmness of cakes made from different types of fats over extended storage time. Clearly, cakes made with liquid oil have much greater firmness than the cakes made with other types of fats ($p<0.05$), and the cake firmness change was much more rapid than others. Liquid shortening and liquid oil with emulsifiers produced cakes which were not significantly different in their firmness ($p>0.05$). Cakes made from plastic shortening were not significantly firmer than cakes made with liquid shortening or liquid oil plus emulsifiers on the 1st and 12th day ($p>0.05$), but they were significantly more firm than cake containing liquid shortening and liquid oil plus emulsifiers on the 5th and 21st day ($p<0.05$). The 12th day's firmness of cakes made from plastic shortening had very high standard deviation. This might be the reason that the difference between plastic shortening and liquid shortening did not show significant statistical differences.

Liquid oil with no emulsifiers produced cakes in which firmness increased rapidly, which indicates that liquid oil alone produces firm cakes but the addition of emulsifiers to that liquid oil softens the cakes, essentially equivalent in firmness to the liquid shortening cakes. This confirms previously published data (Stauffer, 1999; Rusch, 1981).

Figure 4-20. Cake firmness
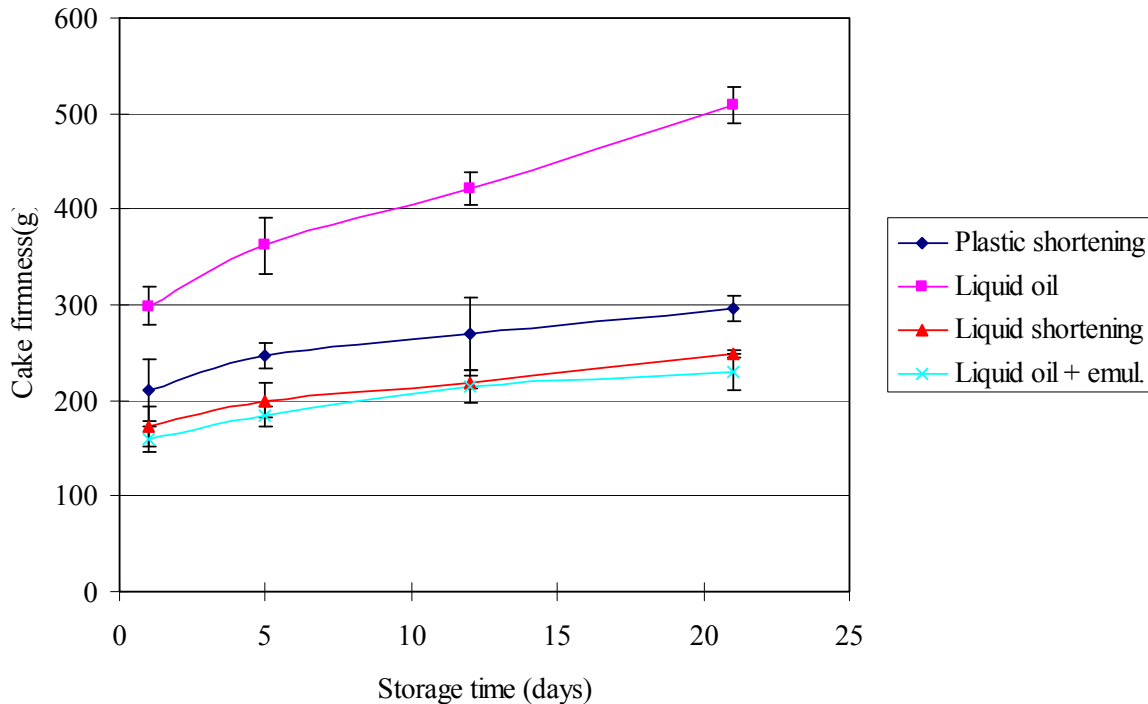
On the first day after baking, cakes baked with plastic shortening showed no significant differences in firmness from those baked with liquid shortening or liquid oil plus emulsifiers, but they showed significant differences later. According to the ingredient statements, Mono- and diglycerides were added to the plastic shortening by the manufacturer. Mono- and diglycerides work the same as monoglycerides in starch antistaling, and may be better than simple monoglycerides in increasing the aeration, depending on the source of the fat and the iodine value (Orthoefer, 2008).

In the liquid shortening formula, Mono- and Diglycerides, Propylene Glycol Mono- and Diesters of Fatty acids, and Glyceryl-Lacto Esters of Fatty acids were used. The differences between liquid shortening and liquid oil plus emulsifiers are:

(1) Fat crystals. In liquid shortening production, ß tending hard fats are used to serve as quick-forming nuclei that cause solids in the base oil to precipitate in small enough crystals to ensure pourablity and prevent separation (O'Brien, 1996).

(2) Special processing. Many different crystallization procedures have been patented for liquid shortening production. The commonality of the procedures including: (a) all are dispersions of solids in liquid fractions; (b) the heat of crystallization must be dissipated before a stable product is achieved; (c) aeration of the liquid shortenings must be avoided at all stages of processing; (d) storage temperature is critical. It should be stored between 18-35℃ (O'Brien, 1996).

(3) Emulsifier's formula and content. It is difficult to determine the exact formula for the commercial liquid shortening, but from the ingredient statement, it appears that the difference is just the Glyceryl-Lacto Esters of Fatty acids and lecithin, and these results presented above show similar cake firmness changes.

As discussed above, the processing and storage costs of liquid shortening are very high. The liquid oil plus emulsifiers is less costly in processing, and doesn't require storage at a critical temperature, so it is much easier to handle. It is less expensive and more convenient for large companies to use liquid oil plus emulsifiers instead of liquid shortening. Still, the emulsifier formula and content are critical to success. Using this blend requires a special tank for heating and blending the emulsifiers. More equipment investment will be needed when using the liquid oil plus emulsifiers.

CHAPTER 5 - SUMMARY

Liquid shortening provided the best fresh cake characteristics with a cake volume 132.7, cake score 94, and 1st day firmness of 173g. Liquid oil provided the worst fresh cake characteristics with a cake volume 129.7, cake score 58.7, and 1st day firmness of 299g. Plastic shortening cakes were intermediate with a cake volume 121.3, cake score 85, and 1st day firmness of 211g.

Cake firmness changed slowly during storage for cakes made with liquid shortening. It was 200g (5th day), 219g (12th day), and 249g (21st day). For cakes made with liquid oil, firmness increased rapidly. It was 362g (5th day), 422g (12th day), and 509g (21st day). Plastic shortening cake firmness change was intermediate in rate with 247g (5th day), 270g (12th day), and 296g (21st day).   It may be concluded that liquid shortening was better for use in cake making than was plastic shortening. Cakes made from liquid shortening showed more uniform grain, finer texture, and higher volume. Cake firming shelf-life for cakes made from liquid shortening is longer than for cakes made from plastic shortening.

Liquid oil alone is not suitable for use in cake making, but the incorporation of the blend: PGMS 1.8%/GMS 1.0%/ Lecithin 0.8% produced layer cakes with characteristics: cake volume 130.7, cake score 87. Cake firmness change was 160g (1st day), 184g (5th day), 215g (12th day), and 230g (21st day). It was comparable in cake volume, cake score, and cake firmness to those produced with liquid shortening.

For baking companies, liquid oil plus an emulsifier combination blend would be easy to handle and they can combine different emulsifiers as their requirements change. But more investment for equipment would be needed.

Future work of this project may include more baking tests of different emulsifiers and emulsifier combinations and cake shelf-life tests using vacuum packaging.

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Appendix A - RSM

```
Analysis of Data File: 1st Cake firmness. RSM

Using Model: STD 3_VAR | C 1 2 3 12 23 13 11 22 33

Coefficient of Determination (R^2) =0.70180
Coefficient of Multiple Correlation =0.83774
Standard Error of Estimate    37.40268

EQUATION:
FIRM-1          =    +657.1111111
                     -741.4405094 * GMS
                      +62.3333333 * LECITHIN
                      -17.8353008 * PGMS
                      +60.4428704 * GMS * LECITHIN
                      -66.2214352 * LECITHIN * PGMS
                      +42.6666667 * GMS * PGMS
                     +295.7762038 * GMS * GMS
                      -46.0000000 * LECITHIN * LECITHIN
                      -10.6107176 * PGMS * PGMS
```

```
                          Response in FIRM-1
                        (Stepping Variable: GMS = .5)


    +3.000 |        DDDDDDDDD        CCCCCCCC       BBBBBBB       AAAAA
    +2.950 |         DDDDDDDD        CCCCCCCC       BBBBBB        AAA
    +2.900 |E           DDDDDDDD        CCCCCCCC       BBBBBB        A
    +2.850 |EEE          DDDDDDDDD       CCCCCCCC       BBBBBB
    +2.800 |EEEE          DDDDDDDD        CCCCCCCC       BBBBBB
    +2.750 |EEEEE          DDDDDDDDD       CCCCCCCC       BBBBBB
    +2.700 |EEEEEE           DDDDDDDDD       CCCCCCCC       BBBBBBB
    +2.650 |EEEEEEEE           DDDDDDDDD       CCCCCCCC       BBBBB
    +2.600 |EEEEEEEEEE           DDDDDDDDD       CCCCCCCC       BBB
    +2.550 |EEEEEEEEEEE           DDDDDDDDD       CCCCCCCC       B
    +2.500 | EEEEEEEEEEEE           DDDDDDDDD       CCCCCCCCC
    +2.450 |  EEEEEEEEEEEEE          DDDDDDDDD       CCCCCCCCC
    +2.400 |   EEEEEEEEEEEEE          DDDDDDDDD       CCCCCCCC
    +2.350 |    EEEEEEEEEEEEE          DDDDDDDDD       CCCCCCCC
    +2.300 |     EEEEEEEEEEEEEE         DDDDDDDDD       CCCCCC
    +2.250 |      EEEEEEEEEEEEEE         DDDDDDDDD       CCCCC
    +2.200 |       EEEEEEEEEEEEE         DDDDDDDDD       CCC
    +2.150 |        EEEEEEEEEEEEEE        DDDDDDDDD       C
    +2.100 |         EEEEEEEEEEEEEE        DDDDDDDDDD
    +2.050 |          EEEEEEEEEEEEEE        DDDDDDDDDD
P   +2.000 |           EEEEEEEEEEEEEE        DDDDDDDDDD
G   +1.950 |            EEEEEEEEEEEEEE        DDDDDDDDDD
M   +1.900 |             EEEEEEEEEEEEEEE       DDDDDDDDDD
S   +1.850 |              EEEEEEEEEEEEEEE       DDDDDDD
    +1.800 |               EEEEEEEEEEEEEEE       DDDDDD
    +1.750 |FF               EEEEEEEEEEEEEEE       DDDD
    +1.700 |FFF               EEEEEEEEEEEEEEEE       D
    +1.650 |FFFFF              EEEEEEEEEEEEEEEE
    +1.600 |FFFFFFF             EEEEEEEEEEEEEEEE
    +1.550 |FFFFFFFFF            EEEEEEEEEEEEEEEE
    +1.500 |FFFFFFFFFFF           EEEEEEEEEEEEEEEE
    +1.450 |FFFFFFFFFFFFF          EEEEEEEEEEEEEEEE
    +1.400 |FFFFFFFFFFFFFFF         EEEEEEEEEEEEEEEE
    +1.350 |FFFFFFFFFFFFFFFFFF       EEEEEEEEEEEEE
    +1.300 |FFFFFFFFFFFFFFFFFFFFF      EEEEEEEEEE
    +1.250 |FFFFFFFFFFFFFFFFFFFFFFFFF     EEEEEEE
    +1.200 |FFFFFFFFFFFFFFFFFFFFFFFFFFFFF    EEEEE
    +1.150 |FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF   EE
    +1.100 |FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
    +1.050 |FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
    +1.000 |FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
           \+---------+---------+---------+---------+---------+---------+
          +0.000    +0.167    +0.333    +0.500    +0.667    +0.833    +1.000

                                 LECITHIN

  Legend:    +100.00=A   +150.00=B   +200.00=C   +250.00=D   +300.00=E
             +350.00=F   +400.00=G   +450.00=H   +500.00=I   +550.00=J
             +600.00=K
```

63

```
                         Response in FIRM-1
                     (Stepping Variable: GMS = 1.5)

      +3.000  |DDDDD                      CCCCCCCCCCCCCCCC              BBBBB
      +2.950  |DDDDDD                      CCCCCCCCCCCCCCCC              BBB
      +2.900  |DDDDDDDD                     CCCCCCCCCCCCCCCC
      +2.850  |DDDDDDDDDD                    CCCCCCCCCCCCCCC
      +2.800  |DDDDDDDDDDDD                   CCCCCCCCCCCCCCCC
      +2.750  |DDDDDDDDDDDDDDD                 CCCCCCCCCCCCCCCC
      +2.700  |DDDDDDDDDDDDDDDDD               CCCCCCCCCCCCCCCC
      +2.650  |DDDDDDDDDDDDDDDDDDDD             CCCCCCCCCCCCCCCC
      +2.600  |DDDDDDDDDDDDDDDDDDDDDDD           CCCCCCCCCCCC
      +2.550  |DDDDDDDDDDDDDDDDDDDDDDDDDD         CCCCCCCCC
      +2.500  |DDDDDDDDDDDDDDDDDDDDDDDDDDDDD       CCCCCCC
      +2.450  |DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD     CCCC
      +2.400  |DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD    C
      +2.350  |DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
      +2.300  |DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
      +2.250  |DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
      +2.200  |DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
      +2.150  |DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
      +2.100  |DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
      +2.050  |DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
P     +2.000  |DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
G     +1.950  |DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
M     +1.900  |DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
S     +1.850  |DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
      +1.800  |DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
      +1.750  |DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD              DDDDDDDD
      +1.700  |DDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
      +1.650  |DDDDDDDDDDDDDDDDDDDDDDDDDDDD
      +1.600  |DDDDDDDDDDDDDDDDDDDDDDDDDD
      +1.550  |DDDDDDDDDDDDDDDDDDDDDDDDD
      +1.500  |  DDDDDDDDDDDDDDDDDDDDDD
      +1.450  |   DDDDDDDDDDDDDDDDDDDD
      +1.400  |    DDDDDDDDDDDDDDDDDDD
      +1.350  |     DDDDDDDDDDDDDDDDDD
      +1.300  |      DDDDDDDDDDDDDDDD
      +1.250  |       DDDDDDDDDDDDDDD
      +1.200  |        DDDDDDDDDDDDDDD
      +1.150  |         DDDDDDDDDDDDDDD                          EEE
      +1.100  |          DDDDDDDDDDDDDD                         EEEEE
      +1.050  |           DDDDDDDDDDDDDD                       EEEEEEEE
      +1.000  |            DDDDDDDDDDDDDD                      EEEEEEEEE
              \+---------+---------+---------+---------+---------+---------+
              +0.000    +0.167    +0.333    +0.500    +0.667    +0.833    +1.000

                                    LECITHIN

    Legend:   +100.00=A   +150.00=B   +200.00=C   +250.00=D   +300.00=E
              +350.00=F   +400.00=G   +450.00=H   +500.00=I   +550.00=J
              +600.00=K
```

64

```
Analysis of Data File: CAKVOLM3.RSM

Using Model: STD 3_VAR | C 1 2 3 12 23 13 11 22 33

Coefficient of Determination (R^2) =0.51182
Coefficient of Multiple Correlation =0.71542
Standard Error of Estimate    4.40101

EQUATION:
VOLUME         =    +115.3845316
                     +14.2265795 * LECITHIN
                     +56.4964316 * PGMS
                    -122.8948239 * GMS
                     -24.4029299 * LECITHIN * PGMS
                      +6.8801743 * PGMS * GMS
                     +44.0825483 * LECITHIN * GMS
                      -2.1307190 * LECITHIN * LECITHIN
                     -12.1132297 * PGMS * PGMS
                     +45.1021561 * GMS * GMS
```

```
                         Response in VOLUME
                     (Stepping Variable: GMS = .5)

    +3.000 |J    III    HHH    GGG    FFF    EEE    DDD    CCC    BBB    AAAAAAA
    +2.950 |JJ    III    HHHH    GGG    FFFF    EEE    DDD    CCC    BBB    AAAA
    +2.900 |JJJ    III    HHH    GGG    FFF    EEE    DDD    CCC    BBB    AA
    +2.850 |JJJ    IIII    HHHH    GGG    FFF    EEE    DDDD    CCC    BBBB
    +2.800 | JJJ    IIII    HHHH    GGG    FFF    EEE    DDDD    CCCC    BBB
    +2.750 | JJJJ    IIII    HHH    GGGG    FFFF    EEE    DDD    CCC
    +2.700 |  JJJJ    IIII    HHHH    GGG    FFFF    EEE    DDDD    CCCC
    +2.650 |  JJJJ    IIII    HHHH    GGGG    FFFF    EEE    DDDD    CC
    +2.600 |  JJJJ    IIII    HHHH    GGGG    FFFF    EEEE    DDD
    +2.550 |  JJJJJ    IIII    HHHHH    GGGG    FFFFF    EEEE    DDDD
    +2.500 |   JJJJJ    IIIII    HHHHH    GGGGG    FFFFF    EEEE    DDD
    +2.450 |   JJJJJ    IIIII    HHHH    GGGGG    FFFFF    EEEE
    +2.400 |   JJJJJ    IIIIII    HHHHH    GGGGG    FFFFF    EEEEE
    +2.350 |   JJJJJ    IIIII    HHHHH    GGGGG    FFFFF    EEEE
    +2.300 |   JJJJJJ    IIIIII    HHHHHH    GGGGGG    FFFFF    EE
    +2.250 |   JJJJJJ    IIIIII    HHHHHH    GGGGG    FFFFF
    +2.200 |  JJJJJJJ    IIIIIII    HHHHHH    GGGGGG    FFFFF
    +2.150 | JJJJJJJ    IIIIIII    HHHHHH    GGGGGG    FFFFFF
    +2.100 |JJJJJJJ    IIIIIII    HHHHHHH    GGGGGGG    FFFF
    +2.050 |JJJJJJ    IIIIIIIII    HHHHHHH    GGGGGGG    FF
  P +2.000 |JJJJ    IIIIIIII    HHHHHHHH    GGGGGGG
  G +1.950 |J    IIIIIIIIII    HHHHHHHHH    GGGGGGGG
  M +1.900 |    IIIIIIIIIII    HHHHHHHHH    GGGGGGGGG
  S +1.850 |    IIIIIIIIIIII    HHHHHHHHH    GGGGGGGGGG
    +1.800 |IIIIIIIIIIIIII    HHHHHHHHHHH    GGGGGGGGGG
    +1.750 |IIIIIIIIII    HHHHHHHHHHHHHH    GGGGGGGGG
    +1.700 |II    HHHHHHHHHHHHHHHH    GGGGGGGG
    +1.650 |    HHHHHHHHHHHHHHHHHHHHH    GGGGGGG
    +1.600 |  HHHHHHHHHHHHHHHHHHHHHHHHHHHH    GGGGGGG
    +1.550 |HHHHHHHHHHHHHHHHHHHHHHHHHH    GGGGGGG
    +1.500 |                                        GGGGGGGG
    +1.450 |                                        GGGGGGGGGGGG
    +1.400 |GGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGG
    +1.350 |GGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGG
    +1.300 |          GGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGG
    +1.250 |FFFFFFFFF          GGGGGGGGGGGGGGGGGGGGGGGGGG
    +1.200 |  FFFFFFFFFFFFFFFFFFFF          GGGGGGGGGG
    +1.150 |        FFFFFFFFFFFFFFFFFFFFF                    GG
    +1.100 |EEEEEEEEEE          FFFFFFFFFFFFFFFFFF
    +1.050 |    EEEEEEEEEEEE          FFFFFFFFFFFFFFFF
    +1.000 |DDDDD          EEEEEEEEEEEE          FFFFFFFFFFFFFFF
           \+---------+---------+---------+---------+---------+---------+
            +0.000    +0.167    +0.333    +0.500    +0.667    +0.833    +1.000

                                  LECITHIN

    Legend:    +100.00=A    +104.00=B    +108.00=C    +112.00=D    +116.00=E
               +120.00=F    +124.00=G    +128.00=H    +132.00=I    +136.00=J
               +140.00=K
```

```
                          Response in VOLUME
                      (Stepping Variable: GMS = 1.5)


    +3.000 |  GGGGGGGGGGGGGGGGGGG                       HHHHHHHHHHHHHHHHHH
    +2.950 |GGGGGGGGGGGGGGG                      HHHHHHHHHHHHHHHHHHHHHHH
    +2.900 |GGGGGGGGGGG                    HHHHHHHHHHHHHHHHH
    +2.850 |GGGGGGGG              HHHHHHHHHHHHH                IIIIIIIIII
    +2.800 |GGGGGGG            HHHHHHHHHHH              IIIIIIIIIIIIII
    +2.750 |GGGGGGG          HHHHHHHHH              IIIIIIIIIIII
    +2.700 |GGGGG          HHHHHHHH          IIIIIIIIII           JJJJJ
    +2.650 |GGGGG         HHHHHHHH         IIIIIIIII          JJJJJJJJJJ
    +2.600 |GGGGG        HHHHHHH         IIIIIIIII        JJJJJJJJJ
    +2.550 |GGGGGG       HHHHHH        IIIIIIII       JJJJJJJJ
    +2.500 | GGGGGG       HHHHH       IIIIIII      JJJJJJJJ       KKKK
    +2.450 |  GGGGGG      HHHHH      IIIIIIII     JJJJJJ       KKKKKKK
    +2.400 |   GGGGGG     HHHHH      IIIIII      JJJJJJJ      KKKKKKKKK
    +2.350 |    GGGGG     HHHHH      IIIIII     JJJJJJ      KKKKKKKKKKK
    +2.300 |     GGGGG     HHHHHH     IIIII      JJJJJ      KKKKKKKKKKKK
    +2.250 |FF    GGGGG     HHHHH     IIIII     JJJJJJ     KKKKKKKKKKKKK
    +2.200 |FFF     GGGG     HHHHH     IIIII     JJJJJ     KKKKKKKKKKKKKK
    +2.150 |FFFF     GGGG     HHHH     IIII     JJJJJ     KKKKKKKKKKKKKK
    +2.100 |  FFFF     GGGG     HHHH     IIIII     JJJJJ     KKKKKKKKKKKKKKK
    +2.050 |   FFFF     GGGG     HHHH     IIII     JJJJJ     KKKKKKKKKKKKKKK
P   +2.000 |E     FFFF     GGGG     HHHH     IIII     JJJJ     KKKKKKKKKKKKKKK
G   +1.950 |EEE     FFFF     GGGG     HHH     IIII     JJJJ     KKKKKKKKKKKKKKK
M   +1.900 |  EEE     FFFF     GGGG     HHH     IIII     JJJJ     KKKKKKKKKKKKKKK
S   +1.850 |   EEE     FFF     GGG     HHH     IIII     JJJJ     KKKKKKKKKKKKKKK
    +1.800 |D     EEE     FFFF     GGG     HHH     III     JJJJ     KKKKKKKKKKKKKKK
    +1.750 |DDD     EEEE     FFF     GGGG     HHH     III     JJJ     KKKKKKKKKKKKKK
    +1.700 |  DDD     EEE     FFFF     GGG     HHH     III     JJJJ     KKKKKKKKKKKKK
    +1.650 |C     DDD     EEE     FFF     GGG     HHHH     III     JJJ     KKKKKKKKKKKK
    +1.600 |CCC     DDD     EEE     FFF     GGG     HHH     III     JJJ     KKKKKKKKKKKK
    +1.550 |  CCC     DD     EEE     FFF     GGG     HHH     III     JJJ     KKKKKKKKKKK
    +1.500 |B     CCC     DDD     EEE     FFF     GGG     HHH     III     JJJ     KKKKKKKKKK
    +1.450 |  BB     CCC     DDD     EEE     FFF     GGG     HHH     III     JJJ     KKKKKKKKK
    +1.400 |   BB     CCC     DDD     EE     FFF     GGG     HHH     III     JJJ     KKKKKKKKK
    +1.350 |AA     BB     CC     DDD     EEE     FFF     GG     HHH     III     JJJ     KKKKKKKK
    +1.300 |AAAA     BB     CC     DD     EE     FFF     GGG     HHH     II     JJJ     KKKKKKK
    +1.250 |AAAAAA     BB     CC     DD     EE     FF     GG     HH     II     JJJ     KKKKKK
    +1.200 |AAAAAAAA     BB     CC     DDD     EEE     FFF     GGG     HHH     III     JJJ     KKKKK
    +1.150 |AAAAAAAAAA BB     CC     DDD     EE     FF     GG     HHH     III     JJJ     KKKK
    +1.100 |AAAAAAAAAAAA BB     CCC     DD     EE     FFF     GG     HH     II     JJJ     KKK
    +1.050 |AAAAAAAAAAAAA BB     CCC     DD     EEE     FF     GG     HH     II     JJJ     KK
    +1.000 |AAAAAAAAAAAAAAAA BB     CC     DD     EE     FFF     GG     HH     II     JJ     K
           \+---------+---------+---------+---------+---------+---------+
            +0.000     +0.167     +0.333     +0.500     +0.667     +0.833     +1.000


                                  LECITHIN

    Legend:    +100.00=A    +104.00=B    +108.00=C    +112.00=D    +116.00=E
               +120.00=F    +124.00=G    +128.00=H    +132.00=I    +136.00=J
               +140.00=K
```

67

```
Analysis of Data File: CAKSCOR3.RSM

Using Model: STD 3_VAR | C 1 2 3 12 23 13 11 22 33

Coefficient of Determination (R^2) =0.64586
Coefficient of Multiple Correlation =0.80366
Standard Error of Estimate     6.47671

EQUATION:
SCORE           =    +45.5882353
                     +30.6339869 * LECITHIN
                      -9.9198587 * PGMS
                     +60.3822011 * GMS
                      +8.3117343 * LECITHIN * PGMS
                      +2.7320261 * PGMS * GMS
                     -23.8652988 * LECITHIN * GMS
                      -8.3529412 * LECITHIN * LECITHIN
                      +2.2441025 * PGMS * PGMS
                     -26.8456909 * GMS * GMS
```

```
                          Response in SCORE
                      (Stepping Variable: GMS = .5)


     +3.000 |  DDDD     EEE     FFFF     GGGG     HHHHH    IIIII     JJJJJ
     +2.950 |   DDD    EEEE     FFFF     GGGG     HHHHH    IIIII    JJJJJJ
     +2.900 |  DDDD    EEEE     FFFF    GGGGG     HHHHH    IIIII     JJJJJ
     +2.850 |   DDDD   EEEE     FFFF     GGGG     HHHHH   IIIIII      JJJJ
     +2.800 |   DDDD   EEEE     FFFF     GGGG     HHHHH    IIIII       JJJ
     +2.750 |   DDDD   EEEE     FFFF    GGGGG     HHHH     IIIII         J
     +2.700 |C  DDDD   EEEE    FFFFF    GGGGG     HHHHH    IIIII
     +2.650 |C   DDDD  EEEE     FFFF     GGGG     HHHHH   IIIIII
     +2.600 |C   DDDD  EEEE    FFFFF    GGGGG     HHHHH   IIIIII
     +2.550 |C   DDDD  EEEEE    FFFF    GGGGG     HHHHH   IIIIII
     +2.500 |CC  DDDD  EEEE    FFFFF    GGGGG     HHHHH   IIIIIII
     +2.450 |CC  DDDD  EEEE    FFFFF   GGGGGG    HHHHHH    IIIII
     +2.400 |CC  DDDD  EEEEE   FFFFF    GGGGG    HHHHHH     IIII
     +2.350 |CC  DDDDD EEEE    FFFFF    GGGGG    HHHHHH      III
     +2.300 |CC   DDDD EEEEE   FFFFF   GGGGGG    HHHHHH       II
     +2.250 |CCC  DDDD EEEEE    FFFFF   GGGGGG   HHHHHH
     +2.200 |CCC  DDDD EEEE     FFFFF   GGGGGG   HHHHHH
     +2.150 |CCC  DDDDD EEEEE   FFFFF    GGGGG   HHHHHH
     +2.100 |CCC  DDDDD EEEEE  FFFFFF   GGGGGG   HHHHHHH
     +2.050 |CCC  DDDDD EEEEE   FFFFF   GGGGGG   HHHHHHH
P    +2.000 |CCC   DDDD EEEEE  FFFFFF   GGGGGG   HHHHHHH
G    +1.950 |CCC   DDDD EEEEE   FFFFF  GGGGGGG   HHHHHHH
M    +1.900 |CCC  DDDDD EEEEE  FFFFFF  GGGGGGG   HHHHHH
S    +1.850 |CCC  DDDDD EEEEE  FFFFFF  GGGGGGG   HHHHH
     +1.800 |CCC  DDDDD EEEEE  FFFFFF  GGGGGGG   HHHH
     +1.750 |CCC  DDDDD EEEEE  FFFFFF  GGGGGGG    HHH
     +1.700 |CCC  DDDDD EEEEEE  FFFFF  GGGGGGG      H
     +1.650 |CCC  DDDDD EEEEEE FFFFFF  GGGGGGGG
     +1.600 |CCC  DDDDD EEEEE  FFFFFFF GGGGGGGG
     +1.550 |CCC  DDDDD EEEEEE  FFFFFF  GGGGGGGG
     +1.500 |CCC  DDDDD EEEEEE FFFFFFF  GGGGGGGG
     +1.450 |CCC  DDDDD EEEEEE FFFFFFF  GGGGGGGGG
     +1.400 |CCC  DDDDD EEEEEE FFFFFFFF  GGGGGGGGG
     +1.350 |CC   DDDDD EEEEEE FFFFFFF  GGGGGGGGGG
     +1.300 |CC  DDDDDD EEEEEE FFFFFFFFF GGGGGGGGGG
     +1.250 |CC  DDDDDD EEEEEE FFFFFFFFF GGGGGGGGGGG
     +1.200 |C   DDDDDD EEEEEE  FFFFFFFF GGGGGGGGGG
     +1.150 |C   DDDDD  EEEEEE  FFFFFFF  GGGGGGGGG
     +1.100 |C   DDDDDD EEEEEE  FFFFFFF  GGGGGGGGG
     +1.050 |    DDDDDD EEEEEEE  FFFFFFFFF GGGGGGGGG
     +1.000 |    DDDDDD EEEEEEE FFFFFFFFF  GGGGGGG
            \+---------+---------+---------+---------+---------+---------+
           +0.000    +0.167    +0.333    +0.500    +0.667    +0.833    +1.000


                                LECITHIN

  Legend:     +50.00=A    +55.00=B    +60.00=C    +65.00=D    +70.00=E
              +75.00=F    +80.00=G    +85.00=H    +90.00=I    +95.00=J
              +100.00=K
```

69

```
                        Response in SCORE
                   (Stepping Variable: GMS = 1.5)


    +3.000 |      GGGGGGGGG          HHHHHHHHHHHHH
    +2.950 |        GGGGGGGGG          HHHHHHHHHHHHHHH
    +2.900 |         GGGGGGGGGG          HHHHHHHHHHHHHHHHHH
    +2.850 |F           GGGGGGGGGG          HHHHHHHHHHHHHHHHHHHHHHHHH
    +2.800 |FF            GGGGGGGGGGG          HHHHHHHHHHHHHHHHHHHHHHHH
    +2.750 |FFF             GGGGGGGGGGGG          HHHHHHHHHHHHHHHHHHHHH
    +2.700 |FFFF              GGGGGGGGGGGGG            HHHHHHHHH
    +2.650 |FFFFFF              GGGGGGGGGGGGGG
    +2.600 |FFFFFFF               GGGGGGGGGGGGGGGGG
    +2.550 |FFFFFFFFF                GGGGGGGGGGGGGGGGGGGGG
    +2.500 |FFFFFFFFFF                 GGGGGGGGGGGGGGGGGGGGGGGGGGGGGGG
    +2.450 | FFFFFFFFFFF                 GGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGG
    +2.400 |  FFFFFFFFFFF                  GGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGG
    +2.350 |   FFFFFFFFFFFF                  GGGGGGGGGGGGGGGGGGGGGGGGGGGG
    +2.300 |    FFFFFFFFFFFFF                  GGGGGGGGGGG
    +2.250 |      FFFFFFFFFFFFFFF
    +2.200 |       FFFFFFFFFFFFFFFF
    +2.150 |        FFFFFFFFFFFFFFFFFF
    +2.100 |          FFFFFFFFFFFFFFFFFFFFFF                               F
    +2.050 |           FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
P   +2.000 |            FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
G   +1.950 |            FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
M   +1.900 |             FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
S   +1.850 |              FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
    +1.800 |                FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
    +1.750 |E                      FFFFFFFFFFFFF
    +1.700 |EE
    +1.650 |EE
    +1.600 |EEE                                                       EEE
    +1.550 |EEEE                                                    EEEEEEE
    +1.500 |EEEE                                                 EEEEEEEEEE
    +1.450 |EEEEE                                               EEEEEEEEEEEEE
    +1.400 |EEEEEE                                           EEEEEEEEEEEEEEEE
    +1.350 |EEEEEE                                        EEEEEEEEEEEEEEEEEEE
    +1.300 |EEEEEEE                                    EEEEEEEEEEEEEEEEEEEEE
    +1.250 |EEEEEEEE                                 EEEEEEEEEEEEEEEEEEEEEE
    +1.200 |EEEEEEEEE                             EEEEEEEEEEEEEEEEEEEEEEEE
    +1.150 |EEEEEEEEE                          EEEEEEEEEEEEEEEEEEEEEEEEEE
    +1.100 |EEEEEEEEEE                      EEEEEEEEEEEEEEEEEEEEEEEEEEEE
    +1.050 |EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE
    +1.000 |EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE           DD
            \+---------+---------+---------+---------+---------+---------+
            +0.000     +0.167     +0.333     +0.500     +0.667     +0.833     +1.000


                               LECITHIN


  Legend:     +50.00=A     +55.00=B     +60.00=C     +65.00=D     +70.00=E
              +75.00=F     +80.00=G     +85.00=H     +90.00=I     +95.00=J
              +100.00=K
```

70

```
Analysis of Data File: CAKF-O1.RSM

Using Model: STD 3_VAR | C 1 2 3 12 23 13 11 22 33

Coefficient of Determination (R^2) =0.70180
Coefficient of Multiple Correlation =0.83774
Standard Error of Estimate    37.40268

EQUATION:
FIRM-1          =    +657.1111111
                     -741.4405094 * GMS
                      +62.3333333 * LECITHIN
                      -17.8353008 * PGMS
                      +60.4428704 * GMS * LECITHIN
                      -66.2214352 * LECITHIN * PGMS
                      +42.6666667 * GMS * PGMS
                     +295.7762038 * GMS * GMS
                      -46.0000000 * LECITHIN * LECITHIN
                      -10.6107176 * PGMS * PGMS
```

```
                           Response in FIRM-1
                       (Stepping Variable: PGMS = 1)

        +1.000 |  EEEEE      DDDDDDD                         DDDDDDD
        +0.975 |  EEEEE      DDDDDDDD                        DDDDDDD
        +0.950 |   EEEEE     DDDDDDD                         DDDDDDD
        +0.925 |   EEEEE     DDDDDDDD                        DDDDDDD
        +0.900 |   EEEEE     DDDDDDDD                        DDDDDDDD
        +0.875 |   EEEEE      DDDDDDDD                       DDDDDDDD
        +0.850 |    EEEEE     DDDDDDDD                       DDDDDDDD
        +0.825 |    EEEEE     DDDDDDDD                       DDDDDDDD
        +0.800 |    EEEEE     DDDDDDDDD                      DDDDDDDDD
        +0.775 |    EEEEE      DDDDDDDD                      DDDDDDDDD
        +0.750 |    EEEEEE     DDDDDDDD                      DDDDDDDDD
        +0.725 |     EEEEE     DDDDDDDD                      DDDDDDDDD
        +0.700 |     EEEEE     DDDDDDDDD                     DDDDDDDD
        +0.675 |F    EEEEE     DDDDDDDDD                     DDDDDDDD
        +0.650 |F    EEEEE     DDDDDDDDD                     DDDDDDDD
        +0.625 |F    EEEEE      DDDDDDDD                     DDDDDDDD
        +0.600 |F    EEEEE      DDDDDDDD                     DDDDDDDDD
        +0.575 |F    EEEEE      DDDDDDDD                     DDDDDDDD
     L  +0.550 |F     EEEEE     DDDDDDDD                     DDDDDDDD
     E  +0.525 |F     EEEEE     DDDDDDDD                     DDDDDDDD
     C  +0.500 |F     EEEEE     DDDDDDDD                      DDDDDDDD
     I  +0.475 |F     EEEEE     DDDDDDDD                      DDDDDDDD
     T  +0.450 |F     EEEEE     DDDDDDDD                      DDDDDDDD
     H  +0.425 |F     EEEEE     DDDDDDDD                      DDDDDDD
     I  +0.400 |FF    EEEEE     DDDDDDD                       DDDDDDD
     N  +0.375 |FF    EEEEE     DDDDDDD                        DDDDDD
        +0.350 |FF    EEEEE     DDDDDDD                        DDDDDD
        +0.325 |FF    EEEEE     DDDDDDD                         DDDDD
        +0.300 |FF    EEEEE     DDDDDDD                         DDDDD
        +0.275 |FF    EEEEE     DDDDDDDD                         DDDD
        +0.250 |FF    EEEEE     DDDDDDDD                          DDD
        +0.225 |FF    EEEEE     DDDDDDDD                          DDD
        +0.200 |FF    EEEE      DDDDDDDD                           DD
        +0.175 |F     EEEE      DDDDDDD                            DD
        +0.150 |F     EEEE      DDDDDDD            C               DD
        +0.125 |F     EEEEE     DDDDDDD         CCCCCCCC            D
        +0.100 |F     EEEEE     DDDDDDD        CCCCCCCCCCCC         D
        +0.075 |F     EEEEE     DDDDDDD       CCCCCCCCCCCCCC
        +0.050 |F     EEEEE     DDDDDDD      CCCCCCCCCCCCCCCC
        +0.025 |F     EEEEE     DDDDDD      CCCCCCCCCCCCCCCCCCC
        +0.000 |F     EEEE      DDDDDD     CCCCCCCCCCCCCCCCCCCCCC
               \+---------+---------+---------+---------+---------+---------+
               +0.500     +0.667     +0.833     +1.000     +1.167     +1.333     +1.500

                                        GMS

      Legend:    +100.00=A    +150.00=B    +200.00=C    +250.00=D    +300.00=E
                 +350.00=F    +400.00=G    +450.00=H    +500.00=I    +550.00=J
                 +600.00=K
```

```
                              Response in FIRM-1
                        (Stepping Variable: PGMS = 1.5)


       +1.000 |    DDDDD        CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC       DDD
       +0.975 |     DDDDD        CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC       DDD
       +0.950 |     DDDDDD        CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC      DDD
       +0.925 |      DDDDDD        CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC     DDD
       +0.900 |      DDDDDD        CCCCCCCCCCCCCCCCCCCCCCCCCCCCCC      DDDD
       +0.875 |E     DDDDDD        CCCCCCCCCCCCCCCCCCCCCCCCCCCCC       DDDD
       +0.850 |E     DDDDDD        CCCCCCCCCCCCCCCCCCCCCCCCCCCC        DDDD
       +0.825 |E     DDDDDDD        CCCCCCCCCCCCCCCCCCCCCCCCCCC        DDDD
       +0.800 |EE     DDDDDD        CCCCCCCCCCCCCCCCCCCCCCCCCC         DDDD
       +0.775 |EE     DDDDDDD        CCCCCCCCCCCCCCCCCCCCCCCCC         DDDDD
       +0.750 |EE      DDDDDD        CCCCCCCCCCCCCCCCCCCCCCCC          DDDDD
       +0.725 |EEE     DDDDDD        CCCCCCCCCCCCCCCCCCCCCCC           DDDDD
       +0.700 |EEE     DDDDDDD        CCCCCCCCCCCCCCCCCCCCCC           DDDDD
       +0.675 |EEE      DDDDDD        CCCCCCCCCCCCCCCCCCCC             DDDDD
       +0.650 |EEEE     DDDDDDD        CCCCCCCCCCCCCCCCCCC             DDDDD
       +0.625 |EEEE     DDDDDDD        CCCCCCCCCCCCCCCCCC              DDDDD
       +0.600 |EEEE      DDDDDDD        CCCCCCCCCCCCCCCC               DDDDD
       +0.575 |EEEEE      DDDDDDD        CCCCCCCCCCCCCC                DDDDD
L      +0.550 |EEEEE      DDDDDDD        CCCCCCCCCCCC                  DDDDDD
E      +0.525 |  EEEE       DDDDDD        CCCCCCCCCCC                  DDDDDD
C      +0.500 |  EEEE       DDDDDDD        CCCCCCCCCC                  DDDDDD
I      +0.475 |  EEEEE      DDDDDDD        CCCCCCCCCC                  DDDDDD
T      +0.450 |  EEEEE      DDDDDDD        CCCCCCCCC                   DDDDD
H      +0.425 |  EEEEE       DDDDDDD        CCCCCCCCC                  DDDDD
I      +0.400 |   EEEE       DDDDDDD        CCCCCCCC                   DDDDD
N      +0.375 |   EEEE       DDDDDDD        CCCCCCCC                   DDDDD
       +0.350 |   EEEEE      DDDDDDD        CCCCCCCC                   DDDDD
       +0.325 |   EEEEE      DDDDDDD         CCCCCCC                   DDDDD
       +0.300 |   EEEEE      DDDDDDDD        CCCCCCC                   DDDDD
       +0.275 |   EEEEE       DDDDDDD        CCCCCCC                   DDDDD
       +0.250 |    EEEE       DDDDDDD        CCCCCCCC                  DDDD
       +0.225 |    EEEE       DDDDDDD        CCCCCCCCC                 DDDD
       +0.200 |    EEEE       DDDDDDD        CCCCCCCCCC                DDDD
       +0.175 |    EEEE       DDDDDDD        CCCCCCCCCC                DDDD
       +0.150 |    EEEEE      DDDDDDD        CCCCCCCCCCC               DDD
       +0.125 |    EEEEE      DDDDDDD        CCCCCCCCCCCC              DDD
       +0.100 |    EEEEE      DDDDDDD        CCCCCCCCCCCCC             DDD
       +0.075 |    EEEEE      DDDDDDD        CCCCCCCCCCCCCC            DD
       +0.050 |    EEEEE      DDDDDDD        CCCCCCCCCCCCCCC           DD
       +0.025 |    EEEEE      DDDDDDD        CCCCCCCCCCCCCCCC          DD
       +0.000 |    EEEEE      DDDDDD        CCCCCCCCCCCCCCCCCCC         D
              \+---------+---------+---------+---------+---------+---------+
               +0.500     +0.667     +0.833     +1.000     +1.167     +1.333     +1.500

                                        GMS


    Legend:    +100.00=A    +150.00=B    +200.00=C    +250.00=D    +300.00=E
               +350.00=F    +400.00=G    +450.00=H    +500.00=I    +550.00=J
               +600.00=K
```

73

```
                            Response in FIRM-1
                       (Stepping Variable: PGMS = 2)


        +1.000 |    CCCCCCC         BBBBBBBBBBBBBBBBBBBBBBBBB         CCCCCC
        +0.975 |     CCCCCCC        BBBBBBBBBBBBBBBBBBBBBBBB          CCCCCC
        +0.950 |      CCCCCC        BBBBBBBBBBBBBBBBBBBB             CCCCCCC
        +0.925 |       CCCCCC        BBBBBBBBBBBBBB                 CCCCCCC
        +0.900 |D      CCCCCCC         BBBBBBBBBB                   CCCCCCC
        +0.875 |D       CCCCCCC           BBB                     CCCCCCC
        +0.850 |DD       CCCCCCC                                  CCCCCCC
        +0.825 |DDD      CCCCCCCC                                CCCCCCCC
        +0.800 |DDD       CCCCCCCC                               CCCCCCCC
        +0.775 |DDDD       CCCCCCCC                              CCCCCCCC
        +0.750 |DDDD       CCCCCCCCC                             CCCCCCCC
        +0.725 |DDDDD       CCCCCCCCC                           CCCCCCCCC
        +0.700 |DDDDD        CCCCCCCCC                          CCCCCCCCCC
        +0.675 | DDDDD        CCCCCCCCCC                        CCCCCCCCC
        +0.650 | DDDDDD       CCCCCCCCCC                        CCCCCCCCC
        +0.625 |  DDDDD        CCCCCCCCCCC                    CCCCCCCCCCC        D
        +0.600 |  DDDDDD       CCCCCCCCCCCC                   CCCCCCCCCCC        D
        +0.575 |  DDDDD        CCCCCCCCCCCCC                 CCCCCCCCCCCCC       D
    L   +0.550 |  DDDDDD        CCCCCCCCCCCCCC              CCCCCCCCCCCCCC       D
    E   +0.525 |   DDDDD        CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC          DD
    C   +0.500 |   DDDDDD       CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC         DD
    I   +0.475 |   DDDDDD       CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC         DD
    T   +0.450 |    DDDDDD      CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC         DD
    H   +0.425 |    DDDDDD      CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC          DD
    I   +0.400 |E    DDDDD      CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC          DD
    N   +0.375 |E    DDDDDD     CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC          DD
        +0.350 |E    DDDDDD      CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC           DDD
        +0.325 |EE    DDDDDD     CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC            DDD
        +0.300 |EE    DDDDDD     CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC             DDD
        +0.275 |EE    DDDDDD     CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC              DDD
        +0.250 |EEE     DDDDDD    CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC              DDD
        +0.225 |EEE     DDDDDD    CCCCCCCCCCCCCCCCCCCCCCCCCCCCCC               DDD
        +0.200 |EEE     DDDDDD    CCCCCCCCCCCCCCCCCCCCCCCCCCCCC                DDD
        +0.175 |EEE      DDDDDD    CCCCCCCCCCCCCCCCCCCCCCCCCCCC                DDD
        +0.150 |EEEE     DDDDDD    CCCCCCCCCCCCCCCCCCCCCCCCCCC                 DDD
        +0.125 |EEEE     DDDDDD    CCCCCCCCCCCCCCCCCCCCCCCCCCC                 DDD
        +0.100 |EEEE     DDDDDDD   CCCCCCCCCCCCCCCCCCCCCCCCCC                  DDD
        +0.075 |EEEE     DDDDDDD   CCCCCCCCCCCCCCCCCCCCCCCCCC                  DDD
        +0.050 |EEEEE     DDDDDD    CCCCCCCCCCCCCCCCCCCCCCCCC                  DDD
        +0.025 |EEEEE     DDDDDD    CCCCCCCCCCCCCCCCCCCCCCCC                   DD
        +0.000 |EEEEE     DDDDDD    CCCCCCCCCCCCCCCCCCCCCCCC                   DD
               \+---------+---------+---------+---------+---------+---------+
                +0.500     +0.667    +0.833    +1.000    +1.167    +1.333    +1.500


                                        GMS


        Legend:    +100.00=A    +150.00=B    +200.00=C    +250.00=D    +300.00=E
                   +350.00=F    +400.00=G    +450.00=H    +500.00=I    +550.00=J
                   +600.00=K
```

74

```
Analysis of Data File: CAKVOLM2.RSM

Using Model: STD 3_VAR | C 1 2 3 12 23 13 11 22 33

Coefficient of Determination (R^2) =0.51182
Coefficient of Multiple Correlation =0.71542
Standard Error of Estimate    4.40101

EQUATION:
VOLUME          =    +115.3845316
                      -82.0127623 * GMS
                      +14.2265795 * LECITHIN
                      +36.0554007 * PGMS
                      +27.7297236 * GMS * LECITHIN
                      -16.2265176 * LECITHIN * PGMS
                       +6.8801743 * GMS * PGMS
                      +28.7493315 * GMS * GMS
                       -2.1307190 * LECITHIN * LECITHIN
                       -8.0250235 * PGMS * PGMS
```

```
                          Response in VOLUME
                       (Stepping Variable: PGMS = 1)


      +1.000 |    FFFFFFFFFFF          FFFFFFFFFFF       GGGGG     HHHH    I
      +0.975 |    FFFFFFFFF             FFFFFFFFF        GGGGG     HHH
      +0.950 |    FFFFFFFF               FFFFFFFF        GGGG      HHHH
      +0.925 |   FFFFFFF                  FFFFFFF        GGGGG     HHH
      +0.900 |FFFFFFF            EE              FFFFFF      GGGGG    HH
      +0.875 |FFFFFF         EEEEEEEEEEEEEEE      FFFFFF      GGGG
      +0.850 |FFFFF        EEEEEEEEEEEEEEEEEEEEE     FFFFF      GGGG
      +0.825 |FFFF        EEEEEEEEEEEEEEEEEEEEEEEE    FFFFF      GGG
      +0.800 |FFFF      EEEEEEEEEEEEEEEEEEEEEEEEEEEEEE    FFFFF      GGG
      +0.775 |FFF     EEEEEEEEEE           EEEEEEEEEE    FFFFF      G
      +0.750 |FF      EEEEEEEE             EEEEEEEE      FFFFF
      +0.725 |FF      EEEEEEE              EEEEEEE      FFFFF
      +0.700 |F       EEEEEEE         DDDD          EEEEE      FFFF
      +0.675 |F       EEEEE      DDDDDDDDDDDDDDDDD     EEEEEE      FF
      +0.650 |        EEEEE    DDDDDDDDDDDDDDDDDDDDDDD      EEEEE
      +0.625 |        EEEEE   DDDDDDDDDDDDDDDDDDDDDDDDDDD       EEEEE
      +0.600 |       EEEEE     DDDDDDDDD        DDDDDDDDDD        EEEE
      +0.575 |       EEEE     DDDDDDDD          DDDDDDDD        EEE
L     +0.550 |      EEEEE    DDDDDDD              DDDDDD        E
E     +0.525 |      EEEE     DDDDD       CCCCCCCC          DDDDDD
C     +0.500 |     EEEE     DDDDD     CCCCCCCCCCCCCCCCCCCC        DDDDDD
I     +0.475 |     EEEE     DDDDDD    CCCCCCCCCCCCCCCCCCCCCCCCCCC        DDDD
T     +0.450 |EEEE     DDDDD     CCCCCCCCCCCCC    CCCCCCCCCCCCCC       DD
H     +0.425 |EEEE     DDDD     CCCCCCCCC                CCCCCCCCC
I     +0.400 |EEE     DDDD     CCCCCCC                CCCCCCC
N     +0.375 |EEE     DDDD     CCCCCCC          BBBBB          CCCCC
      +0.350 |EE      DDDD     CCCCCC        BBBBBBBBBBBBBBBBBBBBB        CCC
      +0.325 |EE      DDDD     CCCCCC      BBBBBBBBBBBBBBBBBBBBBBBBBBB
      +0.300 |E       DDDD     CCCCC       BBBBBBBBBBB       BBBBBBBBBBB
      +0.275 |E       DDDD     CCCCC       BBBBBBBB             BBBBBBBB
      +0.250 |       DDDD     CCCC      BBBBBBB                  BBBB
      +0.225 |       DDD     CCCC      BBBBBB       AAAAAAAAAAAAA
      +0.200 |      DDDD     CCCC      BBBBB      AAAAAAAAAAAAAAAAAAAAAA
      +0.175 |      DDD      CCC      BBBBB      AAAAAAAAAAAAAAAAAAAAAAAAAAA
      +0.150 |      DDD      CCC      BBBB      AAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
      +0.125 |     DDD      CCCC     BBBB     AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
      +0.100 |     DDD      CCC      BBBB     AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
      +0.075 |DDD      CCC      BBBB     AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
      +0.050 |DDD      CCC      BBBB     AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
      +0.025 |DD      CCC      BBBB     AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
      +0.000 |DD      CCC      BBB      AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
             \+---------+---------+---------+---------+---------+---------+
             +0.500     +0.667     +0.833     +1.000     +1.167     +1.333     +1.500


                                    GMS


   Legend:    +100.00=A    +104.00=B    +108.00=C    +112.00=D    +116.00=E
              +120.00=F    +124.00=G    +128.00=H    +132.00=I    +136.00=J
              +140.00=K
```

76

```
                         Response in VOLUME
                     (Stepping Variable: PGMS = 2)


     +1.000 |FFFFFFFFFFFFFFFFFFFFFFFFF        GGGGG     HHHH   IIII  JJJ
     +0.975 | FFFFFFFFFFFFFFFFFFFFFFFFF       GGGGGG    HHHH   III   JJJ
     +0.950 |  FFFFFFFFFFFFFFFFFFFFFFFF       GGGGGG    HHHH   III    JJ
     +0.925 |   FFFFFFFFFFFFFFFFFFFFFFFF      GGGGG     HHHH   III    JJ
     +0.900 |    FFFFFFFFFFFFFFFFFFFFFFFF     GGGGGG    HHHH   III     J
     +0.875 |     FFFFFFFFFFFFFFFFFFFFFFFF    GGGGG     HHHH   III
     +0.850 |      FFFFFFFFFFFFFFFFFFFFFFFF   GGGGG     HHHH   III
     +0.825 |       FFFFFFFFFFFFFFFFFFFFFFFF  GGGGGG    HHHH   III
     +0.800 |        FFFFFFFFFFFFFFFFFFFFFFFF GGGGGG    HHHH   III
     +0.775 |          FFFFFFFFFFFFFFFFFFFFFFFF GGGGG   HHHH   IIII
     +0.750 |           FFFFFFFFFFFFFFFFFFFFFFFF GGGGG  HHHH   III
     +0.725 |G          FFFFFFFFFFFFFFFFFFFFFFFF GGGGGG HHH     II
     +0.700 |GG          FFFFFFFFFFFFFFFFFFFFFFFFF GGGGGG HHHH    I
     +0.675 |GG           FFFFFFFFFFFFFFFFFFFFFFFFFF GGGGGG HHHH
     +0.650 |GGG           FFFFFFFFFFFFFFFFFFFFFFFFFF GGGGGG HHHH
     +0.625 |GGG            FFFFFFFFFFFFFFFFFFFFFFFFFFF GGGGGG  HHHH
     +0.600 |GGGG            FFFFFFFFFFFFFFFFFFFFFFFFFFF GGGGGG  HHHH
     +0.575 |GGGG             FFFFFFFFFFFFFFFFFFFFFFFFFFFF GGGGGG  HHHH
  L  +0.550 |GGGG              FFFFFFFFFFFFFFFFFFFFFFFFFFFFF GGGGGG  HHH
  E  +0.525 |GGGGG              FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF GGGGGG  HH
  C  +0.500 |GGGGG               FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF GGGGG   H
  I  +0.475 |GGGGG                FFFFFFFFFFF       FFFFFFFFFFFF    GGGGG
  T  +0.450 | GGGGG               FFFFFFFFFF        FFFFFFFFFFF     GGGGG
  H  +0.425 | GGGGG               FFFFFFFFFF        FFFFFFFFFF      GGGGG
  I  +0.400 | GGGGG               FFFFFFFFF          FFFFFFFFF      GGGGG
  N  +0.375 |  GGGG               FFFFFFFFF          FFFFFFFFF       GGGG
     +0.350 |  GGGG               FFFFFFFF            FFFFFFFF       GGG
     +0.325 |  GGGGG              FFFFFFFF            FFFFFFFF        GG
     +0.300 |  GGGGG              FFFFFFF              FFFFFFF         G
     +0.275 |   GGGG              FFFFFFF              FFFFFF
     +0.250 |   GGGG              FFFFFFF              FFFFFFF
     +0.225 |   GGGG              FFFFF      EEEEEEEEEE      FFFFFF
     +0.200 |   GGGG              FFFFF     EEEEEEEEEEEEEE      FFFFFF
     +0.175 |   GGGG              FFFFF    EEEEEEEEEEEEEEEEE     FFFFF
     +0.150 |    GGGG             FFFFF   EEEEEEEEEEEEEEEEEEEE     FFF
     +0.125 |    GGGG             FFFFF  EEEEEEEEEEEEEEEEEEEEEEE     F
     +0.100 |    GGGG             FFFFF EEEEEEEEEEEEEEEEEEEEEEEEEEE
     +0.075 |H   GGGG             FFFFF EEEEEEEEEEEE    EEEEEEEEEEEE
     +0.050 |H   GGGG             FFFFF EEEEEEEEE        EEEEEEEEEE
     +0.025 |H   GGGG             FFFFF EEEEEEEE          EEEEEEEEE
     +0.000 |H   GGGG             FFFF EEEEEEE              EEEEE
            \+---------+---------+---------+---------+---------+---------+
             +0.500    +0.667    +0.833    +1.000    +1.167    +1.333    +1.500

                                      GMS


  Legend:    +100.00=A   +104.00=B   +108.00=C   +112.00=D   +116.00=E
             +120.00=F   +124.00=G   +128.00=H   +132.00=I   +136.00=J
             +140.00=K
```

```
                            Response in VOLUME
                        (Stepping Variable: PGMS = 3)


      +1.000 |BBBBBBBBBBBBBBBBB        CCCCCC    DDDD    EEE    FFF   GG   H
      +0.975 |BBBBBBBBBBBBBBBB         CCCCCC    DDDD    EEE    FFF   GG   H
      +0.950 |                         CCCCCC    DDDDD   EEEE   FFF   GG
      +0.925 |                        CCCCCCCC   DDDD    EEEE   FFF   GG
      +0.900 |                       CCCCCCCCC   DDDDD   EEEE   FFF   GG
      +0.875 |CC                    CCCCCCCCCC   DDDDD   EEE    FFF   GG
      +0.850 |CCCCCCCCCCCCCCCCCCCCCCCCCCCC       DDDDD   EEEE   FFF   GG
      +0.825 |CCCCCCCCCCCCCCCCCCCCCCCCCCCC       DDDDDD  EEEE   FFF   GG
      +0.800 |CCCCCCCCCCCCCCCCCCCCCCCC           DDDDD   EEEE   FFFF  GG
      +0.775 |     CCCCCCCCCCCCCCCCC             DDDDDD  EEEE   FFFF  GGG
      +0.750 |          CCCC                     DDDDDD  EEEEE  FFFF  GGG
      +0.725 |                                  DDDDDDD  EEEE   FFFF  GGG
      +0.700 |DD                        DDDDDDDD          EEEE   FFFF  GGG
      +0.675 |DDDDD                    DDDDDDDD  EEEEE   FFFF  GGG
      +0.650 |DDDDDDDDD            DDDDDDDDDDD   EEEEE   FFFF  GGG
      +0.625 | DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD  EEEEE   FFFF  GGG
      +0.600 |   DDDDDDDDDDDDDDDDDDDDDDDDDDDDD   EEEEE   FFFF  GGG
      +0.575 |     DDDDDDDDDDDDDDDDDDDDDDDDD     EEEEE   FFFF  GGG
   L  +0.550 |        DDDDDDDDDDDDDDDDDDD        EEEEE   FFFF  GGGG
   E  +0.525 |EE         DDDDDDDDDDDDDD          EEEEEE  FFFF  GGGG
   C  +0.500 |EEEE           DDDDDD             EEEEEEE  FFFF  GGG
   I  +0.475 |EEEEE                             EEEEEEE  FFFF  GGG
   T  +0.450 | EEEEEEE                          EEEEEE   FFFF  GGG
   H  +0.425 |   EEEEEEE                        EEEEEEE  FFFFF GGG
   I  +0.400 |    EEEEEEEEE                     EEEEEEEE  FFFFF GGGG
   N  +0.375 |       EEEEEEEEE                 EEEEEEEEE  FFFFF GGGG
      +0.350 |F         EEEEEEEEEE              EEEEEEEEEE FFFFF GGGG
      +0.325 |FFF         EEEEEEEEEEEEEEEEEEEEEEEEEEEEEE  FFFFF  GGG
      +0.300 |FFFF        EEEEEEEEEEEEEEEEEEEEEEEEEEEEE   FFFFFF GGG
      +0.275 | FFFFF      EEEEEEEEEEEEEEEEEEEEEEEEEEEE    FFFFFF GGG
      +0.250 |  FFFFF     EEEEEEEEEEEEEEEEEEEEEEEEEEE     FFFFFF GGG
      +0.225 |   FFFFFF     EEEEEEEEEEEEEEEEEEEEEEEE      FFFFFF  GG
      +0.200 |    FFFFFF      EEEEEEEEEEEEEEEEEEE         FFFFFF  GG
      +0.175 |G    FFFFFF       EEEEEEEEEEEEEEEE          FFFFFF  GG
      +0.150 |GG     FFFFFF       EEEEEEEEEEEEE           FFFFFFF GG
      +0.125 |GGG      FFFFFF       EEEEEEEEEE            FFFFFFF  G
      +0.100 |GGGG      FFFFFFF           E               FFFFFFF  G
      +0.075 | GGGG      FFFFFFF                          FFFFFF   G
      +0.050 |  GGGG      FFFFFFF                         FFFFFFF
      +0.025 |   GGGG      FFFFFFF                        FFFFFFF
      +0.000 |   GGGG      FFFFFFF                        FFFFFFF
             \+---------+---------+---------+---------+---------+---------+
             +0.500     +0.667     +0.833     +1.000     +1.167     +1.333     +1.500


                                    GMS


   Legend:    +100.00=A   +104.00=B   +108.00=C   +112.00=D   +116.00=E
              +120.00=F   +124.00=G   +128.00=H   +132.00=I   +136.00=J
              +140.00=K
```

```
Analysis of Data File: CAKESCORE.RSM

Using Model: STD 3_VAR | C 1 2 3 12 23 13 11 22 33

Coefficient of Determination (R^2) =0.64586
Coefficient of Multiple Correlation =0.80366
Standard Error of Estimate     6.47671

EQUATION:
SCORE           =    +45.5882353
                     +45.5438092 * GMS
                     +30.6339869 * LECITHIN
                      -2.5006628 * PGMS
                     -17.9299420 * GMS * LECITHIN
                      +5.3440560 * LECITHIN * PGMS
                      +2.7320261 * GMS * PGMS
                     -20.9103341 * GMS * GMS
                      -8.3529412 * LECITHIN * LECITHIN
                      +0.7602633 * PGMS * PGMS
```

```
                          Response in SCORE
                       (Stepping Variable: PGMS = 1)


    +1.000  |GGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGG        FFFFFFF      EEEEE
    +0.975  |GGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGG        FFFFFFF      EEEE
    +0.950  |GGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGG        FFFFFF       EEEE
    +0.925  |GGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGG         FFFFFFF      EEEE
    +0.900  |GGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGG         FFFFFFF      EEE
    +0.875  | GGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGG         FFFFFFF      EEE
    +0.850  |  GGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGG         FFFFFFF      EEE
    +0.825  |    GGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGG         FFFFFFF      EEE
    +0.800  |     GGGGGGGGGGGGGGGGGGGGGGGGGGGGGG          FFFFFFF      EE
    +0.775  |       GGGGGGGGGGGGGGGGGGGGGGGGGGGG          FFFFFFFF     EE
    +0.750  |          GGGGGGGGGGGGGGGGGGGGGGGG           FFFFFFFF     EE
    +0.725  |            GGGGGGGGGGGGGGGGGGGG             FFFFFFFF     EE
    +0.700  |              GGGGGGGGGGGGG                  FFFFFFFFF    EE
    +0.675  |FF                                          FFFFFFFFF    EE
    +0.650  |FFF                                         FFFFFFFFF    EE
    +0.625  |FFFFF                                       FFFFFFFFFF   EE
    +0.600  |FFFFFFF                                     FFFFFFFFF    EE
    +0.575  |FFFFFFFFF                                   FFFFFFFFFF   EE
  L +0.550  |FFFFFFFFFFF                                 FFFFFFFFFFF  EE
  E +0.525  |  FFFFFFFFFFF                               FFFFFFFFFFFF EE
  C +0.500  |    FFFFFFFFFFFFF                           FFFFFFFFFFFF EE
  I +0.475  |      FFFFFFFFFFFFFF                        FFFFFFFFFFFFFFEE
  T +0.450  |        FFFFFFFFFFFFFFFF               FFFFFFFFFFFFFFFFFF EE
  H +0.425  |          FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF   EE
  I +0.400  |E         FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF    EE
  N +0.375  |EEE          FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF    EEE
    +0.350  |EEEE          FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF     EEE
    +0.325  |EEEEE           FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF      EEE
    +0.300  |EEEEEEE             FFFFFFFFFFFFFFFFFFFFFFFFFFFF        EEEE
    +0.275  |  EEEEEEEE              FFFFFFFFFFFFFFFFFFFFFFFF        EEEE
    +0.250  |   EEEEEEEEE                FFFFFFFFFFFFFFF            EEEEE
    +0.225  |     EEEEEEEEE                                        EEEEEE
    +0.200  |      EEEEEEEEE                                       EEEEEE
    +0.175  |D        EEEEEEEEEE                                   EEEEEEE
    +0.150  |DDD        EEEEEEEEEE                               EEEEEEEEE
    +0.125  |DDDD         EEEEEEEEEEE                            EEEEEEEEE
    +0.100  |DDDDDD          EEEEEEEEEEEE                     EEEEEEEEEEEE
    +0.075  | DDDDDDD           EEEEEEEEEEEEE                 EEEEEEEEEEEEEE
    +0.050  |  DDDDDD             EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE
    +0.025  |   DDDDDDD             EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE
    +0.000  |      DDDDDDD            EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE
            \+---------+---------+---------+---------+---------+---------+
             +0.500     +0.667     +0.833     +1.000     +1.167     +1.333     +1.500

                                    GMS


   Legend:     +50.00=A     +55.00=B     +60.00=C     +65.00=D     +70.00=E
               +75.00=F     +80.00=G     +85.00=H     +90.00=I     +95.00=J
               +100.00=K
```

80

```
                           Response in SCORE
                        (Stepping Variable: PGMS = 2)


      +1.000 |                                       HHHHHHHHH      GGGGGG
      +0.975 |                                       HHHHHHHHH      GGGGGG
      +0.950 |HH                                     HHHHHHHHHH     GGGGGG
      +0.925 |HHHHH                                  HHHHHHHHHHH    GGGGGG
      +0.900 |HHHHHHH                                HHHHHHHHHHH    GGGGGG
      +0.875 |HHHHHHHHH                              HHHHHHHHHHHH   GGGGGG
      +0.850 |HHHHHHHHHHH                          HHHHHHHHHHHHHH    GGGGGG
      +0.825 | HHHHHHHHHHHHHH                    HHHHHHHHHHHHHHHH   GGGGGGG
      +0.800 |    HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH         GGGGGGG
      +0.775 |      HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH         GGGGGGG
      +0.750 |       HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH          GGGGGGG
      +0.725 |        HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH          GGGGGGG
      +0.700 |G         HHHHHHHHHHHHHHHHHHHHHHHHHHHHHH           GGGGGGG
      +0.675 |GG         HHHHHHHHHHHHHHHHHHHHHHHHHHH            GGGGGGGG
      +0.650 |GGGG          HHHHHHHHHHHHHHHHHHHHH              GGGGGGGG
      +0.625 |GGGGG              HHHHHHHHH                    GGGGGGGG
      +0.600 |GGGGGGG                                        GGGGGGGGG
      +0.575 | GGGGGGGGG                                     GGGGGGGGG
  L   +0.550 |   GGGGGGGGG                                  GGGGGGGGG
  E   +0.525 |    GGGGGGGGGG                               GGGGGGGGG
  C   +0.500 |     GGGGGGGGGGGG                           GGGGGGGGGGGG
  I   +0.475 |F       GGGGGGGGGGGGGGG                    GGGGGGGGGGGGGG
  T   +0.450 |FFF         GGGGGGGGGGGGGGGGGG          GGGGGGGGGGGGGGGGG
  H   +0.425 |FFFF           GGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGG
  I   +0.400 |FFFFFF            GGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGG
  N   +0.375 | FFFFFFF            GGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGG
      +0.350 |  FFFFFFF               GGGGGGGGGGGGGGGGGGGGGGGGGGGG        F
      +0.325 |   FFFFFFFF                GGGGGGGGGGGGGGGGGGGGG           FF
      +0.300 |    FFFFFFFFF                 GGGGGGGGGG                  FFF
      +0.275 |E       FFFFFFFFF                                       FFFF
      +0.250 |EEE        FFFFFFFFFF                                  FFFFF
      +0.225 |EEEEE         FFFFFFFFFF                             FFFFFFF
      +0.200 |EEEEEEE          FFFFFFFFFFFF                       FFFFFFFFF
      +0.175 | EEEEE              FFFFFFFFFFFFFF               FFFFFFFFFFFF
      +0.150 |  EEEEEE               FFFFFFFFFFFFFFFFFF     FFFFFFFFFFFFFFFF
      +0.125 |    EEEEEE                 FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
      +0.100 |D       EEEEEEE                FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
      +0.075 |DDD        EEEEEEEE               FFFFFFFFFFFFFFFFFFFFFFFFFFFF
      +0.050 |DDDDD          EEEEEEEE              FFFFFFFFFFFFFFFFFFFFFF
      +0.025 | DDDDD             EEEEEEEE             FFFFFFFFFFFFF
      +0.000 |   DDDDD               EEEEEEEEE
             \+---------+---------+---------+---------+---------+---------+
             +0.500     +0.667     +0.833     +1.000     +1.167     +1.333     +1.500

                                      GMS


  Legend:      +50.00=A      +55.00=B      +60.00=C      +65.00=D      +70.00=E
               +75.00=F      +80.00=G      +85.00=H      +90.00=I      +95.00=J
               +100.00=K
```

81

```
                          Response in SCORE
                       (Stepping Variable: PGMS = 3)


      +1.000 |JJJJJJJJ                         JJJJJJJJJJJJ      IIIIII
      +0.975 |JJJJJJJJJJJ                      JJJJJJJJJJJJ      IIIIII
      +0.950 | JJJJJJJJJJJJJJJ                 JJJJJJJJJJJJJJJ    IIIIIII
      +0.925 |    JJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJ   IIIIIII
      +0.900 |       JJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJ    IIIIIII
      +0.875 |         JJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJ    IIIIIII
      +0.850 |           JJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJ     IIIIIIII
      +0.825 |II          JJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJ      IIIIIIII
      +0.800 |IIII           JJJJJJJJJJJJJJJJJJJJJJ          IIIIIIII
      +0.775 |IIIIIII           JJJJJJJJ                   IIIIIIIII
      +0.750 |IIIIIIIII                                   IIIIIIIIII
      +0.725 |  IIIIIIIIII                               IIIIIIIIII
      +0.700 |    IIIIIIIIIII                          IIIIIIIIIII
      +0.675 |      IIIIIIIIIIIII                    IIIIIIIIIIII
      +0.650 |         IIIIIIIIIIIIII             IIIIIIIIIIIIII
      +0.625 |HH          IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
      +0.600 |HHHH          IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
      +0.575 |HHHHH            IIIIIIIIIIIIIIIIIIIIIIIIIIIIIII         H
  L   +0.550 |  HHHHHHH            IIIIIIIIIIIIIIIIIIIIIIIIIII        HH
  E   +0.525 |    HHHHHHHH            IIIIIIIIIIIIIIIIIIIIII         HHH
  C   +0.500 |     HHHHHHHH              IIIIIIIIII               HHHH
  I   +0.475 |       HHHHHHHHH                                   HHHHH
  T   +0.450 |GG       HHHHHHHHHH                               HHHHHHH
  H   +0.425 |GGGG        HHHHHHHHHHH                         HHHHHHHHH
  I   +0.400 |GGGGGG         HHHHHHHHHHHH                    HHHHHHHHHHH
  N   +0.375 |  GGGGGG          HHHHHHHHHHHHHHH             HHHHHHHHHHHHH
      +0.350 |   GGGGGGG           HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH
      +0.325 |    GGGGGGG             HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH
      +0.300 |F       GGGGGGGG            HHHHHHHHHHHHHHHHHHHHHHHHHHHH
      +0.275 |FFF        GGGGGGGG           HHHHHHHHHHHHHHHHHHHHHHHH
      +0.250 |FFFFF         GGGGGGGG            HHHHHHHH
      +0.225 | FFFFFF         GGGGGGGGG
      +0.200 |  FFFFFF         GGGGGGGGGG                            G
      +0.175 |   FFFFFF         GGGGGGGGGGG                       GGGG
      +0.150 |E       FFFFFF        GGGGGGGGGGGGGG               GGGGGGGG
      +0.125 |EEE        FFFFFFF         GGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGG
      +0.100 |EEEEE         FFFFFFF        GGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGG
      +0.075 | EEEEE          FFFFFFF         GGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGG
      +0.050 |  EEEEE          FFFFFFFF         GGGGGGGGGGGGGGGGGGGGGG
      +0.025 |   EEEEEE          FFFFFFFFF          GGGGGG
      +0.000 |DD      EEEEE         FFFFFFFFF
             \+---------+---------+---------+---------+---------+---------+
            +0.500     +0.667     +0.833     +1.000     +1.167     +1.333     +1.500

                                      GMS

    Legend:      +50.00=A     +55.00=B     +60.00=C     +65.00=D     +70.00=E
                 +75.00=F     +80.00=G     +85.00=H     +90.00=I     +95.00=J
                +100.00=K
```

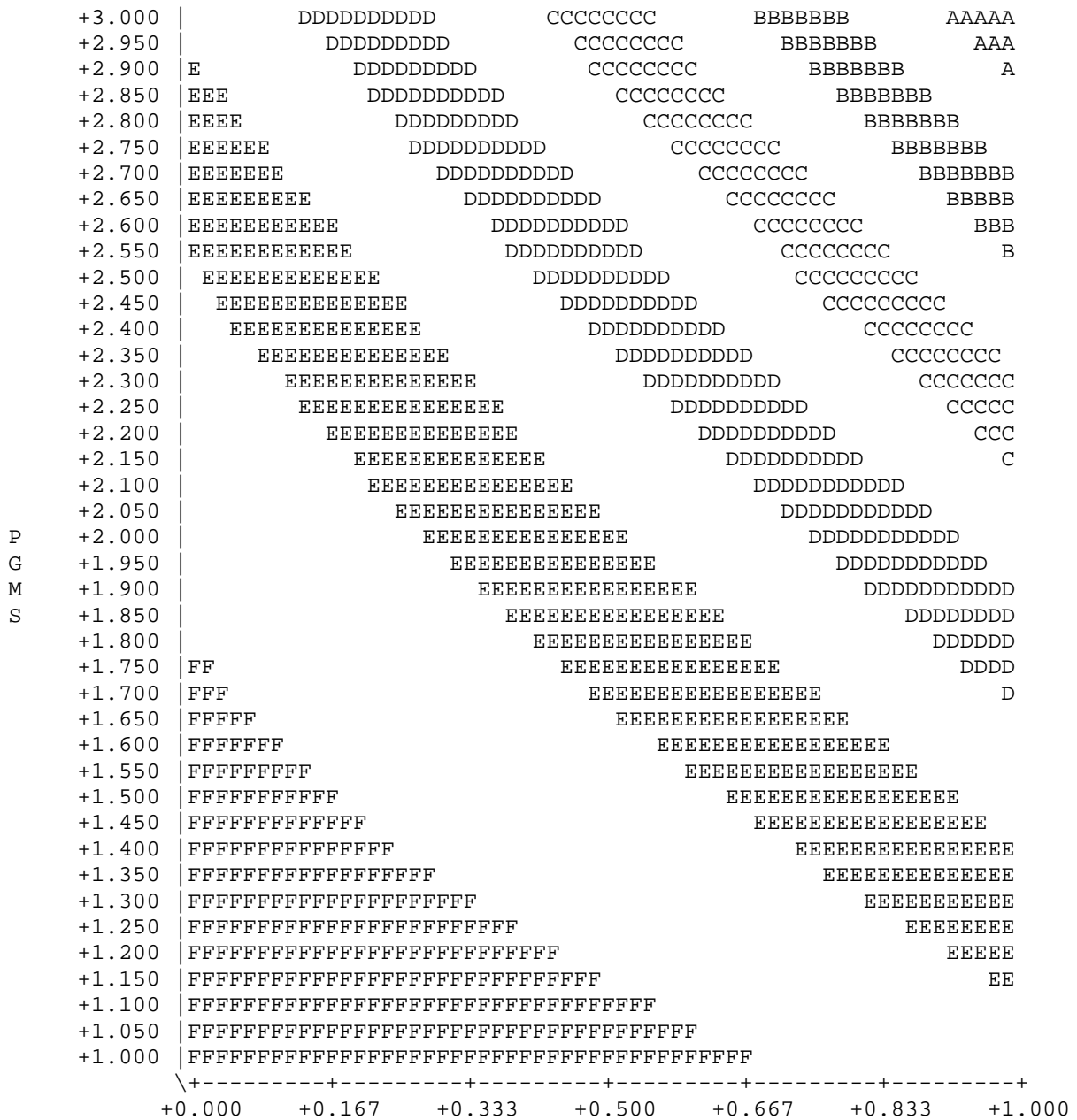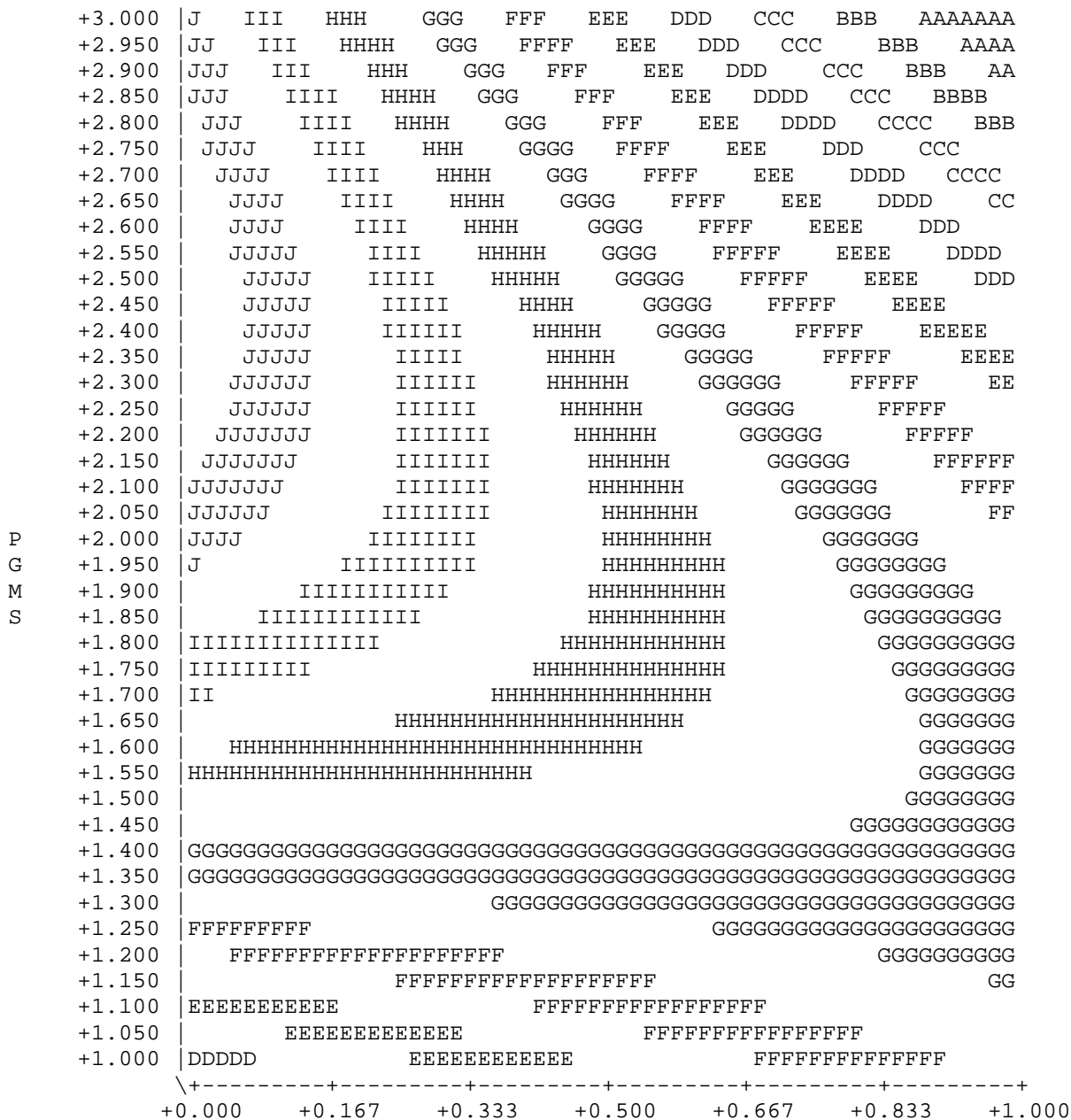82

```
Analysis of Data File: CAKE0109.RSM

Using Model: STD 3_VAR | C 1 2 3 12 23 13 11 22 33

Coefficient of Determination (R^2) =0.70180
Coefficient of Multiple Correlation =0.83774
Standard Error of Estimate     37.40268

EQUATION:
FIRM-1          =    +657.1111111
                      -36.8087927 * PGMS
                     -703.4935258 * GMS
                      +62.3333333 * LECITHIN
                      +42.6666667 * PGMS * GMS
                      +45.2640770 * GMS * LECITHIN
                      -58.6320385 * PGMS * LECITHIN
                       -6.8160192 * PGMS * PGMS
                     +280.5974103 * GMS * GMS
                      -46.0000000 * LECITHIN * LECITHIN
```

```
                          Response in FIRM-1
                      (Stepping Variable: LECITHIN = 0)

    +1.500  |DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
    +1.475  |    DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
    +1.450  |                          DDDD
    +1.425  |
    +1.400  |
    +1.375  |
    +1.350  |                                                CCCCCCCC
    +1.325  |                                             CCCCCCCCCCCCCCCC
    +1.300  |                                          CCCCCCCCCCCCCCCCCCCCCCC
    +1.275  |                                       CCCCCCCCCCCCCCCCCCCCCCCCCCCC
    +1.250  |                                   CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
    +1.225  |                               CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
    +1.200  |CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
    +1.175  |CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
    +1.150  |CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
    +1.125  |   CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
    +1.100  |      CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
    +1.075  |        CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
    +1.050  |        CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
    +1.025  |        CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
G   +1.000  |          CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
M   +0.975  |           CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
S   +0.950  |            CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
    +0.925  |             CCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
    +0.900  |             CCCCCCCCCCCCCCCCCCCCCCCCCCCCC
    +0.875  |D            CCCCCCCCCCCCCCCCCCCCCCCCCCC
    +0.850  |DDDDDDDD        CCCCCCCCCCCCCCCCCCCCCCCC
    +0.825  |DDDDDDDDDDDDDD      CCCCCCCCCCCCCCCCCCC
    +0.800  |DDDDDDDDDDDDDDDDDDDD      CCCCCCCCCCCCC
    +0.775  |DDDDDDDDDDDDDDDDDDDDDDDDD      CCCCCCCCCCC
    +0.750  |   DDDDDDDDDDDDDDDDDDDDDDDDDDDDD      CCCCCCCCC
    +0.725  |         DDDDDDDDDDDDDDDDDDDDDDDDDD        CCCCCC
    +0.700  |            DDDDDDDDDDDDDDDDDDDDDDDD          CCC
    +0.675  |              DDDDDDDDDDDDDDDDDDDDDDD
    +0.650  |EEEE            DDDDDDDDDDDDDDDDDDDDD
    +0.625  |EEEEEEEEEEEE         DDDDDDDDDDDDDDDDD
    +0.600  |EEEEEEEEEEEEEEEEEE         DDDDDDDDDDDDDD
    +0.575  |  EEEEEEEEEEEEEEEEEEEEEEE         DDDDDDDDDDDDD
    +0.550  |       EEEEEEEEEEEEEEEEEEEEE          DDDDDDDDDDD
    +0.525  |            EEEEEEEEEEEEEEEEEEE           DDDDDDDD
    +0.500  |FFFF             EEEEEEEEEEEEEEEEEE             DDD
            \+---------+---------+---------+---------+---------+---------+
            +1.000     +1.333     +1.667     +2.000     +2.333     +2.667     +3.000

                                    PGMS

    Legend:    +100.00=A   +150.00=B   +200.00=C   +250.00=D   +300.00=E
               +350.00=F   +400.00=G   +450.00=H   +500.00=I   +550.00=J
               +600.00=K
```

84

```
                        Response in FIRM-1
                   (Stepping Variable: LECITHIN = .5)


    +1.500 |       DDDDDDDDDDDDDDDDDDDDDDDDDDD            CCCC
    +1.475 |DDDDDDDDDDDDDDDDDDDDDDDDDDDDDD           CCCCCCCCC
    +1.450 |DDDDDDDDDDDDDDDDDDDDDDDDD           CCCCCCCCCCCCC
    +1.425 |DDDDDDDDDDDDDDDDDDD            CCCCCCCCCCCCCCCCC
    +1.400 |DDDDDDDDDDDDD             CCCCCCCCCCCCCCCCCC
    +1.375 |DDDDDDDD             CCCCCCCCCCCCCCCCCC
    +1.350 |DDDDD            CCCCCCCCCCCCCCCCCCC
    +1.325 |DD           CCCCCCCCCCCCCCCCCCC
    +1.300 |          CCCCCCCCCCCCCCCCCCC            B
    +1.275 |         CCCCCCCCCCCCCCCCCCC          BBB
    +1.250 |        CCCCCCCCCCCCCCCCCCC         BBBBBB
    +1.225 |       CCCCCCCCCCCCCCCCCCC         BBBBBBB
    +1.200 |      CCCCCCCCCCCCCCCCCCC         BBBBBBBB
    +1.175 |     CCCCCCCCCCCCCCCCCCC         BBBBBBBBBB
    +1.150 |     CCCCCCCCCCCCCCCCCCC         BBBBBBBBBBB
    +1.125 |    CCCCCCCCCCCCCCCCCCC         BBBBBBBBBBBB
    +1.100 |    CCCCCCCCCCCCCCCCCCC         BBBBBBBBBBBB
    +1.075 |    CCCCCCCCCCCCCCCCCC         BBBBBBBBBBBB
    +1.050 |    CCCCCCCCCCCCCCCCC         BBBBBBBBBBBB
    +1.025 |    CCCCCCCCCCCCCCCC         BBBBBBBBBBB
G   +1.000 |     CCCCCCCCCCCCCCCC         BBBBBBBBBBB
M   +0.975 |     CCCCCCCCCCCCCCC         BBBBBBBBBBB
S   +0.950 |D      CCCCCCCCCCCCCC         BBBBBBBBBBB
    +0.925 |DDD      CCCCCCCCCCCCCC         BBBBBBBBBB
    +0.900 |DDDDD      CCCCCCCCCCCCC         BBBBBBBBBB
    +0.875 |DDDDDDD      CCCCCCCCCCCCC         BBBBBBBBBBB
    +0.850 |DDDDDDDDD       CCCCCCCCCCCCC        BBBBBBBBBB
    +0.825 |DDDDDDDDDDD       CCCCCCCCCCCC        BBBBBBBB
    +0.800 |DDDDDDDDDDDDDD       CCCCCCCCCCC        BBBBBBB
    +0.775 |  DDDDDDDDDDDDDD       CCCCCCCCCCC        BBBBBB
    +0.750 |    DDDDDDDDDDDDDD       CCCCCCCCCCC       BBBBBB
    +0.725 |     DDDDDDDDDDDD       CCCCCCCCCCC        BBBB
    +0.700 |       DDDDDDDDDDDD      CCCCCCCCCC        BB
    +0.675 |E        DDDDDDDDDDD       CCCCCCCCC        B
    +0.650 |EEEE       DDDDDDDDDDD       CCCCCCCCC
    +0.625 |EEEEEEEE       DDDDDDDDDDD      CCCCCCCCC
    +0.600 |EEEEEEEEEEEE       DDDDDDDDDD      CCCCCCCCC
    +0.575 |  EEEEEEEEEEEEE       DDDDDDDDDD      CCCCCCCCC
    +0.550 |     EEEEEEEEEEE       DDDDDDDDDD      CCCCCCCCC
    +0.525 |       EEEEEEEEEEE       DDDDDDDDD      CCCCCCC
    +0.500 |FFF         EEEEEEEEEE       DDDDDDDDD      CCCCC
           \+---------+---------+---------+---------+---------+---------+
            +1.000     +1.333     +1.667     +2.000     +2.333     +2.667     +3.000


                                    PGMS


    Legend:    +100.00=A    +150.00=B    +200.00=C    +250.00=D    +300.00=E
               +350.00=F    +400.00=G    +450.00=H    +500.00=I    +550.00=J
               +600.00=K
```

85

```
                         Response in FIRM-1
                    (Stepping Variable: LECITHIN = 1)

     +1.500 |    DDDDDDDDDDDDDD           CCCCCCCCCCCC              BBBBB
     +1.475 |DDDDDDDDDDDDDDD           CCCCCCCCCCCCC            BBBBBBB
     +1.450 |DDDDDDDDDDD            CCCCCCCCCCCC            BBBBBBBBB
     +1.425 |DDDDDDDD            CCCCCCCCCCCCC           BBBBBBBBB
     +1.400 |DDDDDD           CCCCCCCCCCCC           BBBBBBBBBB
     +1.375 |DDDD          CCCCCCCCCCCCC          BBBBBBBBB
     +1.350 |D           CCCCCCCCCCCC          BBBBBBBBB           A
     +1.325 |          CCCCCCCCCCCC         BBBBBBBBB          AAA
     +1.300 |         CCCCCCCCCCCCC        BBBBBBBBB         AAAAA
     +1.275 |        CCCCCCCCCCCC        BBBBBBBBBB        AAAAAAA
     +1.250 |       CCCCCCCCCCCC       BBBBBBBBB        AAAAAAAA
     +1.225 |       CCCCCCCCCCCC       BBBBBBBBBB       AAAAAAAAAA
     +1.200 |      CCCCCCCCCCCC       BBBBBBBBB       AAAAAAAAAAA
     +1.175 |      CCCCCCCCCCC       BBBBBBBBB       AAAAAAAAAAAA
     +1.150 |      CCCCCCCCCCCC      BBBBBBBBBB      AAAAAAAAAAAAA
     +1.125 |     CCCCCCCCCCC       BBBBBBBBB       AAAAAAAAAAAAA
     +1.100 |     CCCCCCCCCCC      BBBBBBBBB       AAAAAAAAAAAAA
     +1.075 |     CCCCCCCCCCC      BBBBBBBBB       AAAAAAAAAAAAAA
     +1.050 |     CCCCCCCCCCC      BBBBBBBBB       AAAAAAAAAAAAAA
     +1.025 |     CCCCCCCCCCC      BBBBBBBBB       AAAAAAAAAAAAAAA
   G +1.000 |     CCCCCCCCCCC      BBBBBBBBB       AAAAAAAAAAAAAAA
   M +0.975 |      CCCCCCCCCC      BBBBBBBBB       AAAAAAAAAAAAAAA
   S +0.950 |      CCCCCCCCCC      BBBBBBBBB       AAAAAAAAAAAAAAA
     +0.925 |      CCCCCCCCCC      BBBBBBBBB       AAAAAAAAAAAAAA
     +0.900 |       CCCCCCCCC      BBBBBBBB        AAAAAAAAAAAAAA
     +0.875 |       CCCCCCCCC      BBBBBBBBB       AAAAAAAAAAAAAA
     +0.850 |D        CCCCCCCCC      BBBBBBBBB       AAAAAAAAAAAAA
     +0.825 |DD        CCCCCCCCC      BBBBBBBB       AAAAAAAAAAAAA
     +0.800 |DDDD        CCCCCCCCC      BBBBBBBB       AAAAAAAAAAAA
     +0.775 |DDDDD        CCCCCCCCC      BBBBBBBB       AAAAAAAAAAA
     +0.750 |DDDDDDD        CCCCCCCCC      BBBBBBBB       AAAAAAAAAA
     +0.725 |DDDDDDDDD       CCCCCCCC       BBBBBB        AAAAAAAAA
     +0.700 |  DDDDDDDDD        CCCCCCCC       BBBBBBB       AAAAAAAA
     +0.675 |    DDDDDDDDD        CCCCCCCC       BBBBBBB       AAAAAAAA
     +0.650 |     DDDDDDDDD        CCCCCCCC       BBBBBB       AAAAAAA
     +0.625 |       DDDDDDDDD        CCCCCCCC       BBBBBBBB       AAAAA
     +0.600 |EE         DDDDDDDDD        CCCCCCC       BBBBBB        AAAA
     +0.575 |EEEE          DDDDDDDD        CCCCCC        BBBBBBBB       AAA
     +0.550 |EEEEEEE          DDDDDDDD        CCCCCCC       BBBBBB        A
     +0.525 | EEEEEEE          DDDDDDDD        CCCCCCC       BBBBBB
     +0.500 |   EEEEEEEEE          DDDDDD        CCCCCCC       BBBBB
             \+---------+---------+---------+---------+---------+---------+
             +1.000     +1.333     +1.667     +2.000     +2.333     +2.667     +3.000

                                   PGMS

  Legend:    +100.00=A   +150.00=B   +200.00=C   +250.00=D   +300.00=E
             +350.00=F   +400.00=G   +450.00=H   +500.00=I   +550.00=J
             +600.00=K
```
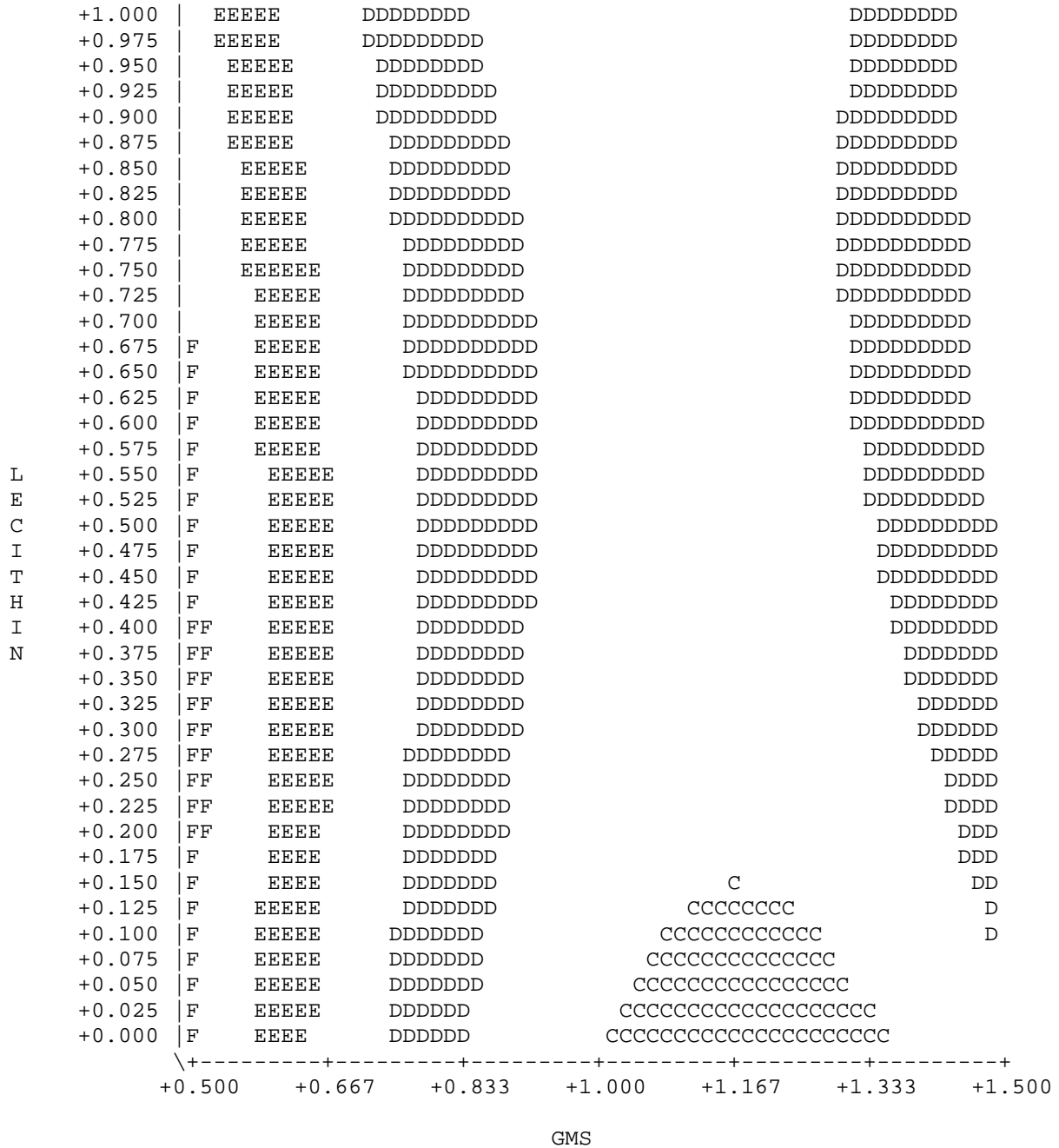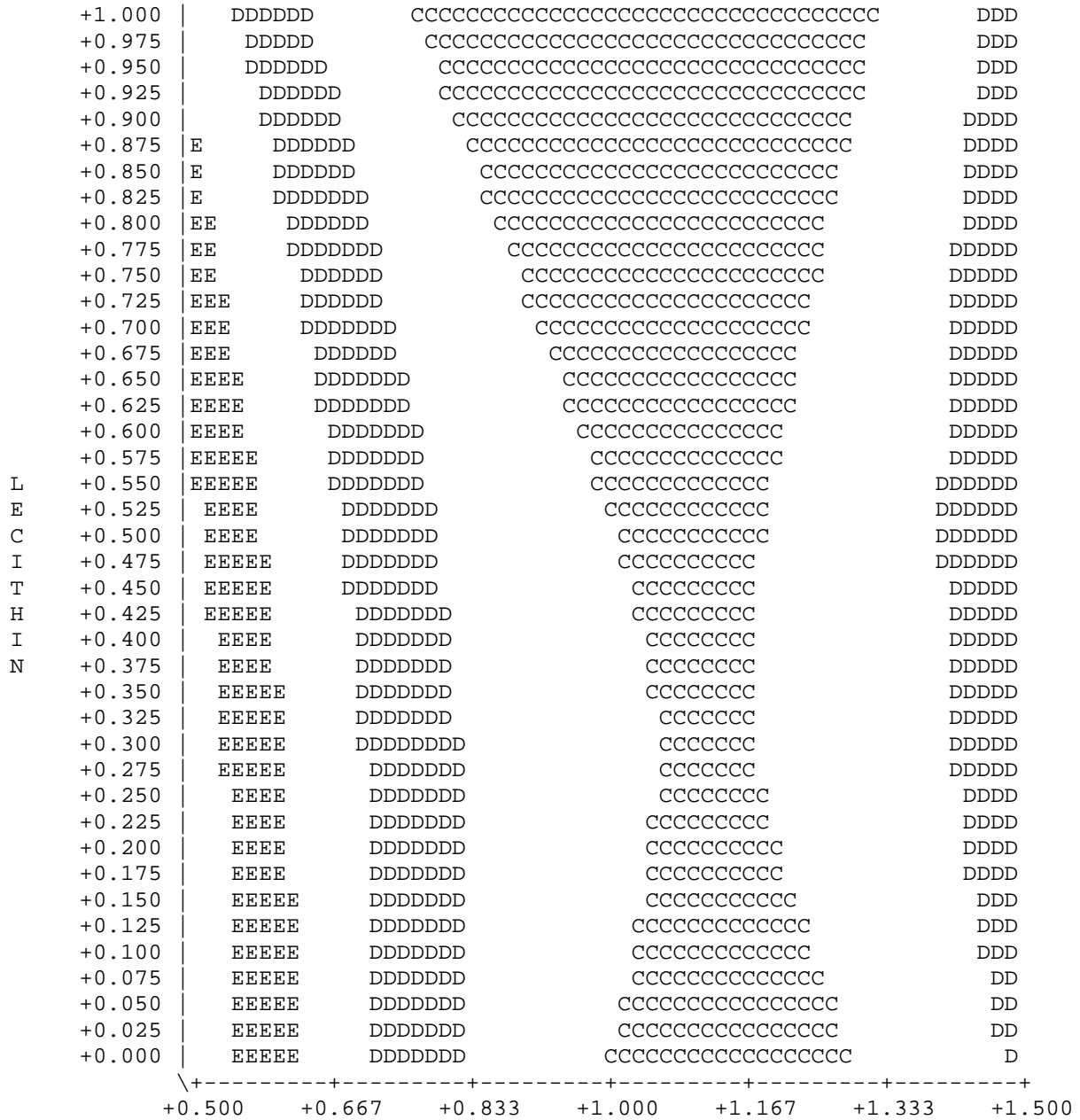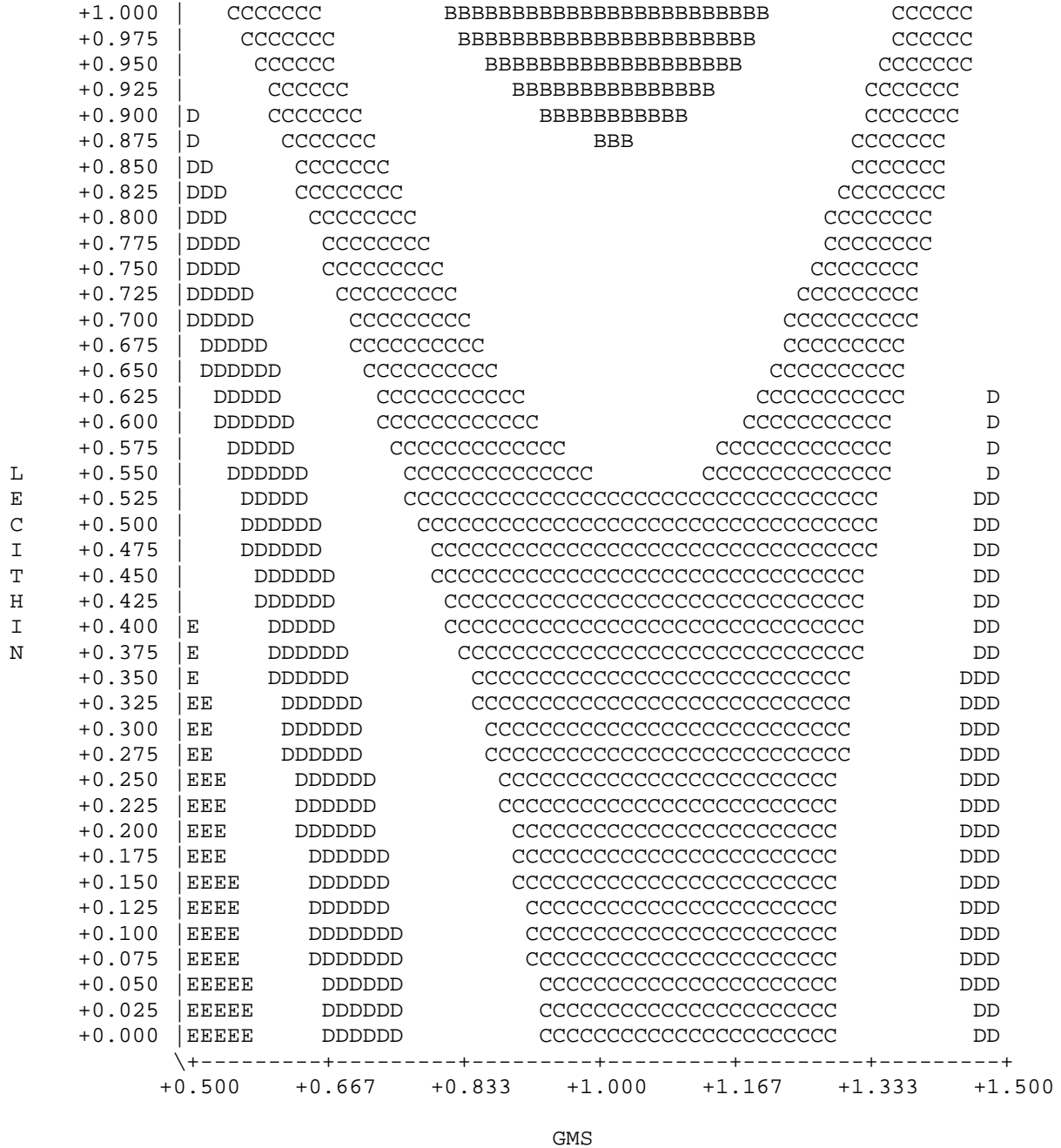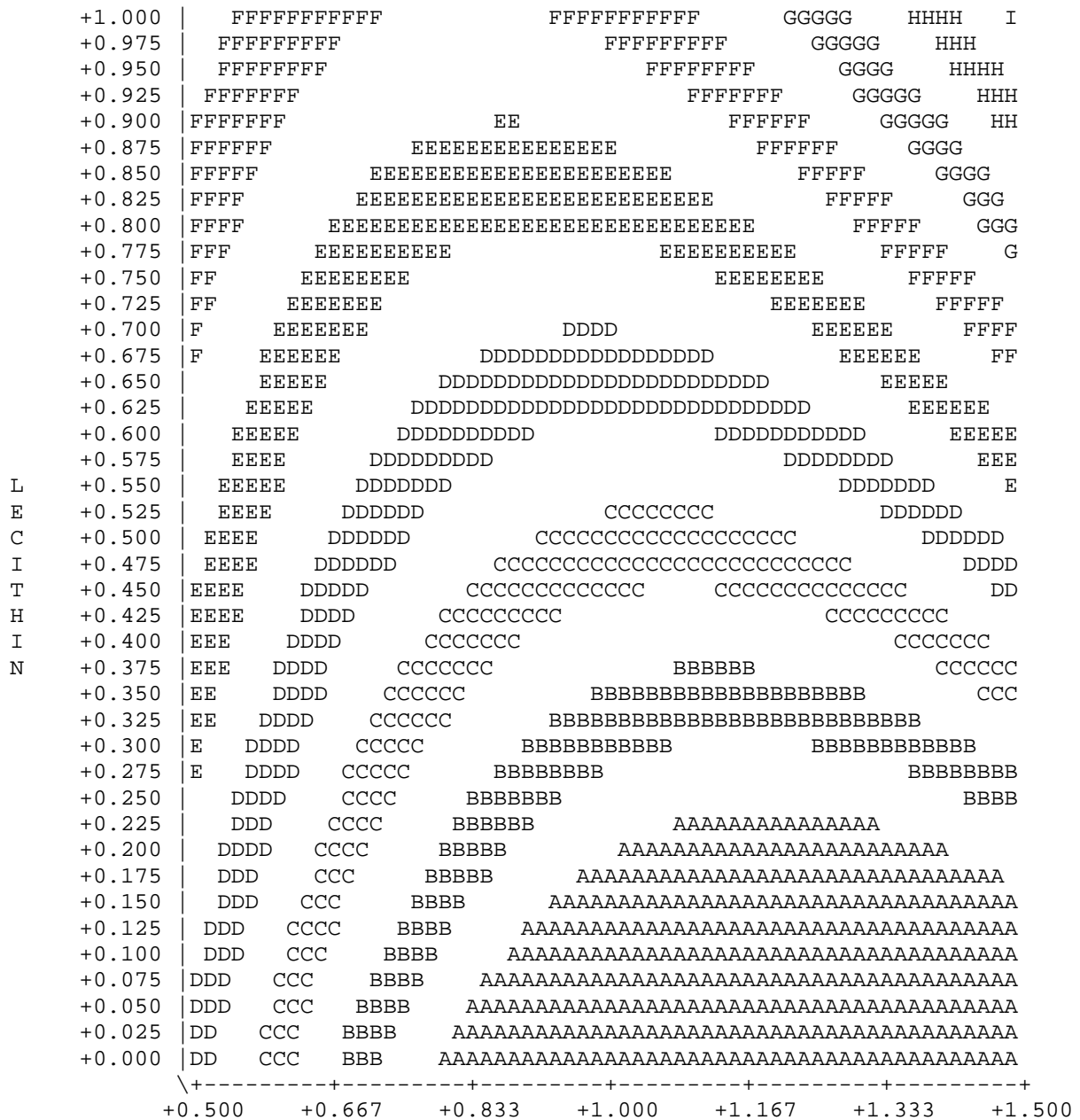
86

```
Analysis of Data File: CAKVOL01.RSM

Using Model: STD 3_VAR | C 1 2 3 12 23 13 11 22 33

Coefficient of Determination (R^2) =0.51182
Coefficient of Multiple Correlation =0.71542
Standard Error of Estimate    4.40101

EQUATION:
VOLUME          =    +115.3845316
                      +31.7003734 * PGMS
                      -73.3027076 * GMS
                      +14.2265795 * LECITHIN
                       +6.8801743 * PGMS * GMS
                      +24.2457018 * GMS * LECITHIN
                      -14.4845067 * PGMS * LECITHIN
                       -7.1540180 * PGMS * PGMS
                      +25.2653096 * GMS * GMS
                       -2.1307190 * LECITHIN * LECITHIN
```

87

```
                        Response in VOLUME
                    (Stepping Variable: LECITHIN = 0)

    +1.500 |AAAAAAA    BBB     CCCC     DDDDD      EEEEEEEEE
    +1.475 |AAAAAAA    BBB     CCCC     DDDDD      EEEEEEEEEE
    +1.450 |AAAAAAA    BBBB    CCCC     DDDDDD      EEEEEEEEEEEE
    +1.425 |AAAAAAA    BBB     CCCC     DDDDD       EEEEEEEEEEEEEEEEEEE
    +1.400 |AAAAAAAA   BBB     CCCCC    DDDDD        EEEEEEEEEEEEEEEEEEE
    +1.375 |AAAAAAAA   BBBB    CCCC     DDDDDD       EEEEEEEEEEEEEEEEE
    +1.350 |AAAAAAAA   BBBB    CCCC     DDDDDD       EEEEEEEEEEEEEEEE
    +1.325 |AAAAAAAA   BBBB    CCCCC    DDDDDDD       EEEEEEEEEEEEEE
    +1.300 |AAAAAAAA    BBB    CCCCC    DDDDDDD        EEEEEEEEEEEE
    +1.275 |AAAAAAAA    BBB    CCCCC    DDDDDDD         EEEEEEEEEE
    +1.250 |AAAAAAAA    BBB     CCCC    DDDDDDD
    +1.225 |AAAAAAAA    BBB     CCCC    DDDDDDDD
    +1.200 |AAAAAAAA   BBBB     CCCC    DDDDDDDD
    +1.175 |AAAAAAAA   BBBB    CCCCC    DDDDDDDD
    +1.150 |AAAAAAAA   BBBB    CCCCC    DDDDDDDD
    +1.125 |AAAAAAA    BBBB    CCCCC    DDDDDDDD
    +1.100 |AAAAAAA     BBB    CCCCC    DDDDDDDD
    +1.075 |AAAAAAA    BBBB    CCCCC    DDDDDDDDD
    +1.050 |AAAAAA     BBBB    CCCCC    DDDDDDD
    +1.025 |AAAAAA     BBBB    CCCCC    DDDDDDD
 G  +1.000 |AAAAA      BBBB    CCCCC    DDDDDDD
 M  +0.975 |AAAAA      BBBB    CCCCC    DDDDDDDD
 S  +0.950 |AAAA       BBBB    CCCCC    DDDDDDD
    +0.925 |AAAA       BBBB    CCCCC    DDDDDDD
    +0.900 |AAA        BBBB    CCCCC    DDDDDDD             EEEEE
    +0.875 |AA         BBB     CCCC     DDDDDDD           EEEEEEEEEEEE
    +0.850 |AA         BBBB    CCCC     DDDDD           EEEEEEEEEEEEEEE
    +0.825 |A          BBBB    CCCC     DDDDD          EEEEEEEEEEEEEEEEEEE
    +0.800 |           BBBB    CCCC     DDDDDDD        EEEEEEEEEEEEEEEEEEEEEE
    +0.775 |           BBBB    CCCC     DDDDD         EEEEEEEEEEEEEEEEEEEEEEEE
    +0.750 |           BBBB    CCCC     DDDDD         EEEEEEEEEEEEEEEEEEEEEEEEEE
    +0.725 |BBBB       CCCC    DDDDD       EEEEEEEEEEEEEEE     EEEEEEEEEE
    +0.700 |BBB        CCCC    DDDDD       EEEEEEEEEEE                EEEEE
    +0.675 |BB        CCCC     DDDDD      EEEEEEEEEE                      EE
    +0.650 |B         CCCC     DDDDD      EEEEEEEE
    +0.625 |          CCCC     DDDDD      EEEEEEE
    +0.600 |          CCC      DDDD      EEEEEEE           FFFFFFFFFFFFF
    +0.575 |CCCC       DDDDD     EEEEE         FFFFFFFFFFFFFFFFFFFFFFF
    +0.550 |CCC        DDDD     EEEEE       FFFFFFFFFFFFFFFFFFFFFFFFFFFFF
    +0.525 |C         DDDD     EEEEE      FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
    +0.500 |          DDDD     EEEEE        FFFFFFFFFFF                FFFFFF
           \+--------+--------+--------+--------+--------+--------+
          +1.000    +1.333    +1.667    +2.000    +2.333    +2.667    +3.000

                                 PGMS

    Legend:    +100.00=A    +105.00=B    +110.00=C    +115.00=D    +120.00=E
               +125.00=F    +130.00=G    +135.00=H    +140.00=I    +145.00=J
               +150.00=K
```

```
                            Response in VOLUME
                     (Stepping Variable: LECITHIN = .5)


    +1.500 | DDDD     EEEEE     FFFFFFFF                              F
    +1.475 |  DDDD     EEEEE      FFFFFFFFFF                       FFFFF
    +1.450 |   DDDD     EEEEEE      FFFFFFFFFFFF                FFFFFFFFFFFF
    +1.425 |    DDDDD     EEEEEE      FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
    +1.400 |     DDDD      EEEEEE      FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
    +1.375 |C    DDDD      EEEEEE       FFFFFFFFFFFFFFFFFFFFFFFF
    +1.350 |C    DDDDD      EEEEEEE        FFFFFFFFFF
    +1.325 |CC    DDDDD     EEEEEEE                                    EEE
    +1.300 |CC     DDDDD    EEEEEEEE                                  EEEEE
    +1.275 |CCC    DDDDD     EEEEEEEEE                              EEEEEEEE
    +1.250 |CCC     DDDDD    EEEEEEEEEEE                          EEEEEEEEEEE
    +1.225 |CCCC    DDDDDD    EEEEEEEEEEEE                      EEEEEEEEEEEE
    +1.200 |CCCC     DDDDD     EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE
    +1.175 |CCCC     DDDDDD    EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE
    +1.150 |CCCC     DDDDDDD    EEEEEEEEEEEEEEEEEEEEEEEEEEEEEE
    +1.125 |CCCCC     DDDDDD    EEEEEEEEEEEEEEEEEEEEEEEEEEE
    +1.100 |CCCCC     DDDDDD     EEEEEEEEEEEEEEEEEEEEEEE          D
    +1.075 |CCCCC     DDDDDDD    EEEEEEEEEEEEEEEEEEEEE           DD
    +1.050 |CCCCC     DDDDDD     EEEEEEEEEEEEEEEEEEE           DDD
    +1.025 |CCCCC     DDDDDDD     EEEEEEEEEEEEEEEE            DDDD
G   +1.000 |CCCCC     DDDDDDD     EEEEEEEEEEEEEE            DDDDD
M   +0.975 |CCCCC     DDDDDDD      EEEEEEEEEEE             DDDDD
S   +0.950 |CCCC      DDDDDDD      EEEEEEEEEE             DDDDDD
    +0.925 |CCCC      DDDDDDD      EEEEEEEEE             DDDDDD
    +0.900 |CCCC      DDDDDDD      EEEEEEEEEE            DDDDDDD
    +0.875 |CCC       DDDDDDD      EEEEEEEEEE            DDDDDDD
    +0.850 |CCC       DDDDDDD      EEEEEEEEEEE           DDDDDDD
    +0.825 |CC        DDDDDDD      EEEEEEEEEEEEE         DDDDDDD
    +0.800 |C         DDDDDDD      EEEEEEEEEEEEEEE       DDDDDDD
    +0.775 |C         DDDDDDD      EEEEEEEEEEEEEEEEEE     DDDDDDD
    +0.750 |          DDDDDDD      EEEEEEEEEEEEEEEEEEE    DDDDDDD
    +0.725 |          DDDDDDD      EEEEEEEEEEEEEEEEEEEE    DDDDDD
    +0.700 |          DDDDDDD     EEEEEEEEEEEEEEEEEEEEEEE   DDDDDD
    +0.675 |          DDDDD      EEEEEEEEEEEEEEEEEEEEEEEE    DDDDD
    +0.650 |          DDDDD     EEEEEEEEEEEEEEEEEEEEEEEEEEE   DDDDD
    +0.625 |DDDDD      EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE      DDDD
    +0.600 |DDDD       EEEEEEEEEEE                EEEEEEEEEEE   DDD
    +0.575 |DDD        EEEEEEEEE                  EEEEEEEEEE    DDD
    +0.550 |D          EEEEEEEE                   EEEEEEEEE    DD
    +0.525 |           EEEEEEE                     EEEEEEE     D
    +0.500 |           EEEEEEEE                    EEEEEEEE    D
           \+---------+---------+---------+---------+---------+---------+
          +1.000     +1.333     +1.667     +2.000     +2.333     +2.667     +3.000


                                    PGMS


   Legend:    +100.00=A    +105.00=B    +110.00=C    +115.00=D    +120.00=E
              +125.00=F    +130.00=G    +135.00=H    +140.00=I    +145.00=J
              +150.00=K
```

```
                              Response in VOLUME
                          (Stepping Variable: LECITHIN = 1)


    +1.500 |GGGG         HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH           GGGGG
    +1.475 |GGGGGG           HHHHHHHHHHHHHHHHHHHHHHHHHHHHHH           GGGGGG
    +1.450 |  GGGGGGG              HHHHHHHHHHHHH            GGGGGGG         F
    +1.425 |    GGGGGGGG                             GGGGGGGG          FFF
    +1.400 |      GGGGGGGGGG                         GGGGGGGGGG       FFFFFF
    +1.375 |F        GGGGGGGGGGGGGGG          GGGGGGGGGGGGGGG        FFFFF
    +1.350 |FFF          GGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGG        FFFFFF
    +1.325 |FFFFF            GGGGGGGGGGGGGGGGGGGGGGGGGGGG         FFFFFF        E
    +1.300 |FFFFFFF              GGGGGGGGGGGGG              FFFFFFF        EEE
    +1.275 | FFFFFFFF                                  FFFFFFFF        EEEEE
    +1.250 |  FFFFFFFFF                              FFFFFFFFF        EEEEE
    +1.225 |    FFFFFFFFFF                          FFFFFFFFFFF       EEEEEE
    +1.200 |      FFFFFFFFFFFFF              FFFFFFFFFFFFFFF        EEEEEE
    +1.175 |       FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF        EEEEE        DD
    +1.150 |E         FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF        EEEEEE       DDD
    +1.125 |EE           FFFFFFFFFFFFFFFFFFFFFFFFFFFFFF        EEEEE        DDDD
    +1.100 |EEE             FFFFFFFFFFFFFFFFFFFF        EEEEEE       DDDDD
    +1.075 |EEEE                FFFFFFFF              EEEEEEE       DDDDD
    +1.050 |EEEEE                                    EEEEEEEE       DDDDD
    +1.025 |EEEEE                                    EEEEEEE       DDDDD
G   +1.000 |EEEEEE                              EEEEEEE       DDDDD       C
M   +0.975 |EEEEEEEE                            EEEEEEEE       DDDDD      CC
S   +0.950 |EEEEEEEEEE                          EEEEEEEEE       DDDDD      CCC
    +0.925 |EEEEEEEEEEE                         EEEEEEEEEE       DDDDD      CCC
    +0.900 |EEEEEEEEEEEE                        EEEEEEEEEEE       DDDDD      CCCC
    +0.875 | EEEEEEEEEEEE                     EEEEEEEEEEEE       DDDDD      CCCC
    +0.850 | EEEEEEEEEEEEEE                 EEEEEEEEEEEEE       DDDDD      CCCC
    +0.825 | EEEEEEEEEEEEEEEE     EEEEEEEEEEEEEEEE       DDDDD      CCCC
    +0.800 | EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE       DDDDDD      CCCC
    +0.775 |EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE       DDDDD      CCCC
    +0.750 |EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE       DDDDDD      CCCC
    +0.725 |EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE       DDDDDD      CCCCC
    +0.700 |EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE       DDDDD       CCCC
    +0.675 |EEEEEEEEEEE         EEEEEEEEEEEE       DDDDD       CCCC
    +0.650 |EEEEEEEEEE           EEEEEEEEEEE       DDDDD       CCCC
    +0.625 |EEEEEEEE              EEEEEEEEEEE       DDDDD       CCCC
    +0.600 |EEEEEEE                EEEEEEEEEE       DDDDD       CCCC       B
    +0.575 |EEEEE                  EEEEEEEEE       DDDDD       CCCC       B
    +0.550 |EEE                    EEEEEEEEE       DDDDD       CCCC       B
    +0.525 |E                      EEEEEEEEE       DDDDDD      CCCC
    +0.500 |                       EEEEEEEEE       DDDDD       CCCC
           \+---------+---------+---------+---------+---------+---------+
           +1.000     +1.333     +1.667     +2.000     +2.333     +2.667     +3.000

                                       PGMS


   Legend:    +100.00=A    +105.00=B    +110.00=C    +115.00=D    +120.00=E
              +125.00=F    +130.00=G    +135.00=H    +140.00=I    +145.00=J
              +150.00=K
```

```
Analysis of Data File: CAKSCORE.RSM

Using Model: STD 3_VAR | C 1 2 3 12 23 13 11 22 33

Coefficient of Determination (R^2) =0.64586
Coefficient of Multiple Correlation =0.80366
Standard Error of Estimate     6.47671

EQUATION:
SCORE           =    +45.5882353
                      -2.0951846 * PGMS
                     +44.7328528 * GMS
                     +30.6339869 * LECITHIN
                      +2.7320261 * PGMS * GMS
                     -17.6055594 * GMS * LECITHIN
                      +5.1818647 * PGMS * LECITHIN
                      +0.6791676 * PGMS * PGMS
                     -20.5859516 * GMS * GMS
                      -8.3529412 * LECITHIN * LECITHIN
```
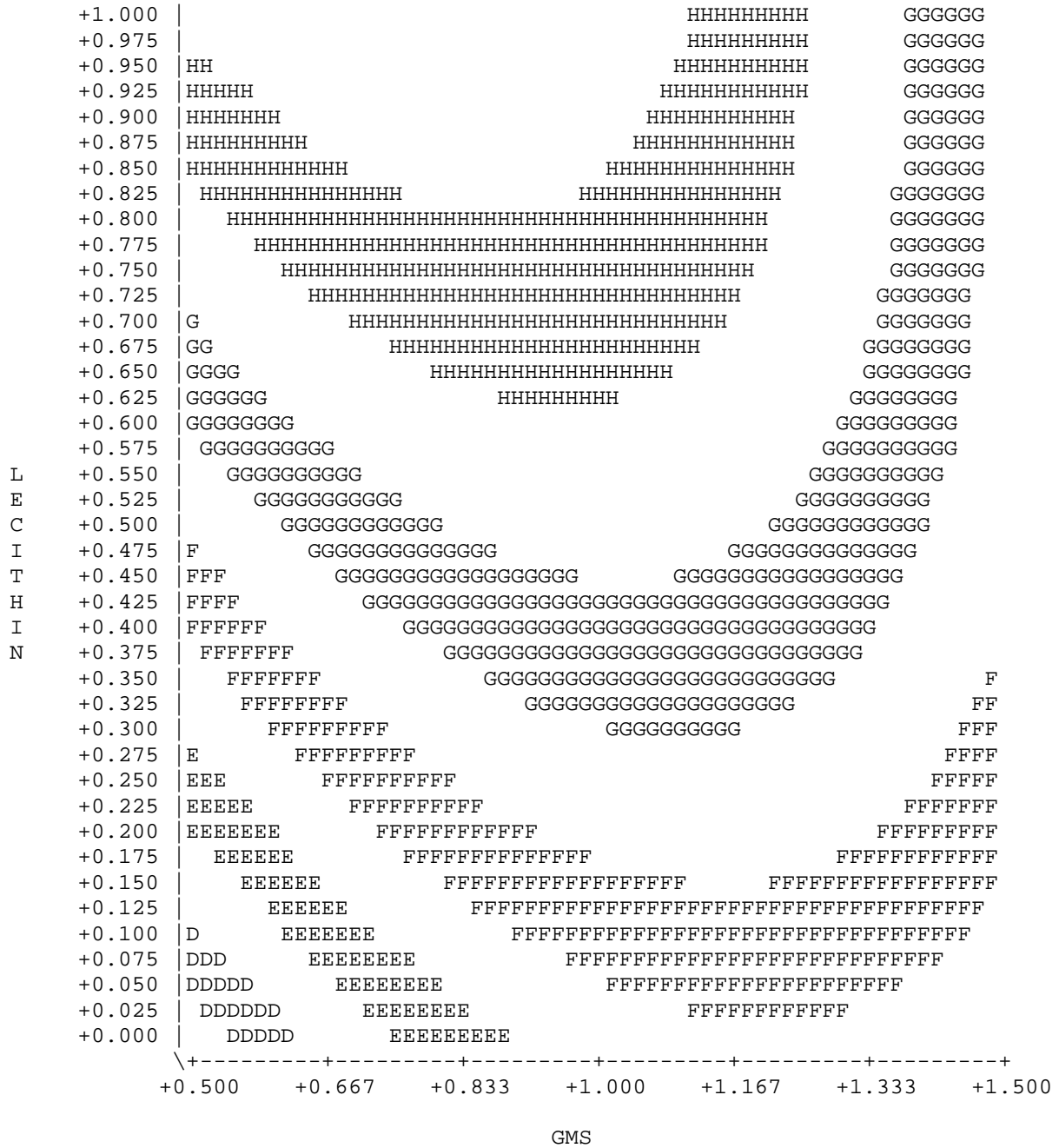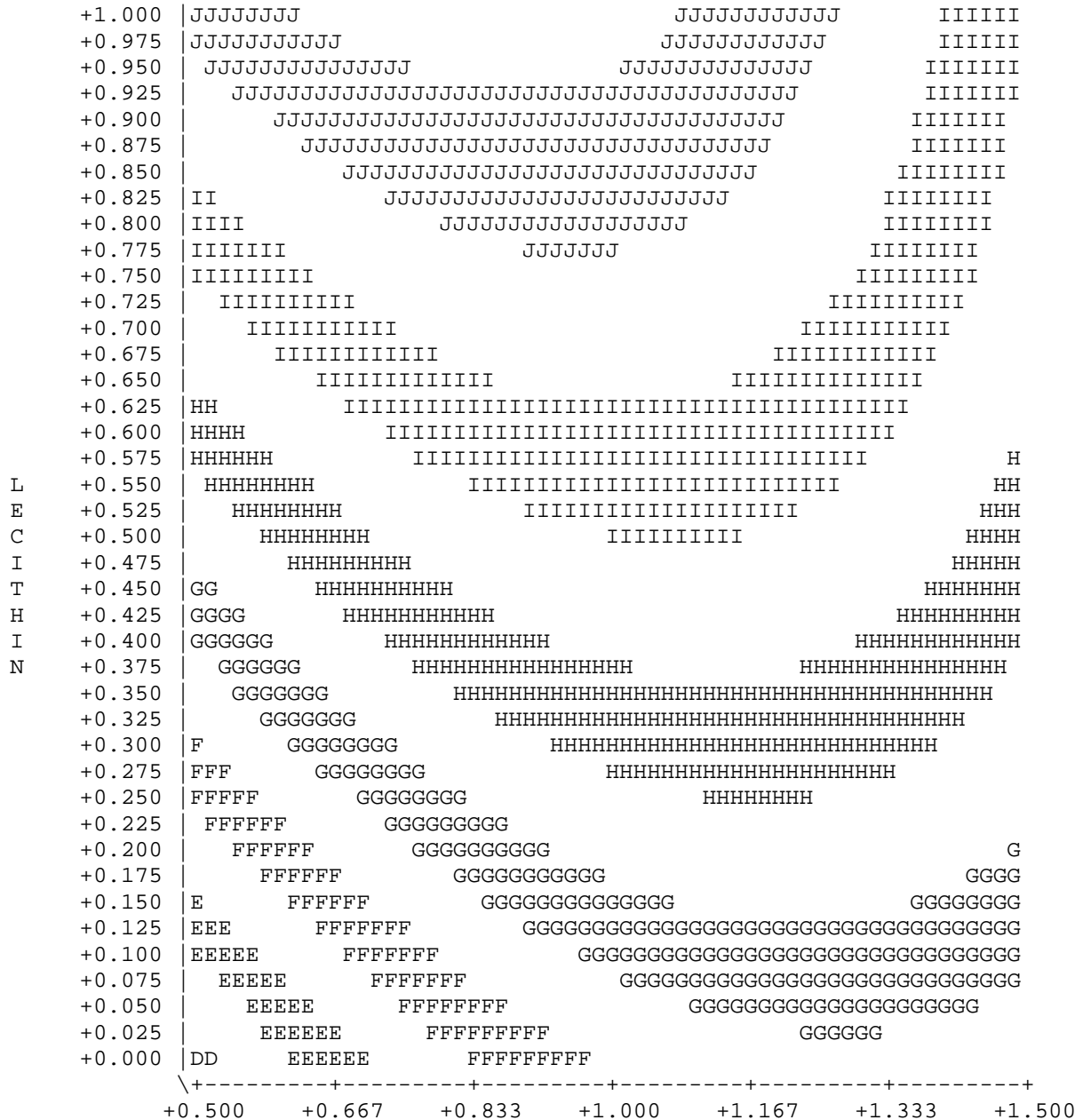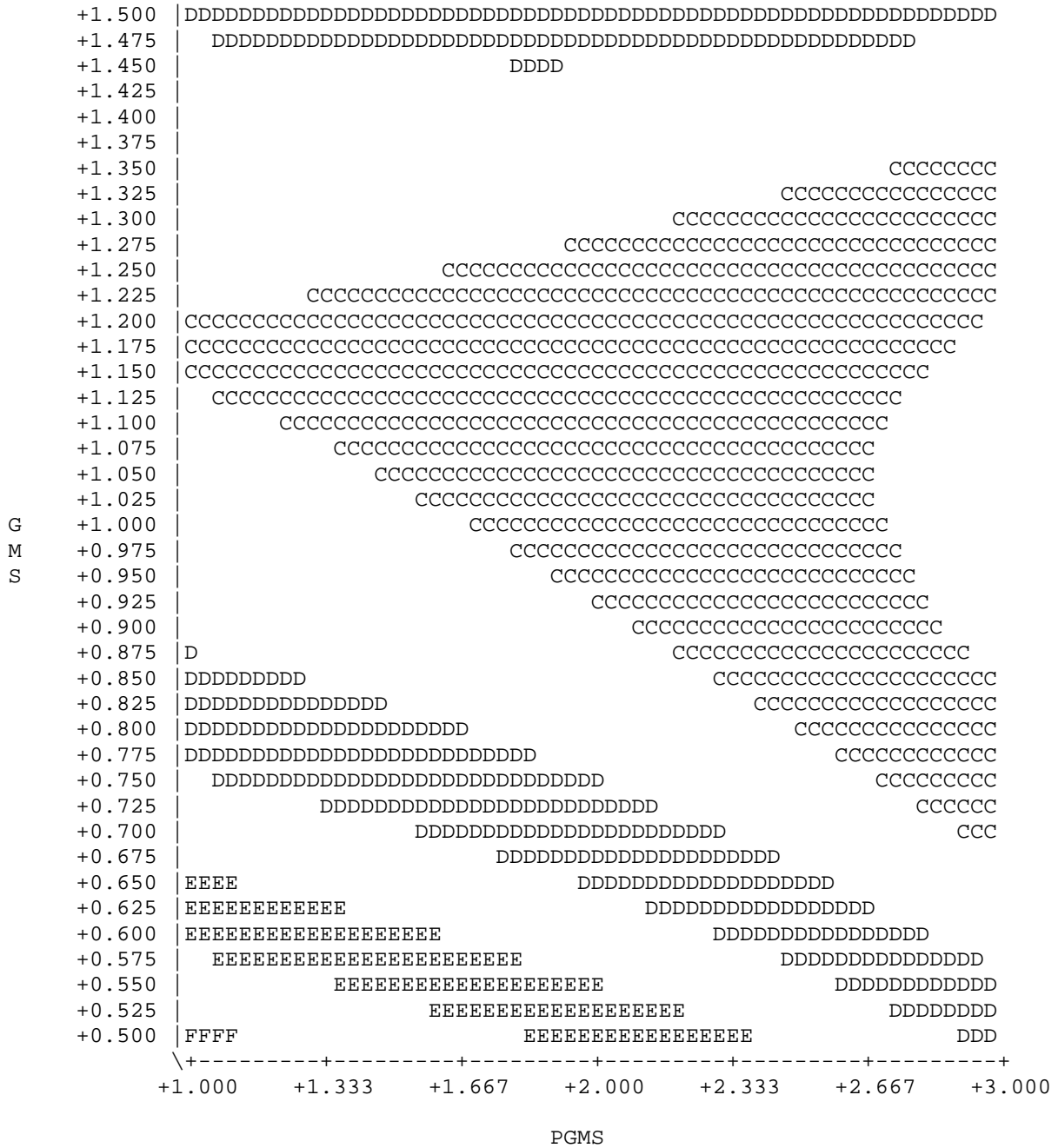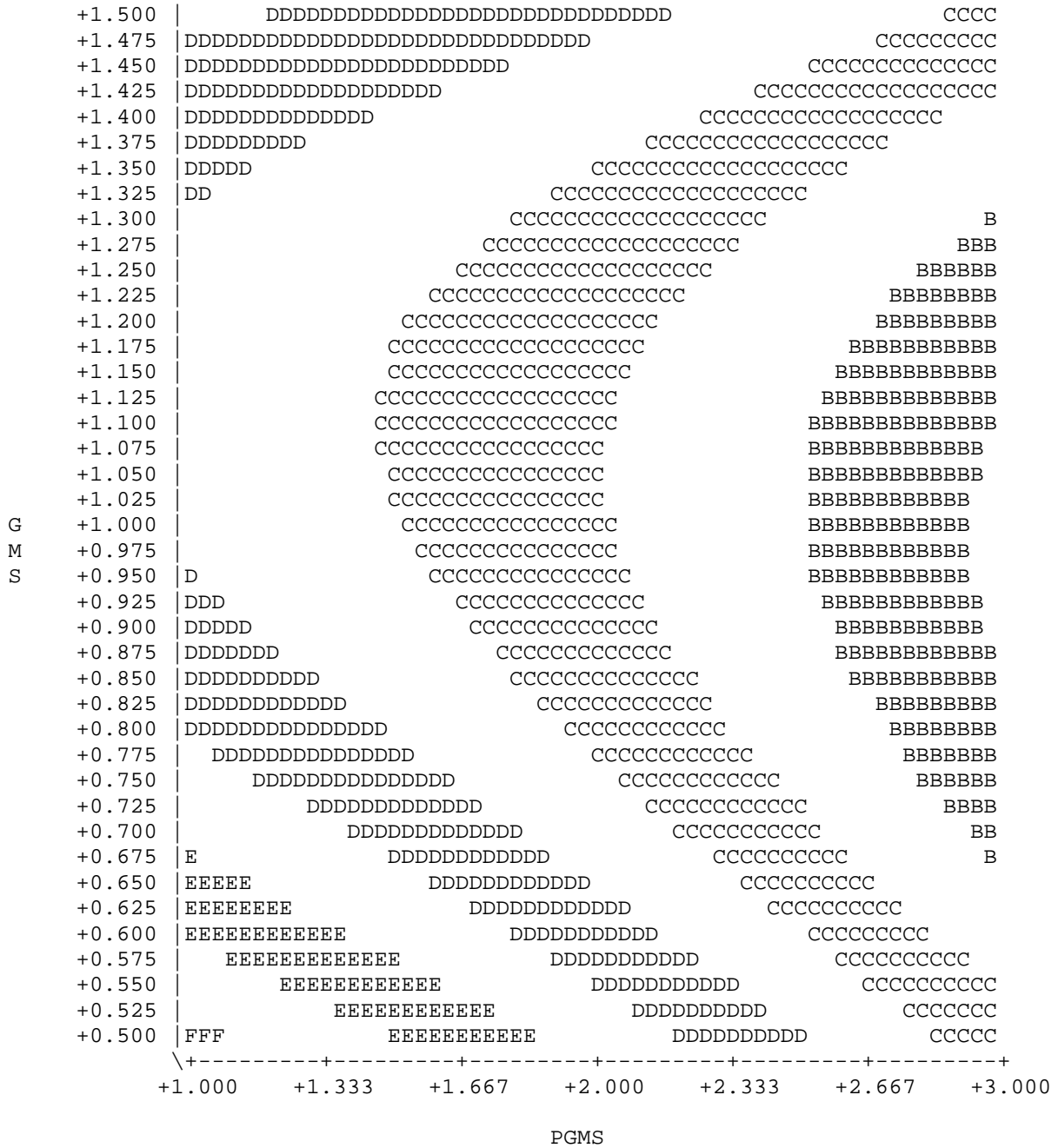
```
                        Response in SCORE
                    (Stepping Variable: LECITHIN = 0)


    +1.500 |         EEEEEEEEEEEEEEEEEE                 FFFFFFFFFFFFFF
    +1.475 |          EEEEEEEEEEEEEEEEEE               FFFFFFFFFFFFF
    +1.450 |         EEEEEEEEEEEEEEEEEEE              FFFFFFFFFFFFFF
    +1.425 |EEEEEEEEEEEEEEEEEEEEE                    FFFFFFFFFFFFFF
    +1.400 |EEEEEEEEEEEEEEEEEEEE                    FFFFFFFFFFFFFFF
    +1.375 |EEEEEEEEEEEEEEEEEEE                    FFFFFFFFFFFFFFF
    +1.350 |EEEEEEEEEEEEEEEEEE                    FFFFFFFFFFFFFFF
    +1.325 |EEEEEEEEEEEEEEEE                     FFFFFFFFFFFFFFFF
    +1.300 |EEEEEEEEEEEEEE                      FFFFFFFFFFFFFFFFF
    +1.275 |EEEEEEEEEEEE                       FFFFFFFFFFFFFFFF
    +1.250 |EEEEEEEEEEE                        FFFFFFFFFFFFFFFF
    +1.225 |EEEEEEEEEEE                       FFFFFFFFFFFFFFFFF
    +1.200 |EEEEEEEEEE                        FFFFFFFFFFFFFFFFF
    +1.175 |EEEEEEEEEE                        FFFFFFFFFFFFFFFFF
    +1.150 |EEEEEEEEEE                         FFFFFFFFFFFFFFFFFF
    +1.125 |EEEEEEEEEE                         FFFFFFFFFFFFFFFFFFF
    +1.100 |EEEEEEEEEEE                         FFFFFFFFFFFFFFFFFFF
    +1.075 |EEEEEEEEEEEE                        FFFFFFFFFFFFFFFFFFFF
    +1.050 |EEEEEEEEEEEEE                       FFFFFFFFFFFFFFFFFFF
    +1.025 |EEEEEEEEEEEEEEE                      FFFFFFFFFFFFFFFFFFFF
G   +1.000 |EEEEEEEEEEEEEEEEE                    FFFFFFFFFFFFFFFFFFFF
M   +0.975 |EEEEEEEEEEEEEEEEEEEE                 FFFFFFFFFFFFFFFFFFF
S   +0.950 |EEEEEEEEEEEEEEEEEEEEEEE              FFFFFFFFFFFFFFF
    +0.925 |EEEEEEEEEEEEEEEEEEEEEEEEEEE             FFFFFFFFFFFF
    +0.900 |EEEEEEEEEEEEEEEEEEEEEEEEEEEEEE            FFFFFFFFF
    +0.875 |  EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE            FFFFFF
    +0.850 |     EEEEEEEEEEEEEEEEEEEEEEEEEEEEEE            FFF
    +0.825 |        EEEEEEEEEEEEEEEEEEEEEEEEEEEE
    +0.800 |           EEEEEEEEEEEEEEEEEEEEEEEEEE
    +0.775 |             EEEEEEEEEEEEEEEEEEEEEEEEE
    +0.750 |              EEEEEEEEEEEEEEEEEEEEEEEEE
    +0.725 |               EEEEEEEEEEEEEEEEEEEEEEEEE
    +0.700 |DDDDD            EEEEEEEEEEEEEEEEEEEEEEEE
    +0.675 |DDDDDDDDDDDDDD      EEEEEEEEEEEEEEEE
    +0.650 |DDDDDDDDDDDDDDDDDDDDDD       EEEEEEEEE
    +0.625 |DDDDDDDDDDDDDDDDDDDDDDDDDDDDDD         EEE
    +0.600 |DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
    +0.575 |       DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
    +0.550 |            DDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
    +0.525 |              DDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
    +0.500 |               DDDDDDDDDDDDDDDDDD
         \+---------+---------+---------+---------+---------+---------+
          +1.000    +1.333    +1.667    +2.000    +2.333    +2.667    +3.000


                              PGMS


   Legend:    +50.00=A    +55.00=B    +60.00=C    +65.00=D    +70.00=E
              +75.00=F    +80.00=G    +85.00=H    +90.00=I    +95.00=J
            +100.00=K
```

```
                        Response in SCORE
                  (Stepping Variable: LECITHIN = .5)


   +1.500  |EEEEE           FFFFFFFFFFF          GGGGGGGGGG           HHHH
   +1.475  |EE             FFFFFFFFFFF           GGGGGGGGG            HHHHHH
   +1.450  |            FFFFFFFFFFF              GGGGGGGGG           HHHHHHH
   +1.425  |           FFFFFFFFFFFF              GGGGGGGGGG          HHHHHHHH
   +1.400  |          FFFFFFFFFFFF               GGGGGGGGGG         HHHHHHHHH
   +1.375  |         FFFFFFFFFFFF                GGGGGGGGGGG         HHHHHHHHH
   +1.350  |       FFFFFFFFFFFFF                GGGGGGGGGG          HHHHHHHHHH
   +1.325  |FFFFFFFFFFFFFF                      GGGGGGGGGGG         HHHHHHHHHH
   +1.300  |FFFFFFFFFFFF                    GGGGGGGGGGGG          HHHHHHHHHH
   +1.275  |FFFFFFFFFF                    GGGGGGGGGGGG           HHHHHHHHHH
   +1.250  |FFFFFFFF                    GGGGGGGGGGGG           HHHHHHHHHH
   +1.225  |FFFFFF                    GGGGGGGGGGGGG           HHHHHHHHHH
   +1.200  |FFFFF                   GGGGGGGGGGGGGG           HHHHHHHHHHH
   +1.175  |FFF                  GGGGGGGGGGGGGG            HHHHHHHHHH
   +1.150  |FF                 GGGGGGGGGGGGGGG            HHHHHHHHHHH
   +1.125  |F                GGGGGGGGGGGGGGG             HHHHHHHHHH
   +1.100  |               GGGGGGGGGGGGGGG             HHHHHHHHHHH
   +1.075  |               GGGGGGGGGGGGGGG             HHHHHHHHHHH
   +1.050  |              GGGGGGGGGGGGGGGG             HHHHHHHHHHH
   +1.025  |              GGGGGGGGGGGGGGG              HHHHHHHHHH
G  +1.000  |              GGGGGGGGGGGGGGGG             HHHHHHHHHHH
M  +0.975  |              GGGGGGGGGGGGGGGG             HHHHHHHHHHH
S  +0.950  |              GGGGGGGGGGGGGGGG             HHHHHHHHHHH
   +0.925  |              GGGGGGGGGGGGGGGG             HHHHHHHHHHH
   +0.900  |             GGGGGGGGGGGGGGGG              HHHHHHHHHHHH
   +0.875  |             GGGGGGGGGGGGGGGGG            HHHHHHHHHHHH
   +0.850  |            GGGGGGGGGGGGGGGGG            HHHHHHHHHHHH
   +0.825  |            GGGGGGGGGGGGGGGGGG           HHHHHHHHHHHH
   +0.800  |            GGGGGGGGGGGGGGGGG            HHHHHHHHHHHH
   +0.775  |           GGGGGGGGGGGGGGGGG            HHHHHHHHHHHH
   +0.750  |F             GGGGGGGGGGGGGGGG            HHHHHHHHHHHH
   +0.725  |FFF             GGGGGGGGGGGGGGGGG           HHHHHHHHHHHHH
   +0.700  |FFFFF             GGGGGGGGGGGGGGGGG          HHHHHHHHHH
   +0.675  |FFFFFFF             GGGGGGGGGGGGGGGGG          HHHHHHHH
   +0.650  |FFFFFFFFF             GGGGGGGGGGGGGGGGG          HHHHHH
   +0.625  |FFFFFFFFFFF             GGGGGGGGGGGGGGGG           HHHH
   +0.600  |FFFFFFFFFFFFFF            GGGGGGGGGGGGGG             HH
   +0.575  |FFFFFFFFFFFFFFFFFF            GGGGGGGGGGGGGGGG
   +0.550  |FFFFFFFFFFFFFFFFFFFFF          GGGGGGGGGGGGGG
   +0.525  |     FFFFFFFFFFFFFFFFFFFFFF          GGGGGGGGGGGGGG
   +0.500  |       FFFFFFFFFFFFFFFFFFFFFF          GGGGGGGGGGGGGG
           \+---------+---------+---------+---------+---------+---------+
          +1.000     +1.333     +1.667     +2.000     +2.333     +2.667     +3.000


                                PGMS


  Legend:      +50.00=A     +55.00=B     +60.00=C     +65.00=D     +70.00=E
               +75.00=F     +80.00=G     +85.00=H     +90.00=I     +95.00=J
              +100.00=K
```
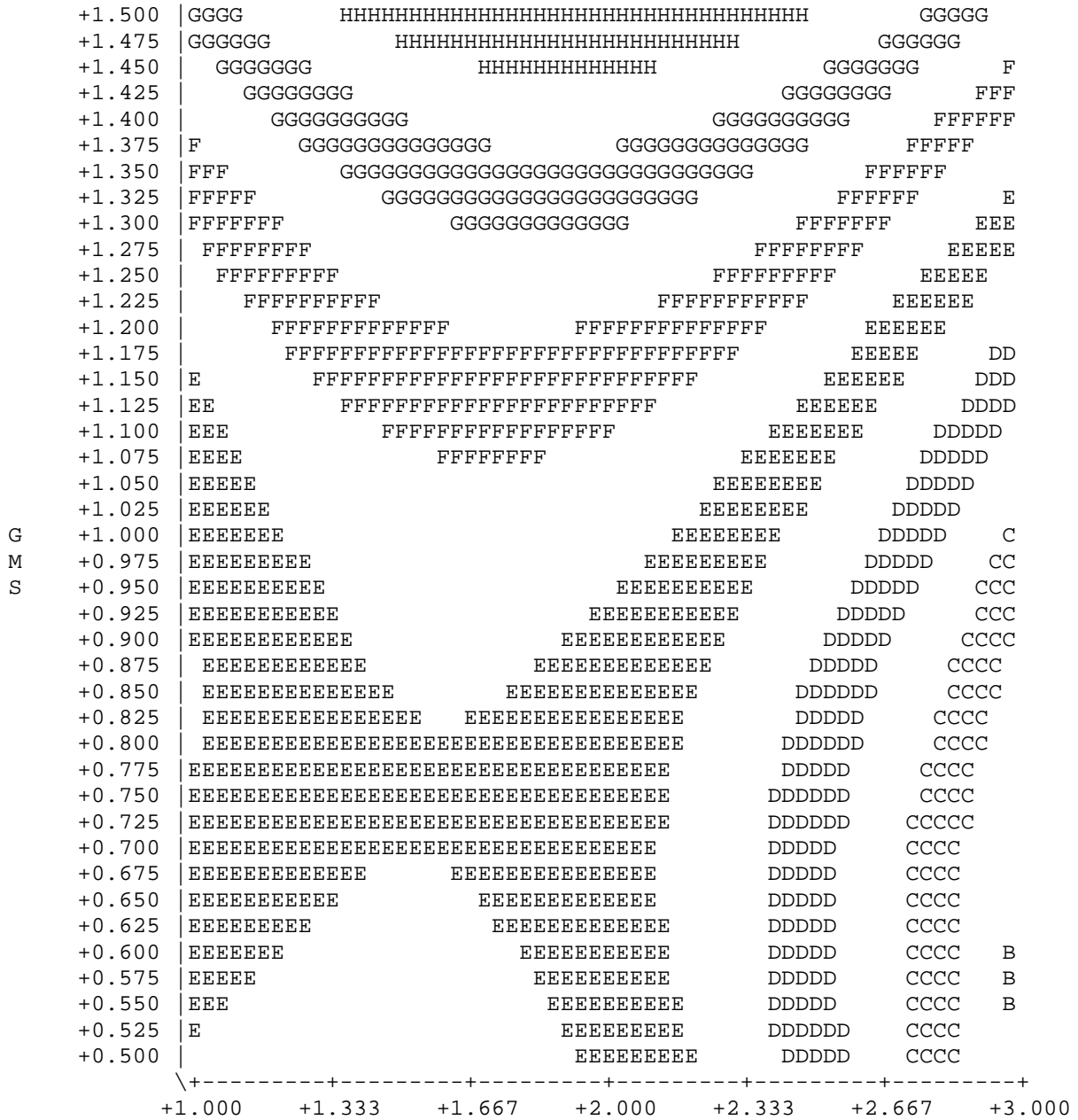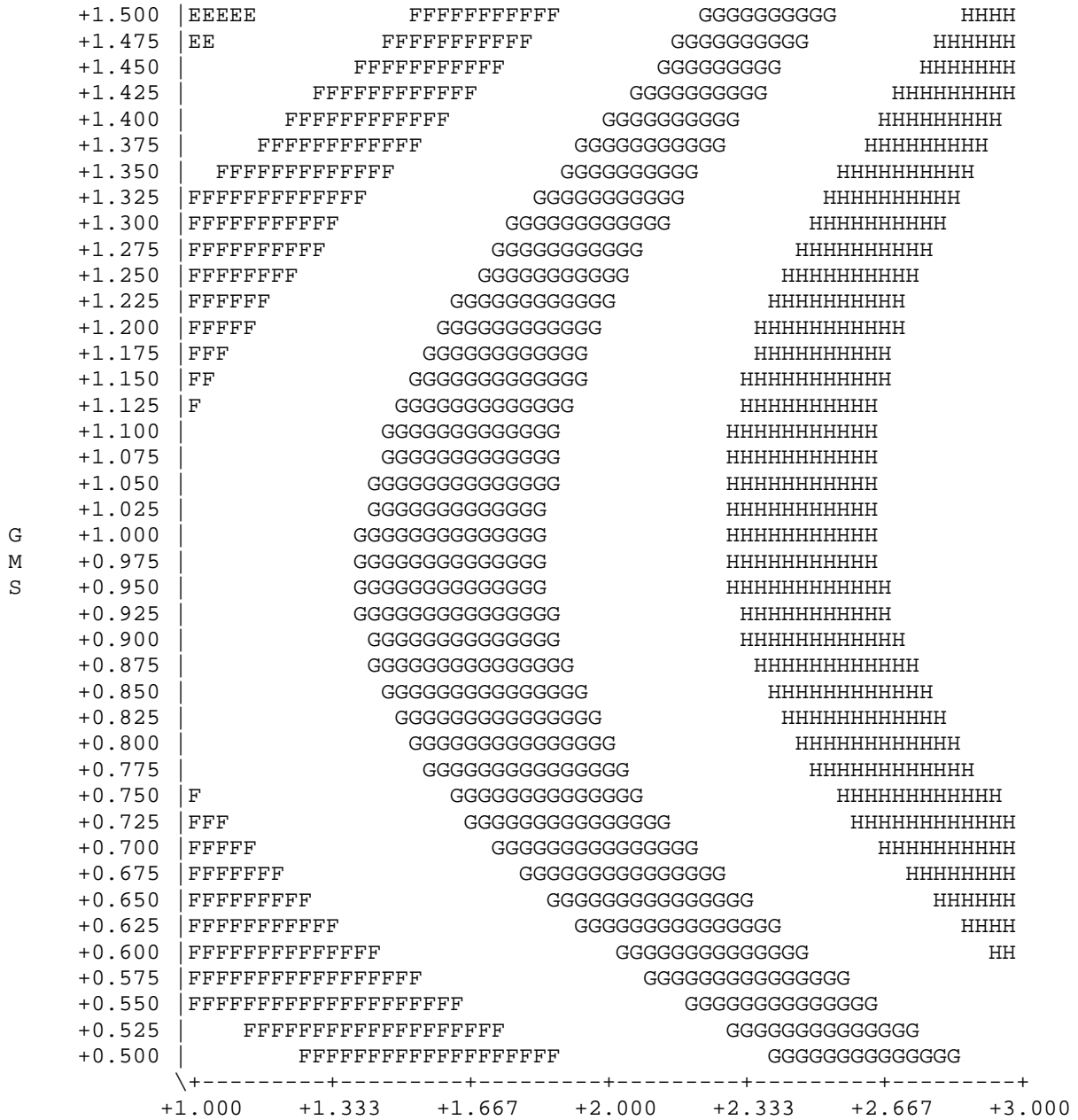
```
                          Response in SCORE
                   (Stepping Variable: LECITHIN = 1)

    +1.500  |EEEEEEEEE        FFFFFFFF        GGGGGGG        HHHHHHH
    +1.475  |EEEEE          FFFFFFFF        GGGGGGGG       HHHHHHH         I
    +1.450  |EEEE         FFFFFFFF        GGGGGGGG       HHHHHHH         III
    +1.425  |E          FFFFFFFF        GGGGGGGG       HHHHHHHH        IIII
    +1.400  |          FFFFFFFFF        GGGGGGGG       HHHHHHH        IIIIII
    +1.375  |        FFFFFFFFF        GGGGGGGG       HHHHHHH        IIIIIII
    +1.350  |       FFFFFFFF        GGGGGGGG       HHHHHHHH        IIIIIII
    +1.325  |FFFFFFFFF        GGGGGGG       HHHHHHHH        IIIIIIIII
    +1.300  |FFFFFFF        GGGGGGGGG       HHHHHHH        IIIIIII
    +1.275  |FFFFF        GGGGGGGGG       HHHHHHHH        IIIIIII
    +1.250  |FFF         GGGGGGGGG       HHHHHHH        IIIIIIIII
    +1.225  |F          GGGGGGGG       HHHHHHHH        IIIIIII         J
    +1.200  |          GGGGGGGGG        HHHHHHHHH        IIIIIII         JJ
    +1.175  |         GGGGGGGGG        HHHHHHHH        IIIIIIIII        JJJ
    +1.150  |        GGGGGGGGGG        HHHHHHHH        IIIIIIIII        JJJJ
    +1.125  |        GGGGGGGG        HHHHHHHHH        IIIIIIII        JJJJJ
    +1.100  |       GGGGGGGGGG        HHHHHHHHH        IIIIIIII        JJJJJJ
    +1.075  |       GGGGGGGGGG        HHHHHHHHH        IIIIIIII        JJJJJJJ
    +1.050  |GGGGGGGGG        HHHHHHHHH        IIIIIIIII        JJJJJJJJ
    +1.025  |GGGGGGGG        HHHHHHHHH        IIIIIIII        JJJJJJJJ
G   +1.000  |GGGGGGG        HHHHHHHHH        IIIIIIIII        JJJJJJJJ
M   +0.975  |GGGGGG        HHHHHHHHH        IIIIIIIII        JJJJJJJJ
S   +0.950  |GGGGG        HHHHHHHHHH        IIIIIIIII        JJJJJJJJ
    +0.925  |GGGG        HHHHHHHHHH        IIIIIIIIII        JJJJJJJJ
    +0.900  |GGG        HHHHHHHHH        IIIIIIIII        JJJJJJJJ
    +0.875  |GGG        HHHHHHHHH        IIIIIIIIII        JJJJJJJJ
    +0.850  |GG        HHHHHHHHHH        IIIIIIIIII        JJJJJJJJJ
    +0.825  |GG        HHHHHHHHHH        IIIIIIIII        JJJJJJJJJ
    +0.800  |G        HHHHHHHHHH        IIIIIIIII        JJJJJJJJ
    +0.775  |G        HHHHHHHHHH        IIIIIIIII        JJJJJJJJ
    +0.750  |G        HHHHHHHHHH        IIIIIIIII        JJJJJJJJ
    +0.725  |G        HHHHHHHHHH        IIIIIIIII        JJJJJJJJJ
    +0.700  |G        HHHHHHHHHHH        IIIIIIIIII        JJJJJJJJ
    +0.675  |G        HHHHHHHHHH        IIIIIIIII        JJJJJJJJJ
    +0.650  |G        HHHHHHHHHH        IIIIIIIIIII        JJJJJJJJ
    +0.625  |GG        HHHHHHHHHHH        IIIIIIIIIII        JJJJJJJ
    +0.600  |GG        HHHHHHHHHHH        IIIIIIIIII        JJJJJJJ
    +0.575  |GGG        HHHHHHHHHHH        IIIIIIIIII        JJJJJJ
    +0.550  |GGGG        HHHHHHHHHHH        IIIIIIIII        JJJJJ
    +0.525  |GGGGG        HHHHHHHHHHH        IIIIIIIIII        JJJ
    +0.500  |GGGGG        HHHHHHHHHHH        IIIIIIIIII        JJ
            \+---------+---------+---------+---------+---------+---------+
            +1.000    +1.333    +1.667    +2.000    +2.333    +2.667    +3.000

                                    PGMS

    Legend:     +50.00=A      +55.00=B      +60.00=C      +65.00=D      +70.00=E
                +75.00=F      +80.00=G      +85.00=H      +90.00=I      +95.00=J
                +100.00=K
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94

Appendix B - RAW DATA

Table 13. Cake firmness (The first set test)

First Round test
Firmness: Plastic shortening

	L	C	R	L	C	R	average	S.D
1st day	175	198	165	149	180	176	173.8	14.85
5th day	253	229	232	225	229	239	234.5	9.31
12th day	220	254	217	223	261	231	234.3	17.05
21th day	238	344	255	269	328	254	281.3	39.95

Firmness: liquid shortening

	L	C	R	L	C	R	average	S.D
1st day	145	168	162	170	160	135	156.7	12.59
5th day	204	189	188	195	198	197	195.2	5.46
12th day	193	193	206	208	203	189	198.7	7.27
21th day	225	257	238	245	252	228	240.8	11.74

Firmness: liquid oil

	L	C	R	L	C	R	average	S.D
1st day	267	341	229	298	332	258	287.5	40.14
5th day	359	472	362	327	500	356	396.0	65.16
12th day	323	531	327	345	522	366	402.3	88.93
21th day	464	567	485	450	568	485	503.2	47.08

Firmness: liquid oil+emul.

	L	C	R	L	C	R	average	S.D
1st day	155	146	124	138	163	144	145.0	12.36
5th day	165	187	163	169	178	175	172.8	8.21
12th day	187	242	199	197	245	184	209.0	24.96
21th day	203	217	214	221	221	203	213.2	7.58

Table 14. Cake firmness (The second set test)

Firmness: Plastic shortening

	L	C	R	L	C	R	average	S.D
1st day	234	257	263	211	209	239	235.5	20.56
5th day	232	233	263	239	266	247	246.7	13.55
12th day	261	281	267	272	257	261	266.5	8.08
21th day	294	303	336	313	297	270	302.2	19.96

Firmness: liquid shortening

	L	C	R	L	C	R	average	S.D
1st day	201	200	180	189	187	178	189.2	8.86
5th day	192	193	192	209	215	203	200.7	9.03
12th day	229	242	219	240	239	234	233.8	7.90
21th day	261	272	238	229	267	240	251.2	16.18

Firmness: liquid oil

	L	C	R	L	C	R	average	S.D
1st day	302	318	327	302	379	303	321.8	27.24
5th day	352	404	312	291	361	390	351.7	39.89
12th day	395	538	405	401	507	358	434.0	65.03
21th day	595	625	439	419	640	466	530.7	91.33

Firmness: liquid oil+emul.

	L	C	R	L	C	R	average	S.D
1st day	170	183	165	161	176	154	168.2	9.55
5th day	188	194	205	201	184	189	193.5	7.41
12th day	203	206	208	194	202	197	201.7	4.85
21th day	258	253	226	227	269	266	249.8	17.30

Table 15. Cake firmness (The third set test)

Firmness: Plastic shortening

	L	C	R	L	C	R	average	S.D
1st day	240	219	223	211	227	223	223.8	8.76
5th day	269	281	245	245	262	257	259.8	12.81
12th day	301	323	305	295	340	299	310.5	15.91
21th day	312	321	306	286	299	301	304.2	10.92

Firmness: liquid shortening

	L	C	R	L	C	R	average	S.D
1st day	169	188	176	165	166	172	172.7	7.78
5th day	195	209	209	206	198	208	204.2	5.58
12th day	214	235	219	213	243	216	223.3	11.47
21th day	234	277	237	252	279	238	252.8	18.69

Firmness: liquid oil

	L	C	R	L	C	R	average	S.D
1st day	255	365	279	257	302	274	288.7	37.53
5th day	319	360	314	330	405	310	339.7	33.52
12th day	426	462	389	399	485	421	430.3	33.63
21th day	455	562	424	477	612	431	493.5	69.79

Firmness: liquid oil+emul.

	L	C	R	L	C	R	average	S.D
1st day	170	165	173	165	158	172	167.2	5.15
5th day	173	192	180	177	182	204	184.7	10.42
12th day	227	256	240	229	232	226	235.0	10.46
21th day	218	210	229	235	246	232	228.3	11.64

Table 16. The first set of cake scores

A.Cells (30points)	Score Points	Plastic shortening	Liquid oil	Liquid shortening	Liquid oil+emul.
1. Uniformity(10points) (a) Even (normal)	10	7	5	10	9
(b) Slightly uneven	6				
© Uneven	2				
2. Size (10points) (a) Dense(normal)	10	9	5	9	7
(b)close	8				
© Slightly open	6				
©open	4				
3. Thickness of walls(10points) (a)Thin (normal)	10	9	6	9	8
(b) Slightly thick	6				
© Thick	2				
B. Grain (16point)		14	10	15	13
1. Sliky(normal)	16				
2.Harsh	10				
3.Coarse (corn bread)	8				
C. Texture (34points)					
1. Moistness(10 points) (a) Moist (normal)	10	9	8	10	10
(b) Slightly dry	8				
© Gummy	6				
(d) Dry	4				
2.Tenderness (14points) (a) Very tender (normal)	14	12	10	14	14
(b) Tender	12				
© Slightly tough	10				
(d) tough	4				
3. Softness (10points) (a) Soft (normal)	10	10	6	10	10
(b) Slightly firm	8				
© Firm	4				
D. Crumb color (10points)		9	7	9	9
1.Bright white (normal)	10				
2.White	8				
3. Slightly dull	8				
4. Slightly creamy	8				
5.Creamy	6				
6. Slightly dull and slightly creamy	4				
E. Flavor (10points)					
1. Normal (no off-flavor due to flour)	10	10	10	10	10
2.Foreigh	0				
Total	100	89	67	96	90
B		40	42	45	44
C		45	51	47	48
D		39	41	41	42
Volume(B+C+D)		124	134	133	134
Symmetry(2C-B-D)		11	19	8	10
Uniformity(B-D)		1	1	4	2
note			tuneling problem		sticky,fragil

Table 17. The second set of cake scores

A.Cells (30points)	Score Points	Plastic shortening	Liquid oil	Liquid shortening	Liquid oil+emul.
1. Uniformity(10points) (a) Even (normal)	10	7	2	8	9
(b) Slightly uneven	6				
© Uneven	2				
2. Size (10points) (a) Dense(normal)	10	8	5	9	6
(b)close	8				
© Slightly open	6				
©open	4				
3. Thickness of walls(10points) (a)Thin (normal)	10	8	2	10	6
(b) Slightly thick	6				
© Thick	2				
B. Grain (16point)		13	8	14	13
1. Sliky(normal)	16				
2.Harsh	10				
3.Coarse (corn bread)	8				
C. Texture (34points)					
1. Moistness(10 points) (a) Moist (normal)	10	8	8	10	10
(b) Slightly dry	8				
© Gummy	6				
(d) Dry	4				
2.Tenderness (14points) (a) Very tender (normal)	14	12	8	13	13
(b) Tender	12				
© Slightly tough	10				
(d) tough	4				
3. Softness (10points) (a) Soft (normal)	10	8	6	10	10
(b) Slightly firm	8				
© Firm	4				
D. Crumb color (10points)		9	7	9	9
1.Bright white (normal)	10				
2.White	8				
3. Slightly dull	8				
4. Slightly creamy	8				
5.Creamy	6				
6. Slightly dull and slightly creamy	4				
E. Flavor (10points)					
1. Normal (no off-flavor due to flour)	10	10	10	10	10
2.Foreigh	0				
Total	100	83	56	93	86
B		39	39	42	41
C		44	41	48	45
D		38	40	41	41
Volume(B+C+D)		121	120	131	127
Symmetry(2C-B-D)		11	3	13	8
Uniformity(B-D)		1	1	1	0
note			tuneling problem		sticky,fragil

Table 18. The third set of cake scores

A.Cells (30points)	Score Points	Plastic shortening	Liquid oil	Liquid shortening	Liquid oil+emul.
1. Uniformity(10points) (a) Even (normal)	10	7	5	9	9
(b) Slightly uneven	6				
(c) Uneven	2				
2. Size (10points) (a) Dense(normal)	10	8	4	9	8
(b)close	8				
(c) Slightly open	6				
(d)open	4				
3. Thickness of walls(10points) (a)Thin (normal)	10	8	3	9	7
(b) Slightly thick	6				
(c) Thick	2				
B. Grain (16point)		13	8	14	13
1. Sliky(normal)	16				
2.Harsh	10				
3.Coarse (corn bread)	8				
C. Texture (34points)					
1. Moistness(10 points) (a) Moist (normal)	10	8	4	10	6
(b) Slightly dry	8				
(c) Gummy	6				
(d) Dry	4				
2.Tenderness (14points) (a) Very tender (normal)	14	12	8	13	13
(b) Tender	12				
(c) Slightly tough	10				
(d) tough	4				
3. Softness (10points) (a) Soft (normal)	10	8	5	10	10
(b) Slightly firm	8				
(c) Firm	4				
D. Crumb color (10points)		9	6	9	9
1.Bright white (normal)	10				
2.White	8				
3. Slightly dull	8				
4. Slightly creamy	8				
5.Creamy	6				
6. Slightly dull and slightly creamy	4				
E. Flavor (10points)					
1. Normal (no off-flavor due to flour)	10	10	10	10	10
2.Foreigh	0				
Total	100	83	53	93	85
B		40	43	44	42
C		41	50	46	47
D		38	42	44	42
Volume(B+C+D)		119	135	134	131
Symmetry(2C-B-D)		4	15	4	10
Uniformity(B-D)		2	1	0	0
note			tuneling problem		sticky,fragil