STUDIES OF FAT AND SURFACTANT SYSTEMS IN BREAD-MAKING

by

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INTRODUCTION

Fats and oils have long been recognized as important food substances. They provide the most concentrated source of energy of any food stuff, contribute greatly to the feeling of satietry after eating, are carriers for the fat soluble vitamins, and serve to make other foods more palatable (1). Although verified statistics are different to obtain, most sources agree that the U.S. baking industry currently uses in excess of 1.6 billion pounds of edible fats and oils each year. At the present time, wholesale bakeries use about 95 percent and retail bakeries about 5 percent of the total. The change in baking from a retail shop-oriented trade to a wholesale industry has been of the greatest significance in the buying and use patterns of fats, oils and other baked food ingredients. It has also been a major factor in the direction of research being done on fats and oils for use in bakeries (2). Fats and oils are present in varying amounts in many foods. Most vegetables and fruits contain only small amounts of fat. The principle sources of fat in the diet are meats, dairy products, poultry, fish, nuts, and certain vegetable seeds (1). Most commercial bakers in the United States add 3 percent shortening, generally textured lard, to produce regular white bread (3). In the early 1950's when the continuous process was first introduced, one of the major problems was the so-called shortening failure which resulted in low volume, caved in top and side walls, and coarse grain and dark color. This was eventually overcome by the addition of hard, fully hydrogenated cotton-seed flakes (m.p. approx. 145^{o}f) to the shortening (4). The sources of fats and oils used, however, has not remained stable. Of greatest significance in oil usage has been the increase in the use of soybean oil in bakery fat and oil products. Several factors have contributed to this change:

a) increased plantings of soybeans;

b) decrease in available edible lard and cotton-seed oil;

c) improved flavor characteristics of soybean oil shortening;

d) an upsurge in interest in unsaturates and polyunsaturated shortenings;

e) a market which has frequently been tipped in favor of soybean oil over meat fats (2).

Prior to the development of a highly specialized shortening industry, the principle fat used for edible purposes was lard, the body fat of hogs. Two attributes of lard ensured for it this position of pre-eminence. One was its characteristic flavor which found a more wide spread acceptance. The other, and probably more important, attribute was its consistency which at room temperature was nearly ideal for the proper incorporation of the fat into pie crusts, cakes, pasteries and bread. Lard, however, was handicapped by the fact that it was a by-product rather than a primary product of the meat packing industry. This meant that the supply of lard was never directly related to the demand for it, but rather to the demand for pork. Also the use of plastic shortening agents expanded the production of lard fell far short of the requirements. Vegetable oils could now by completely hardened by means of the hydrogenation process and blended with liquid vegetable oils to the desired consistency (5).

It appears clear that the baking industry is going through a transition in the types of fat or shortening used in the production of breads and rolls, and in the amounts of these that are believed necessary for best results. Briefly, the thrust is away from animal fats (lard) towards vegetable fats (liquid soya oil), and away from higher levels such as 3% to 4% towards lower levels such as 2% and in some cases even 1% or less. The availability of new surface active dough conditioners in recent years has played a major role in the thrust away from animal fat (lard) to vegetable oil (soya), and elimination of the use of hard fats (fully hydrogenated cotton-seed flakes) (4).

Surface active agents, variously referred to as "emulsifiers" and "bread softeners", may be defined as substances that modify the surface behavior of liquids in which they are dispersed in low concentrations. Properly speaking, when used in breadmaking, they function neither as emulsifiers nor as softeners and are, hence, more accurately designated as surfactants or as staling inhibitors or staling retardants (5). The evolution of surfactant-based dough conditioners is a continuing success story. The beginning of their use is traceable at least to the early 1940's, when Swanson and Andrews (6) reported that certain surface-active materials could modify the mixing characteristics of flour-water doughs.

A surfactant is a substance which can alter conditions prevailing of interfaces of systems. Surfactant activities are accomplished as a result of adsorption at and subsequent lowering of one or more boundary tensions, and/or stabilization of one or more of the interfaces of the systems (7).

A wide variety of monoglyceride types are used by the baking industry, which vary not only in mono-, di-, and triglyceride ratio, but also as to degree of saturation (8).

In considering the use of surfactants in baking or food processing, it has become evident that their applications are based more upon emperical observations of the changes they produce than upon a thorough comprehension of their underlying chemical and physical nature. However, steady progress is being made in understanding many of the mechanisms that are of importance to bread improvement (9).

In recent years other types of fats and oils have become of interest to the baking industry for various reasons, including economics, ethnic, and nutritional considerations. Relatively little information appears to be available on the effects of various fats in breadmaking, especially in combination with the surfactants now used by the industry. The objective of the present study was to systematically investigate the effects of four fats, used at three levels, in various combinations with four commercial surfactants, also at three levels. The fats used were: lard; unhydrogenated soybean oil; lightly hydrogenated soybean oil; and palm oil. The surfactants employed were succinylated monoglycerides with monoglycerides; sodium stearoyl-2-lactylate; and 2 types of polysorbate 60-mono- and diglyceride combinations. Observations were made on bread firmness (1 and 3 days), loaf volume, and overall bread quality.

LITERATURE REVIEW

Fats in Baking

Fats and oils are predominantly the trifatty acid esters of glycerine commonly called "triglycerides". A triglyceride is composed of glycerol and three fatty acids. When all of the fatty acids in a triglyceride are identical, it is termed a "simple" triglyceride. The more common forms, however, are the "mixed" triglycerides in which two or three kinds of fatty acid radicals are present in the molecule. Illustrations of typical simple and mixed triglyceride molecular structures are shown below. R_1-COOH, R_2-COOH and R_3-COOH represent the different fatty acid moeties as they are esterfied with the glycerol moiety (CH_2-CH-CH_2) (1).

A simple triglyceride	A mixed triglyceride
R_1-COO-CH_2	R_1-COO-CH_2
|	|
R_1-COO-CH	R_2-COO-CH
|	|
R_1-COO-CH_2	R_3-COO-CH_2

A simple triglyceride   A mixed triglyceride

Fat not only plays a major role in terms of performance in conventional-process but also in continuous-process bread production. Model fat systems were chosen in an attempt to answer specific questions; e.g., is it necessary to have solid or crystalline fats present at the dough temperature encountered in continuous-process bread, and if so, is the nature of the crystalline structure of significance? Is there a requirement for unsaturated fats? How important are the lipids in the flour itself in continuous process bread? (10).

Many workers have suggested that shortenings function as improving agents in bread by acting as a lubricant between the starch granules and by lubricating the gluten filaments, thus allowing greater extensibility in the dough (11). It has been reported (12) that hard fats were superior to semi-solid fats, both being superior to oils in improving bread quality.

Interaction between the shortening and starch, even if not strong enough to be classed as "lipid binding" in terms of solvent extraction, may contribute to the effect of fat in baking (13). The lipids in dough are derived from two main sources, the bakery fat and the flour lipids, with a very small contribution from the yeast lipids and the optional ingredients. When flour is made into dough, a change takes place in the association of the lipids with the other dough ingredients. During baking, the shortening previously dispersed along the starch granules coalesced into droplets. These phenomena were held to support the lubrication hypothesis. However, this idea failed to explain why small amounts of solid or semi-solid fats were superior improvers to larger amounts of liquid oils (14). Most liquid fats, although they blend into the dough completely, are incapable of raising the melting point or increasing the viscosity of the flour-fats. Semi-solid fats, on the other hand, are capable of blending with the flour fat and raising its melting point and increasing its viscosity (12).

Among benefits derived from the use of shortening in white bread, are greater loaf volume, improvement of texture and grain, increased tenderness, better machining properties, and superior keeping quality. Without exception, fat systems which were completely liquid at dough temperature produced poor-quality bread, usually with low volume and open grain. Such crystalline fats seem to serve as reservoires to supply liquid fat during the baking process, helping to prevent the escape of gas and coalescence of gas cells (10). The lipids have been found to have a pronounced effect on dough quality as their presence or absence either depress or stimulates baking properties (15-19). It was found that doughs containing no shortening or containing semi-solid shortening are able to retain much of the gas until after starch swelling and on into the zone of gluten coagulation (20). The presence of air was found to cause a fall in the linoleic acid content of the triglyceride lipids, an effect apparently related to the reduction in lipid binding. Replacement of the free lipid of flour (the main source of triglyceride linoleate) by extra shortening fat caused a large increase in bound lipid in doughs mixed either in air or in nitrogen, together with the drop in bread quality and volume observed previously (21).

The ability of fats to disperse through doughs is probably related to their shortening action, and the more hydrophilic compounds, such as emulsifiers, maybe expected to be better shortening agents than triglycerides.

The plastic shortening maybe roughly separated into two components, each of which contributes to bread quality. According to Bayfield and Young (11), the liquid or oil component helps to retain gasses, probably by acting as a lubricant. It also contributes to the softness and shelf-life of bread. The solid component gives the desired crumb color and internal structure of the crumb. It seems that the harder the solid fraction, the more effective it is in improving the bread.

In the fat-free starch doughs, materials containing higher proportions of diglycerides produced starch breads with the most desirable structure regardless of mixing procedure. In the presence of fat, starch breads were finest and most even textured with the materials containing the highest percentage of alpha-monoglycerides. However, these differences were small (8). The addition of a hard fat fraction of fat systems for continuous-mix bread results in better grain, volume, and softness in the bread (22).

DeStefanis and Ponte (23) shows that the steryl esters and triglycerides produced volumes similar to the intact non-polar fraction. The diglycerides decreased loaf volume slightly. They also show, the addition of the free fatty acids brought a substantial loss in volume. Their data shows that the free fatty acids were primarily responsible for poor baking performance. Their results show that the addition of steryl esters triglycerides and diglycerides had little or no effect on starch gelatinization. Non-polar lipids and free fatty acids not only increased amylogram peak viscosity but also delayed peak time. Peak viscosity of the bread crumb was directly related to the level of linoleic acid used in baking.

In addition to playing a role in lipoprotein formation, lipids have been implicated in the mechanism of oxidizing sulfhydryl groups in dough, thus exerting an improving effect (24). At first, there appeared to be a good correlation between the iodine values of the fats and their ability to increase loaf volume, a low iodine value being preferred. However, it proved possible to get the same improvement in loaf volume from two specially prepared fats with iodine values as 20 and 100, both used as the same concentration and having similar slip points. Slip point itself appeared to correlate well with the improving ability of the commercial fats, a fat of high slip point giving the full bread-improving effect at a lower level of addition than a fat of low slip point (25). The chemical composition of edible lipids affects dough-handling properties and, indirectly, loaf volume and crumb grain. The strengthening of dough structure by high-melting components can be responsible for a major part of the beneficial effects of shortening (26). Pomeranz and Hays (27) studied seven hydrogenated corn oils varying in iodine value between 127.5 and 22.5 and melting points from below 25^{o} to 58^{o} were added at 3 percent (on flour basis). They found, in all hard red spring and most hard red winter wheat flours the range of iodine values from 40 to 60 was optimum for the corn oils studied. In a study on the mechanism of bread improving effects of lipids, Pomeranz et al. (26); the effects of commercial vegetable shortening could be duplicated by adding comparable amounts of certain microcrystalline waves. Similarly, the improving effects of shortening could be attained very efficiently by adding polar (but not nonpolar) wheat flour lipids (28, 29). The effects on bread quality of shortening or polar lipids were independent of wheat class or variety (26).

The concept of amount of fat solids at different temperatures is well-known to oil and fat chemists, but has not been fully related to baking performance by cereal chemists. If we believe that lard has the properties of SFI (Solid Fraction Index) values to produce good loaf of bread. On the other hand, the vegetable oils (soya) have no portion of the oil in the solid phase, and therefore provide additional softening, but do not solidify the dough cell walls sufficiently to retain gas. Palm oil provides sufficient solid fat at the higher temperatures to strengthen cell walls but at lower temperature has much solid fat. Some of the problems with the use of vegetable oils seem to arise from not specifying correctly the characteristics of the oil to be used. In addition to the usual specifications, including peroxide value, iodine value, free fatty acids, etc., it becomes necessary to specify the specific oil (usually soya), its conditions of preparation (usually refined, deoderized, and winterized), and that it be lightly hydrogenated (to prevent possibility off-flavor development). It should also have a stability rating of not less than 25 hr. in the active oxygen method (AOM). The AOM stability is important in indicating that the vegetable oil will not turn rancid under normal bakery bulk holding temperatures and times. It also indicates that bread croutons and bread crumbs, which have lengthly shelf lives, will not become rancid during normal storage periods (4).

The presence of fat may both decrease its initial permeability to CO_2 and also increase its resistance to thermal change (30). Microscopic studies have shown that gas cell walls (after proof) consist of gluten layers in which the large starch granules are embeded tangentially (31, 32). It is generally held that the gluten network is the component most involved in gas retention, particularly in preserving the mechanical integrity of the cell walls under stress (31, 33). The importance of the free lipid fraction is supported by recent histological (34) and chemical (35) evidence that much of the shortening fat added to dough remains in the free state, as globules of varying size.

Some of the baking industries use a fluid shortening in their formulation in bread-making. A fluid shortening can be composed of fat, oil, stearine, emulsifier and/or other non-fat additives. As the name implies, fluid shortening is a fluid at room temperature. Thus, it is easily stored in bulk at temperatures ranging from 65^{o} to 90^{o}f. Among primary advantages of fluid shortenings are:

a) ease in handling (because they are fluid they require no heating);

b) easy incorporation into automated systems;

c) they are easily dispersed and contain readily dispersed and more effective emulsifier systems;

d) reduce costs due to elimination of scaling errors involved in adding separate ingredients and reduction of labor involved in scaling'

e) fluid systems, by their nature, promote the possibility of labelling products containing them as sources of polyunsaturated fats. The basic properties are achieved by careful hydrogenation and/or crystallization of a refined oil in order to meet a specific solids profile (36).

It was found that the induction period was longer with doughs containing fat than with those without fat (30). Elton and Fisher (37) studied the relationship of loaf height with "crust" temperature and they show, a) that there is a virtually linear relationship (this is probably a simplification of the actual changes) up to the region of the boiling point of water; the result of expansion of gas in accordance with Charles law, increase of vapor pressure of water and other volatiles, the production of fresh CO_2 before the yeast is killed; b) inclusion of fat increase the rate of rise of the dough with temperature during this "linear" phase.

Surfactants in Baking

It seemed almost incredible a few years ago when the discovery was made that hard fat flakes could be eliminated, if the dough conditioners were used, without the danger of shortening failures (4).

The use of conditioner/softeners has become a very important practice in the baking industry. They can help the baker produce soft products with good interior characteristics and loaf volume, as well as provide dough strengthening functionality to overcome the mechanical abuse of modern bakery processing. They also reduce production costs by lowering shortening requirements (38).

Monoglycerides have the longest history of usage, having been employed by bakers for about 40 years. These compounds have little effect on dough properties, but do have an anti-firming effect on crumb (39). Depending on the degree of unsaturation of the fatty acids making up the monoglycerides, the latter will range in consistency from a relatively soft plastic mass for the more unsaturated product, to a hard, brittle waxy material for the highly saturated mono- and monoglycerides and the second series was of the unsaturated compounds. And it was found that the degree of saturation appeared to be of greater significance than the mono- to diglyceride ratio, the fully saturated materials being considerably more effective in influencing structure in a desirable manner (8). The most distinguishing feature of surfactants is amphipathie or amphephilic nature, i.e., they contain two distinct types of functional groups with conflicting solubility properties. Usually a hydrophilic or "water loving" group is in conflict with a hydrophobic or "water hating" group ("hated by water" is a more accurated description). The hydrophobic group is usually hydrocarbon in nature while the hydrophilic one may be an ionic or polar nonionic group (such as polyhydrol or polyoxyethylene).

This duality generally causes surfactants to adopt configurations such that the hydrophilic group has maximum and the hydrophobic group minimum contact with water. Surfactants may also act as wetting agents. Wetting can be defined as the process in which one fluid phase is displaced by another fluid phase from the surface of a solid or liquid, the driving force being reduction of interfacial free energy (7). Current uses of surfactant based dough conditioners in baking processes include: a) modification of mixing properties of doughs to promote higher and/or later-arriving consistency peaks, increased mixing tolerance, increased tolerance of non-wheat proteins, and an accommodation to the process and economic demands of modern bakery technology, and b) improvement of bread quality through stabilization of higher loaf volumes, better crumb texture and cell structure, and greater resistance to staling (7). In addition to mono- and diglycerides, lecithin, hydroxylated lecithin, polysorbate 60 and ethoxylated mono- and diglycerides, other optional ingredients permitted by the Standard of Identity for bread that fall within this general category include diacetyl tartaric acid esters of mono- and diglycerides, propylene glycol mono- and diglycerides, calcium and sodium stearoyl-2 lactylate, lactylic stearate, sodium stearoyl fumarate, and succinylated monoglycerides. The use levels in most instances is limited to 0.5 percent based on flour weight (5).

Table 1 summarizes the compounds permitted in breadmaking that, although possessing surfactant ability, perform their functions by means other than stabilization of emulsions. As indicated in table 1, the primary function of these compounds is to provide crumb softening and/or dough strengthening (39). Dough conditioners, or strengtheners, not possessing marked crumb firmness retarding effects are available, in propietary mixtures, blended with monoglycerides to provide a balanced dough strengthening-crumb firming retarding action (40). The importance of the physical state of fat-derived emulsifiers in bread-making has been studied by Wren (41). He found that the most effective baking emulsifiers exhibit alpha-crystallinity, but also that some emulsifiers with alpha-crystallinity proved to be much inferior to others without alpha-crystallinity.

It follows that in bread baked from a dough containing amylose-complexing surfactants, there will be little or no free amylose exrudate in the interstices between the granules. In the cool bread the structural network of denatured gluten will contain less or perhaps no crystalline amylose and the bread crumb will consequently be softer (42). The ionic surfactants decreased the lipids associated with all four protein fractions (glutenins, gliadins, albumins, and nitrogenous non-protein compounds, respectively). The non-ionic surfactant increased lipids greatly in glutenins and slightly in nitrogenous non-protein compounds, but decreased the associated lipids in the other two fractions (43). De Stefanis et al. (44) shows that the dough strengtheners, as well as the crumb softeners, did not associate with the flour components at the sponge stage. After dough-mixing (dough stage), SSL, SMG, and GMS formed a

Table 1

Crumb Softeners and Dough Strengtheners Used in Breadmaking

Compounds	Primary function
1 - Mono- and diglyceride	Crumb softener
2 - Diacetyl tartaric acid ester of mono- and diglycerides	Crumb softener
3 - Calcium and sodium stearoyl 2-lactylate	Crumb softener and dough strengthener
4 - lactylic stearate	Crumb softener and dough strengthener
5 - Sodium Stearoyl fumarate	Crumb softener and dough strengthener
6 - Succinylated monoglycerides	Crumb softener and dough strengthener
7 - Ethoxylated monoglycerides	Dough strengthener
8 - Polysorbate 60	Dough strengthener

Source: Adapted from Ponte (1971).

strong bond with the proteins. In bread, the additive was found strongly bound to the starch, rather than to the proteins. However, at baking temperatures, SSL, SMG, and GMS formed a strong complex with the starch. During baking, two concurrent phenomena occur: a) the bonds between the gluten proteins and the additive become increasingly weak (protein denaturation) as the dough temperature increases; and b) as starch gelatinizes above 50°C, the weakly bonded (proteins) additive readily forms a strong complex with the former, thus allowing a translocation to occur from the proteins to the starch. It would seem that the relative effectiveness of those additives is largely dependent upon how well the additive is dispersed in a dough system before starch gelatinization takes place.

A popular theory is that the softener interacts with the amylose fraction of the starch contained in the flour. This interaction is believed to retard starch gelatinization and hence extend the softness of the crumb (38). Excellent discussion of dough conditioners use include those by Ponte (40), Zobel (45) and Knightly (46). Their well-known effect in retarding bread firming appears to be due to the ability of the monoglycerides to enter starch granules and to complex with amylose with the formation of helices (47). Numerous studies designed to determine the cause of bread stailing have indicated the changes in the starch component are of major importance. The underlying factor in these changes has been attributed to increasing starch crystallization as measured by x-ray diffraction. Seeking to confirm the role of starch in staling, Cornford et al. (48) studied the relationships between the elastic modules of bread crumb and time and temperature.

Function of Starch in Baking

It is well known that many chemicals affect the gelatinization of starch. Compounds with two hydrophilic groups, such as the monoglycerides, have been to reduce the swelling of starch more than those compounds containing only one hydrophilic group. It should be remembered that the linear amylose component (A-fraction) of the starch is regarded as being completely retrograded after baking, whereas the branched amylopectin (B-fraction) aggregates during aging of the bread, and in the starch fraction that causes staling (49). The basic and important rheological properties of dough being attributed to the gluten structure developed during mixing (8). Betchel and Meizner (50), using a synthetic dough system of gluten and wheat starch, reported that changes in starch were responsible for the staling during the first three days and thereafter gluten affected the staling properties of bread.

Since the starch forms the main bulk of the dough, the restricted gelatinization which the starch undergoes during baking has a primary effect on the physical structure of a loaf of bread and on the post-baking change known as "staling". The extent of mechanical "damage" to starch granules in flour milling is a further factor in this system which affects both bread quality and the economics of breadmaking. Increased starch damage increases the water absorbing capacity of the dough which, in turn, increases the ultimate extent of swelling and gelatinization during baking. Amylase attack before heat gelatinization is also facilitated. Starch damage affects the baking changes, the bread structure and its acceptability to consumers. Relatively high degrees of "damage" are now accepted as beneficial to bread quality, providing that baking conditions are matched to the increased proportion of water in doughs (51). The small granules were found to have a lower swelling power than the regular granules, except at temperatures above $90^{o}C$ when the swelling power of the small granules exceeded that of the regular starch (52). The amylose presumably is thereby prevented from migrating to the aqueons phase outside the granules and setting up a rigid matrix (40). Some of the functions performed by starch seem to be quite definite: a) dilute the gluten to a desirable consistency; b) furnishes sugar through amylase action (damage starch); c) furnishes a surface suitable for a strong union with the gluten adhesive; d) becomes flexible, but does not disintegrate, during partially gelatinization (gelatinization in a deficiency of water) permitting further stretching of the gas-cell film; e) takes water from the gluten by gelatinization thus causing the film to set and become rigid enough to lose its expanding potential and to break, thus giving a bread structure that is readily permeable to gas so that the loaf of bread coming from the oven does not collapse on cooling. In proper amount the beta-limit dextrin, resulting from beta-amylase action on the damaged starch, gives: water holding capacity and good handling properties to the dough, and softness and tenderness to the bread crumb (53). Starch bread without the additive has a stiff crumb with an irregular, very coarse structure. By the addition of very little (0.1%) GMS a loose crumb with a fine and regular structure. The influence of GMS on the texture of the dough is explained by assuming that GMS is absorbed on the surface of the starch granules and that, consequently, the stable system is transformed into a flocculated one. In accordance with this, GMS greatly increases the rate of settling and the sediment volume in a 2% starch suspension. The large decrease of the rigidity of the crumb by GMS is probably caused by weakening of the bindings between the swollen starch granules (54). Katz (55) was the first to show that the x-ray diffraction pattern of fresh bread was similar to that of freshly gelatinized wheat starch; where as the pattern for stale bread was similar to that of retrograded starch.

Patterns of retrograded starch were characterized by an increased number of lines, which showed that part of the starch had crystallized during retrogradation. Helman, Fairchild and Senti (56) measured the rate of crystallization of starch gels at moisture levels comparable to that found in bread. The curve found by these authors relating extent of crystallinity to age of the gel is similar to that relating crumb firmness to the age of bread, and it serves to support the assumption that crystallization of starch plays an important role in bread staling. Zobel and Senti (57) shows a good correlation between firmness and degree of crystallinity in conventional bread.

MATERIAL AND METHODS

All materials used in the investigation were of commercial origin.

Flour

The flour used is a bleached bread flour from Dixie-Portland Flour Mills, Inc., Arkansas City, Kansas.

Our analytical laboratory showed the following analysis: 11.8% protein, 10.7% moisture, and 0.50% ash (on dry basis). The Farinograph showed: 60.6% water absorption, and 8 min. peak time.

Fats

Four different fats and four different surfactants were involved in this study.

Lard

The lard used for our study was sent by Swift Edible Oil Company, who also supplied the following data:

11% fully hydrogenated lard hard fat

89% bleached lard

with 0.05% of Tenox 4 (BHA and BHT) added.

PV	0.1 me/kg
moisture	0.03%
FFA	0.04%

color	3 yellow/0.3 red lovibond
MMP	116.1°f
AOM	30 hours plus.

Palm Oil and Fluid Shortening

The two samples were received from Anderson Clayton Foods, Dallas, Texas, who supplied the following analysis:

	Palm Oil	Fluid Shortening
Color	2.5	1.5
Free Fatty Acid, %	0.04	0.05
Iodine value	58.0	108
% Solid at 50°f	29.0	4.0
70°f	15.0	3.5
80°f	13.0	3.0
92°f	10.0	2.8
104°f	5.0	2.0
Mettler melting point, °C	42.3	39.0

(No added emulsifiers)

Soya Oil

A sample of refined soya oil received from SCM Glidden-Durkee, Strongsville, Ohio. Their quality assurance analysis for this sample is shown below:

Color (lovibond)	0.6 Red - 6.0 Yellow
Free Fatty Acid	0.02
Peroxide Value	0.80
Cold Test*	5½ hr +

Refractive Index 59.0 Butyro Units

*The cold test is a measure of the time required for cloudiness to appear when an oil is held at 32°f.

Surfactants

The four surfactants used for this investigation were:

Sodium stearoyl-2-lactylate (SSL). A sample of SSL received from C.J. Patterson Co., Kansas City, Mo.

Two types of polysorbate 60-Mono- and diglyceride combinations were received from ICI United States Inc., Wilmington, Delaware. The following data were supplied by the manufacturer:

	P60-MDG	P60-MDG
Form at 70°F	creamy white plastic solid	clear, golden liquid
Melting point, °F	128	45
Iodine Value	23	39
Total monoglycerides (alpha and beta form)	37%	32%

The fourth surfactant used in our study was succinylated monoglycerides with monoglycerides. This surfactant was sent by Eastman Chemical Products, Inc., Kingsport, Tennessee. The following table lists the typical properties of this product:

Iodine value	5.0
Hydroxyl value	205
Melting point, °C (°F)	57.5 (135.5)
Fatty acid ester proportion, % saturates	99
% unsaturants	1

Baking Procedure

The sponge and dough method was used for baking bread. In the sponge and dough method, the major fermentative action takes place in a pre-ferment, which is referred to as a sponge, in which normally more than one-half of the total dough flour is subjected to the physical, chemical and biological action of an active yeast fermentation (58). A normal sponge will expand in volume by a factor of 4 or 5 during fermentation (39). As in so many phases of the baking process, experience, and a thorough understanding of the existing bake-shop conditions must to a large degree govern the manner in which sponge mixing is carried out (58).

Hobart mixer, model A-200, which was made by the Hobart MFG. Co., Troy, Ohio, was used for mixing the dough.

Formula

Ingredients	Bakers %	Ingredients in sponge (grams)	Ingredients in dough (grams)	Total grams
Flour	100	490 (70%)	210 (30%)	700
Water	61	282 (66%)[1]	145 (34%)[2]	427
Yeast	2.5	17.5	-	17.5
Salt	2.0	-	14	14.0
Sugar	7.0	-	49	49.0
NFDM	2.0	-	14	14.0
Malted barley flour	0.05	0.35	-	0.35
Yeast food	0.25	1.75	-	1.75
Shortening	Variable	-	Variable	Variable
Surfactant	Variable	-	Variable	Variable

[1]Water temp. = 75°F.

[2]Water temp. = 64°F.

1. Weigh the sponge and the dough ingredients separately.

2. Mix sponge for 3 min. with No. 1 speed. Sponge temperature was 76 $\pm$ 1^{O}F.

3. Place mixed sponge in lightly greased fermentation jar and into fermentation cabinet. Adjust to give 85^{O}F and 86% Relative Humidity (R.H.). Allow to ferment for 4 hours to reach the proper degree of maturity or ripeness which is indicated by perceptible drop in the sponge, usually called the break (69).

4. After 4 hours, place dough ingredients in mixing bowl and mix 30 sec. at speed 1.

5. Place fermented sponge into mixer bowl and mix 1$\frac{1}{4}$ minutes on speed 1, then shift mixer to speed 2 and mix dough to optimum development (dough mixing time 4 min. or depending upon the flour). The dough temperature after mixing was 82 $\pm$ 1^{O}F.

6. Place dough into the fermentation cabinet at 85^{O}F and 86% R.H. for 30 min. rest, then scale two dough pieces to 539 grams.

7. Sheet each dough piece separately on the national rollar punching machine first at 5/16" and then 1/4". Reverse the dough through an angle of 180 for sheeting on the second setting. Roll the dough triple fold.

8. Place the dough piece into the fermentation cabinet at 85^{O}F and 86% R.H. for an intermediate proof period of 10 min.

9. Mould (adjust head rollers on Moline 100 moulder to 2 and 0.7 units, respectively, and pressure board 1-1/8 inches in the front and 7/8 inches in the back from belt level),

pan and proof to height (1.5 cms above pan) at 105°F and 92% R.H.

10. Bake at 425°F for 23 min. Put water in the oven to generate steam to eliminate caping while baking.

11. Loaf volume and weight were measured within three minutes after the loaf being out from the oven.

12. Cool for one hour, then wrap the loaf in a moisture proof plastic bag for firmness measurements and loaf scoring.

Firming Measurements

Firmness measurements were taken at day 1 (24 hours), and day 3 (72 hours) after baking, using a Bloom gelometer equipped with a plunger of one-inch diameter. Here, a cut slice of bread, is placed on a platform of the gelometer that can be vertically adjusted so that the slice just touches the bottom surface of the plunger. Lead shot is then released into a cup that depresses the plunger into the slice. The degree of firmness of the crumb is expressed in terms of the weight of shot required to compress the slice by 4 mm (14). Six slices were taken from each loaf for firming measurements. The measurements were taken from the ends toward the center.

After the first day firmness measurement, the loaf was saved for scoring (grain and external characteristics) of bread and further measuring the crumb color by using an Agtron.

Color Measurements

Agtron M-300-A was used for color measurement in this study. Six slices were taken for color measurement from each loaf.

For bracketing the color range for our study, disk 44 was used to zero meter and disk 75 was used to bring meter to read 100 by turning "standardize" control knob.

A mask of black paper 1-3/4" X 1-3/4" was placed on the viewer, then the slice of the bread was placed on the mask then disk 44 was placed on the top of the slice. After that the reading was recorded.

Statistical Method

As mentioned previously, 4 different commercial fats at three different levels (0, 1.0, and 3.0%, on flour basis) and 4 different commercial surfactants at three different levels (0, 0.25, and 0.50%) and fat-surfactant combinations were employed in this investigation. An experimental design for this study (table 2 and 3) was designed, by Dr. Dallas Johnson, Statistical Laboratory, Kansas State University, to investigate the effects of fats and surfactants and combinations and the interactions between them to produce a desirable loaf of bread. The experiment required a total of 162 doughs, each dough yielding two loaves of bread. In both replicates, the order of the bakes were randomized to eliminate the time effect.

Amylograph Procedure

The control of alpha-amylase activity appears to be of particular importance in bread-making (59). Considerable

Table 2

Experimental Design for Fats and Surfactants and their Combinations in Bread-making.
Rep. #1

Dough # / Days	1	2	3	4	5	6	7	8	9
1	S_{4a}	$F_{2d}S_{3a}$	$F_{3c}S_{4d}$	$F_{1c}S_{3b}$	$F_{2c}S_{1b}$	$F_{2c}S_{2b}$	$F_{3d}S_{1a}$	$F_{4d}S_{2a}$	F_{1d}
2	$F_{4c}S_{4a}$	$F_{1d}S_{2a}$	$F_{3c}S_{3a}$	F_{1c}	$F_{3d}S_{1b}$	$F_{2c}S_{4b}$	$F_{2d}S_{2b}$	S_{1a}	$F_{4d}S_{3b}$
3	S_{1b}	F_{4d}	$F_{1c}S_{2a}$	F_{2d}	S_{4b}	$F_{4c}S_{1a}$	$F_{3d}S_{4a}$	$F_{2c}S_{3a}$	$F_{3c}S_{2b}$
4	$F_{1d}S_{3a}$	$F_{4c}S_{3b}$	$F_{1c}S_{4b}$	None	$F_{2d}S_{4a}$	$F_{3d}S_{2a}$	$F_{4d}S_{2b}$	$F_{3c}S_{1b}$	$F_{2c}S_{1a}$
5	S_{2a}	$F_{3c}S_{4a}$	$F_{4d}S_{4b}$	$F_{2d}S_{1a}$	$F_{1c}S_{3a}$	$F_{2c}S_{1b}$	F_{4c}	$F_{1d}S_{2b}$	$F_{3d}S_{3b}$
6	$F_{3c}S_{1a}$	$F_{2c}S_{4a}$	F_{3d}	$F_{4d}S_{3a}$	$F_{2d}S_{4b}$	$F_{1d}S_{4d}$	$F_{4c}S_{2a}$	$F_{1c}S_{2b}$	S_{3b}
7	$F_{3d}S_{2b}$	$F_{1c}S_{1b}$	$F_{4c}S_{4b}$	$F_{2c}S_{2a}$	F_{2d}	$F_{1d}S_{4a}$	$F_{4d}S_{1a}$	$F_{3c}S_{3b}$	S_{3a}
8	$F_{2d}S_{2a}$	$F_{3d}S_{4b}$	$F_{4c}S_{3a}$	$F_{1d}S_{1a}$	S_{2b}	$F_{1c}S_{4a}$	F_{3c}	$F_{2c}S_{3b}$	$F_{4d}S_{1b}$
9	$F_{3c}S_{2a}$	$F_{4c}S_{2b}$	$F_{1d}S_{1b}$	$F_{3d}S_{3a}$	S_{4d}	$F_{4d}S_{4a}$	$F_{1c}S_{1a}$	$F_{2d}S_{3b}$	F_{2c}

Table 2 (continued)

Definitions:

F = Fat   S = Surfactant

1, 2, 3, and 4 refers to the type of fats and surfactants used;
a, b, c, and d refers to the level (on flour basis) of fats and surfactant used;

a = 0.25%   b = 0.50%   c = 1.0%   d = 3.0%

	Type of Fats	Type of Surfactants
1 -	Palm oil	P60-MDG-39
2 -	Lard	SMG-MG
3 -	Fluid Shortening	SSL
4 -	Salad oil (soya oil)	P60-MDG-23

Table 3

Experimental Design for Fats and Surfactants and Their Combinations in Bread-making
Rep. #2

Loaf # / Days	1	2	3	4	5	6	7	8	9
1	S_{4b}	$F_{3d}S_{2b}$	$F_{4d}S_{2a}$	$F_{1d}S_{3b}$	F_{1c}	$F_{2c}S_{1a}$	$F_{3c}S_{4a}$	$F_{4c}S_{3a}$	$F_{2d}S_{1b}$
2	$F_{4d}S_{3b}$	$F_{2d}S_{4a}$	$F_{4c}S_{2b}$	$F_{2c}S_{1b}$	S_{3a}	$F_{3d}S_{4b}$	$F_{1c}S_{2a}$	$F_{3c}S_{1a}$	F_{1d}
3	$F_{1d}S_{2a}$	S_{2b}	$F_{1c}S_{3b}$	$F_{3d}S_{3a}$	$F_{2c}S_{4a}$	F_{4d}	$F_{4c}S_{4b}$	$F_{2d}S_{1a}$	$F_{3c}S_{1b}$
4	$F_{2d}S_{3b}$	F_{3c}	$F_{1d}S_{4b}$	S_{1b}	$F_{2c}S_{2a}$	$F_{4c}S_{4a}$	$F_{4d}S_{2b}$	$F_{1c}S_{3a}$	$F_{3d}S_{1a}$
5	$F_{3c}S_{2a}$	S_{4a}	$F_{1c}S_{2b}$	F_{2d}	$F_{3d}S_{1b}$	$F_{4c}S_{1a}$	$F_{1d}S_{3a}$	$F_{2c}S_{3b}$	$F_{4d}S_{4d}$
6	F_{2c}	$F_{1d}S_{2b}$	$F_{3c}S_{3b}$	$F_{4c}S_{1b}$	$F_{4d}S_{3a}$	S_{1a}	$F_{2d}S_{2a}$	$F_{3d}S_{4a}$	$F_{1c}S_{4b}$
7	$F_{1c}S_{4a}$	$F_{4d}S_{1a}$	$F_{1d}S_{1b}$	F_{4c}	$F_{3c}S_{3a}$	S_{3b}	$F_{2c}S_{2b}$	$F_{3d}S_{2a}$	$F_{2d}S_{4b}$
8	$F_{3d}S_{3b}$	$F_{4c}S_{2a}$	$F_{1c}S_{1a}$	$F_{4d}S_{1b}$	$F_{2c}S_{4b}$	$F_{1d}S_{4a}$	None	$F_{2d}S_{3a}$	$F_{3c}S_{2b}$
9	S_{2a}	$F_{1c}S_{1b}$	$F_{2d}S_{2b}$	$F_{2c}S_{3a}$	$F_{1d}S_{1a}$	$F_{4d}S_{4a}$	F_{3d}	$F_{3c}S_{4b}$	$F_{4c}S_{3b}$

attention has been given to the development of convenient tests for the detection of excess amylase activity in relation to its undesirable effects on the crumb characteristic of baked goods. An apparatus, known as the amylograph, provides a continuous automatic record of the changes in viscosity of a flour-water suspension as the temperature is increased at a uniform rate.

To investigate the effect of the type of fats at level 3%, all loaves were baked with 0.50% SSL.

On the other hand, to investigate the effect of the type of surfactant at level 0.50%, all loaves were baked with 3.0% soya oil.

Bread was stored at room temperature for three days (72 hours), then stored in the freezer for two days then were taken out for amylograph study.

The method used is basically the same as Yasunaga et al. (60) used. The loaf of bread was taken out from the freezer, left to defrost for half hour then 100 grams of crumb was soaked in 300 ml. distilled water at 30^{o}C for one hour and thereafter dispersed in a Waring Blender (15 sec. at low and 60 sec. at high speed) to form a smooth slurry. The slurry is transferred to the amylograph bowl and a further 150 ml. of distilled water is added. The amylograph is then determined, with the 700 cm. g. cartridge and normal heating cycle.

RESULTS AND DISCUSSION

Effects of Surfactants and Fats on Bread Quality

Tables 4-7 show the effects of the four surfactants on the bread quality made with the different fats.

The addition of either fats or surfactants in bread-making increased loaf volume compared to the control. Without the addition of fats, increasing the level of the surfactant from 0.25 to 0.50%, increased loaf volume and improved bread quality. If no fat was added in treatment, bread made with 0.25% SSL, had a higher loaf volume than bread made with 0.50% of any of the other three surfactants.

Total Effects of Surfactants on Bread Quality

Table 8 shows the total effect of different surfactants on bread quality (combining all the effects of fats). The type and the level of the surfactants affect bread desirable quality. Bread made with SSL has a higher loaf volume and better grain. There was no significant difference in bread quality between bread made with P60-MDG-39 and bread made with P60-MDG-23.

Total Effects of Fats on Bread Quality

Table 9 shows the total effects of different fats on bread quality (combining all the effects of surfactants). Bread made with soya oil slightly increased loaf volume over the other three fats. However, the differences were small.

All fats increased loaf volume compared to the control.

Table 4

Effect of SSL, P60-MDG-39, P60-MDG-23, SMG-MG, and Palm Oil and Combinations of Them on Bread Quality

SSL %	P60-MDG-39 %	P60-MDG-23 %	SMG-MG %	Palm Oil %	Av. Specific Loaf Vol. cc/g	Loaf Score Grain	Loaf Score External
0	0	0	0	0	5.60	7.65	7.63
0.25	0	0	0	0	6.27	7.75	7.75
0.25	0	0	0	1.0	6.24	7.90	7.63
0.25	0	0	0	3.0	6.20	8.10	7.79
0.50	0	0	0	0	6.40	8.15	7.70
0.50	0	0	0	1.0	6.36	8.00	7.71
0.50	0	0	0	3.0	6.22	8.25	7.92
0	0.25	0	0	0	5.93	8.00	7.56
0	0.25	0	0	1.0	6.10	7.85	7.81
0	0.25	0	0	3.0	6.23	7.75	7.85
0	0.50	0	0	0	6.05	7.65	7.74
0	0.50	0	0	1.0	6.14	7.70	7.63
0	0.50	0	0	3.0	6.32	7.65	7.71

Table 4 (continued)

SSL %	P60-MDG-39 %	P60-MDG-23 %	SMG-MG %	Palm Oil %	Av. Specific Loaf Vol. cc/g	Loaf Score Grain	Loaf Score External
0	0	0.25	0	0	5.68	7.85	7.70
0	0	0.25	0	1.0	6.11	7.60	7.83
0	0	0.25	0	3.0	6.38	7.85	7.75
0	0	0.50	0	0	6.12	7.85	7.68
0	0	0.50	0	1.0	6.15	7.85	7.64
0	0	0.50	0	3.0	6.39	7.60	7.79
0	0	0	0.25	0	5.87	8.15	7.56
0	0	0	0.25	1.0	6.01	7.75	7.73
0	0	0	0.25	3.0	6.04	7.75	7.72
0	0	0	0.50	0	6.10	7.50	7.98
0	0	0	0.50	1.0	6.21	7.85	7.63
0	0	0	0.50	3.0	6.16	7.60	7.73
0	0	0	0	1.0	5.87	7.80	7.42
0	0	0	0	3.0	5.99	8.00	7.39

Table 5

Effect of SSL, P60-MDG-39, P60-MDG-23, SMG-MG, and Lard and Combinations of Them on Bread Quality

SSL %	P60-MDG-39 %	P60-MDG-23 %	SMG-MG %	Lard %	Av. Specific Loaf Vol. cc/g	Loaf Score Grain	Loaf Score External
0	0	0	0	0	5.60	7.65	7.63
0.25	0	0	0	0	6.27	7.75	7.75
0.25	0	0	0	1.0	6.27	7.95	7.89
0.25	0	0	0	3.0	6.20	8.15	7.65
0.50	0	0	0	0	6.40	8.15	7.70
0.50	0	0	0	1.0	6.56	8.00	7.91
0.50	0	0	0	3.0	6.40	7.65	7.78
0	0.25	0	0	0	5.93	8.00	7.56
0	0.25	0	0	1.0	5.97	7.95	7.70
0	0.25	0	0	3.0	6.40	7.60	7.92
0	0.50	0	0	0	6.05	7.65	7.74
0	0.50	0	0	1.0	6.13	7.65	7.68
0	0.50	0	0	3.0	6.61	7.55	7.69

Table 5 (continued)

SSL %	P60-MDG-39 %	P60-MDG-23 %	SMG-MG %	Lard %	Av. Specific Loaf Vol. cc/g	Loaf Score Grain	Loaf Score External
0	0	0.25	0	0	5.68	7.85	7.70
0	0	0.25	0	1.0	6.33	7.55	7.78
0	0	0.25	0	3.0	5.93	8.05	7.74
0	0	0.50	0	0	6.12	7.85	7.68
0	0	0.50	0	1.0	6.22	7.70	7.64
0	0	0.50	0	3.0	6.17	8.35	7.85
0	0	0	0.25	0	5.87	8.15	7.56
0	0	0	0.25	1.0	6.22	7.65	7.75
0	0	0	0.25	3.0	6.17	7.75	7.73
0	0	0	0.50	0	6.10	7.50	7.78
0	0	0	0.50	1.0	6.03	7.75	7.63
0	0	0	0.50	3.0	6.07	7.90	7.50
0	0	0	0	1.0	6.24	7.80	7.87
0	0	0	0	3.0	6.15	7.80	7.93

Table 6

Effect of SSL, P60-MDG-39, P60-MDG-23, SMG-MG, and Fluid Shortening and Combinations of them on Bread Quality

SSL %	P60-MDG-39 %	P60-MDG-23 %	SMG-MG %	Fluid Short. %	Av. Specific Loaf Vol. cc/g	Loaf Score Grain	Loaf Score External
0	0	0	0	0	5.60	7.65	7.63
0.25	0	0	0	0	6.27	7.75	7.75
0.25	0	0	0	1.0	6.23	8.0	7.61
0.25	0	0	0	3.0	6.46	7.75	8.0
0.50	0	0	0	0	6.40	8.15	7.70
0.50	0	0	0	1.0	6.52	7.95	8.03
0.50	0	0	0	3.0	6.53	7.95	8.29
0	0.25	0	0	0	5.93	8.00	7.56
0	0.25	0	0	1.0	6.30	7.75	7.74
0	0.25	0	0	3.0	6.18	7.75	7.73
0	0.50	0	0	0	6.05	7.65	7.74
0	0.50	0	0	1.0	6.16	7.45	7.91
0	0.50	0	0	3.0	6.36	7.95	7.75

Table 6 (continued)

SSL %	P60-MDG-39 %	P60-MDG-23 %	SMG-MG %	Fluid Short. %	Av. Specific Loaf Vol. cc/g	Loaf Score Grain	Loaf Score External
0	0	0.25	0	0	5.68	7.85	7.70
0	0	0.25	0	1.0	6.06	7.75	7.87
0	0	0.25	0	3.0	6.29	8.00	7.83
0	0	0.50	0	0	6.12	7.85	7.68
0	0	0.50	0	1.0	6.28	7.80	7.74
0	0	0.50	0	3.0	6.48	7.75	7.82
0	0	0	0.25	0	5.87	8.15	7.56
0	0	0	0.25	1.0	6.10	7.75	7.74
0	0	0	0.25	3.0	6.13	7.85	7.73
0	0	0	0.50	0	6.10	7.50	7.78
0	0	0	0.50	1.0	5.98	8.00	7.63
0	0	0	0.50	3.0	5.98	7.45	7.72
0	0	0	0	1.0	6.21	7.75	7.71
0	0	0	0	3.0	6.23	7.65	7.76

Table 7

Effects of SSL, P60-MDG-39, P60-MDG-23, SMG-MG, and Soya Oil and Combinations of them on Bread Quality

SSL %	P60-MDG-39 %	P60-MDG-23 %	SMG-MG %	Soya Oil %	Av. Specific Loaf Vol. cc/g	Loaf Score Grain	Loaf Score External
0	0	0	0	0	5.60	7.65	7.63
0.25	0	0	0	0	6.27	7.75	7.75
0.25	0	0	0	1.0	6.47	7.70	7.63
0.25	0	0	0	3.0	6.41	7.65	7.81
0.50	0	0	0	0	6.40	8.15	7.70
0.50	0	0	0	1.0	6.31	7.90	7.83
0.50	0	0	0	3.0	6.42	8.20	7.80
0	0.25	0	0	0	5.93	8.00	7.56
0	0.25	0	0	1.0	6.17	7.65	7.74
0	0.25	0	0	3.0	6.29	7.70	7.73
0	0.50	0	0	0	6.05	7.65	7.74
0	0.50	0	0	1.0	6.40	7.85	7.80
0	0.50	0	0	3.0	6.65	7.80	8.01

Table 7 (continued)

SSL %	P60-MDG-39 %	P60-MDG-23 %	SMG-MG %	Soya Oil %	Av. Specific Loaf Vol. cc/g	Loaf Score Grain	Loaf Score External
0	0	0.25	0	0	5.68	7.85	7.70
0	0	0.25	0	1.0	6.16	7.80	7.68
0	0	0.25	0	3.0	6.44	7.85	7.78
0	0	0.50	0	0	6.12	7.85	7.68
0	0	0.50	0	1.0	6.44	7.89	7.81
0	0	0.50	0	3.0	6.27	8.00	7.78
0	0	0	0.25	0	5.87	8.15	7.56
0	0	0	0.25	1.0	6.17	7.85	7.60
0	0	0	0.25	3.0	6.29	8.00	7.71
0	0	0	0.50	0	6.10	7.50	7.78
0	0	0	0.50	1.0	6.40	7.85	7.63
0	0	0	0.50	3.0	6.65	7.90	7.66
0	0	0	0	1.0	5.89	7.80	7.67
0	0	0	0	3.0	6.29	7.85	7.93

Table 8

Total Effects of SSL, P60-MDG-39, P60-MDG23, and SMG-MG on Bread Quality

SSL %	P60-MDG-39 %	P60-MDG-23 %	SMG-MG %	Av. Specific Loaf Vol. cc/g	Grain
0	0	0	0	6.05	7.79
0.25	0	0	0	6.31	7.89
0	0.25	0	0	6.17	7.78
0	0	0.25	0	6.15	7.81
0	0	0	0.25	6.09	7.83
0.50	0	0	0	6.42	8.01
0	0.50	0	0	6.31	7.69
0	0	0.50	0	6.28	7.89
0	0	0	0.50	6.10	7.76

Table 9

Total Effects of Palm Oil, Lard, Fluid Shortening, and Soya Oil on Bread Quality

Palm Oil %	Lard %	Fluid Short. %	Soya Oil %	Av. Specific Loaf Vol. cc/g	Grain
0	0	0	0	6.00	7.85
1.0	0	0	0	6.13	7.81
0	1.0	0	0	6.22	7.78
0	0	1.0	0	6.21	7.80
0	0	0	1.0	6.24	7.80
3.0	0	0	0	6.21	7.84
0	3.0	0	0	6.23	7.87
0	0	3.0	0	6.29	7.79
0	0	0	3.0	6.34	7.88

Differences in grain did not seem to be significant.

Effects of Surfactants and Fats on Bread Firmness

Tables 10-13 show the effects of the four surfactants on bread firmness made with different fats. The addition of either fats or surfactants softened the bread. Increasing the level of surfactants from 0.25 to 0.50% decreased firmness (the bread is softer). Bread made with 3.0% fat was softer than bread made with 1.0% fat.

Total Effects of Surfactants on Bread Firmness

Table 14 shows the total effect of different surfactants on bread firmness (combining all the effects of fats). The type and the level of the surfactants affected bread firmness. Bread made with surfactants were softer compared to the control. Bread made with SSL produced softer bread than any of the other three surfactants. Bread made with P60-MDG-39 was as soft as bread made with P60-MDG-23.

Total Effects of Fats on Bread Firmness

Table 15 shows the total effect of different fats on bread firmness (combining all the effects of surfactants). Bread made with fat was softer than bread made without fat. Increasing the level of fats from 1.0 to 3.0 percent increased softeness of the bread. Bread made with soya oil was softer than bread made with any of the other three fats.

Table 10

Effects of SSL, P60-MDG-39, P60-MDG-23, SMG-MG, and Palm Oil and Combinations of Them on Bread Firmness

SSL %	P60-MDG-39 %	P60-MDG-23 %	SMG-MG %	Palm Oil %	Firmness 24 hrs g	Firmness 72 hrs g
0	0	0	0	0	113.33	190.77
0.25	0	0	0	0	105.61	181.46
0.25	0	0	0	1.0	96.94	151.82
0.25	0	0	0	3.0	93.80	143.58
0.50	0	0	0	0	95.80	145.32
0.50	0	0	0	1.0	96.00	159.24
0.50	0	0	0	3.0	90.56	146.20
0	0.25	0	0	0	114.02	191.36
0	0.25	0	0	1.0	118.38	184.52
0	0.25	0	0	3.0	102.76	160.02
0	0.50	0	0	0	98.40	156.08
0	0.50	0	0	1.0	100.84	175.83
0	0.50	0	0	3.0	108.89	167.91
0	0	0.25	0	0	109.94	180.42
0	0	0.25	0	1.0	105.91	162.91
0	0	0.25	0	3.0	96.70	157.83
0	0	0.50	0	0	104.94	167.78
0	0	0.50	0	1.0	108.58	157.04
0	0	0.50	0	3.0	98.37	153.78
0	0	0	0.25	0	100.60	174.23
0	0	0	0.25	1.0	106.78	179.97
0	0	0	0.25	3.0	110.85	167.11
0	0	0	0.50	0	107.25	168.32
0	0	0	0.50	1.0	110.16	160.86
0	0	0	0.50	3.0	105.82	152.00
0	0	0	0	1.0	108.96	187.44
0	0	0	0	3.0	114.99	193.43

Table 11

Effects of SSL, P60-MDG-39, P60-MDG-23, SMG-MG, and Lard and Combinations of Them on Bread Firmness

SSL %	P60-MDG-39 %	P60-MDG-23 %	SMG-MG %	Lard %	Firmness 24 hrs g	Firmness 72 hrs g
0	0	0	0	0	113.33	190.77
0.25	0	0	0	0	105.61	181.46
0.25	0	0	0	1.0	96.50	143.92
0.25	0	0	0	3.0	105.98	181.37
0.50	0	0	0	0	95.80	145.32
0.50	0	0	0	1.0	92.60	132.97
0.50	0	0	0	3.0	107.34	146.43
0	0.25	0	0	0	114.02	191.36
0	0.25	0	0	1.0	99.82	163.60
0	0.25	0	0	3.0	102.91	164.30
0	0.50	0	0	0	98.40	156.08
0	0.50	0	0	1.0	105.30	157.21
0	0.50	0	0	3.0	97.21	140.65
0	0	0.25	0	0	109.94	180.42
0	0	0.25	0	1.0	110.08	164.80
0	0	0.25	0	3.0	111.04	179.84
0	0	0.50	0	0	104.94	167.78
0	0	0.50	0	1.0	114.21	162.98
0	0	0.50	0	3.0	99.48	159.87
0	0	0	0.25	0	100.60	174.23
0	0	0	0.25	1.0	106.19	168.94
0	0	0	0.25	3.0	115.26	181.15
0	0	0	0.50	0	107.25	168.32
0	0	0	0.50	1.0	110.46	186.21
0	0	0	0.50	3.0	102.05	169.67
0	0	0	0	1.0	124.30	189.29
0	0	0	0	3.0	112.67	168.44

Table 12

Effects of SSL, P60-MDG-39, P60-MDG-23, SMG-MG, and Fluid Shortening and Combinations of Them on Bread Firmness

SSL %	P60-MDG-39 %	P60-MDG-23 %	SMG-MG %	Fluid Short. %	Firmness 24 hrs %	Firmness 72 hrs %
0	0	0	0	0	113.33	190.77
0.25	0	0	0	0	105.61	181.46
0.25	0	0	0	1.0	107.41	150.93
0.25	0	0	0	3.0	101.39	160.48
0.50	0	0	0	0	95.80	145.32
0.50	0	0	0	1.0	91.99	136.29
0.50	0	0	0	3.0	85.17	122.88
0	0.25	0	0	0	114.02	191.36
0	0.25	0	0	1.0	107.71	163.32
0	0.25	0	0	3.0	118.65	169.84
0	0.50	0	0	0	98.40	156.08
0	0.50	0	0	1.0	102.41	172.79
0	0.50	0	0	3.0	90.81	161.13
0	0	0.25	0	0	109.94	180.42
0	0	0.25	0	1.0	95.06	165.13
0	0	0.25	0	3.0	100.25	165.04
0	0	0.50	0	0	104.94	167.78
0	0	0.50	0	1.0	107.20	169.18
0	0	0.50	0	3.0	103.23	150.33
0	0	0	0.25	0	100.60	174.23
0	0	0	0.25	1.0	106.72	167.51
0	0	0	0.25	3.0	98.11	174.70
0	0	0	0.50	0	107.25	168.32
0	0	0	0.50	1.0	102.22	169.30
0	0	0	0.50	3.0	102.40	161.83
0	0	0	0	1.0	112.70	184.78
0	0	0	0	3.0	92.84	147.45

Table 13

Effects of SSL, P60-MDG-39, P60-MDG-23, SMG-MG, and Soya Oil and Combinations of Them on Bread Firmness

SSL %	P60-MDG-39 %	P60-MDG-23 %	SMG-MG %	Soya Oil %	Firmness 24 hrs g	Firmness 72 hrs g
0	0	0	0	0	113.33	190.77
0.25	0	0	0	0	105.61	181.46
0.25	0	0	0	1.0	95.92	161.43
0.25	0	0	0	3.0	87.13	144.15
0.50	0	0	0	0	95.80	145.32
0.50	0	0	0	1.0	96.80	151.91
0.50	0	0	0	3.0	100.58	138.69
0	0.25	0	0	0	114.02	191.36
0	0.25	0	0	1.0	102.38	157.90
0	0.25	0	0	3.0	99.37	148.99
0	0.50	0	0	0	98.40	156.08
0	0.50	0	0	1.0	99.00	161.46
0	0.50	0	0	3.0	89.50	140.88
0	0	0.25	0	0	109.94	180.42
0	0	0.25	0	1.0	106.42	163.42
0	0	0.25	0	3.0	105.81	151.53
0	0	0.50	0	0	104.94	167.78
0	0	0.50	0	1.0	95.33	151.14
0	0	0.50	0	3.0	95.98	136.36
0	0	0	0.25	0	100.60	174.23
0	0	0	0.25	1.0	102.32	157.90
0	0	0	0.25	3.0	99.37	148.99
0	0	0	0.50	0	107.25	168.32
0	0	0	0.50	1.0	99.00	161.46
0	0	0	0.50	3.0	89.50	140.88
0	0	0	0	1.0	109.36	174.31
0	0	0	0	3.0	102.15	164.73

Table 14

Total Effects of SSL, P60-MDG-39, P60-MDG-23, and SMG-MG on Bread Firmness

SSL %	P60-MDG-39 %	P60-MDG-23 %	SMG-MG %	Firmness 24 hrs. g	Firmness 72 hrs. g
0	0	0	0	110.14	177.85
0.25	0	0	0	98.96	157.64
0	0.25	0	0	107.32	167.14
0	0	0.25	0	104.58	165.67
0	0	0	0.25	105.02	171.72
0.50	0	0	0	95.02	141.98
0	0.50	0	0	99.15	159.32
0	0	0.50	0	103.03	156.49
0	0	0	0.50	105.47	167.49

Table 15

Total Effects of Palm Oil, Lard, Fluid Shortening, and Soya Oil on Bread Firmness

Palm Oil %	Lard %	Fluid Short. %	Soya Oil %	Firmness 24 hrs. g	Firmness 72 hrs. g
0	0	0	0	105.55	172.86
1.0	0	0	0	105.83	168.64
0	1.0	0	0	106.61	163.31
0	0	1.0	0	103.70	164.36
0	0	0	1.0	102.80	160.55
3.0	0	0	0	102.53	160.22
0	3.0	0	0	105.99	165.74
0	0	3.0	0	99.20	156.98
0	0	0	3.0	96.48	152.66

Pattern of Firmness Within the Loaf of Bread

Figure 1 showed the pattern of firmness within the loaf of bread. It was concluded that the loaf centers were firmer than their ends. This might be explained by the specific volume of the slice. The specific volume of the center loaves were lower than their ends.

Effects of Surfactants and Fats on Crumb Color

Tables 16-19 show the effects of the four surfactants on bread crumb color, made with the different fats. The addition of either fats or surfactants and their combinations improved bread crumb color compared to the control. If no fats were added, increasing the level of P60-MDG-23 or SMG-MG from 0.25 to 0.50% improved crumb color.

Total Effects of Surfactants on Crumb Color

Table 20 shows the total effect of different surfactants on bread crumb color (combining all the effects of fats). In general, all surfactants at both levels 0.25 and 0.50% improved the crumb color compared to bread made without surfactants. Bread made with SSL at both levels 0.25 and 0.50% had better crumb color than bread made with the other surfactants.

Increasing the level of either SSL or P60-MDG-39 from 0.25 to 0.50% did not improve the crumb color. Small amount of SSL improved the crumb color.

Total Effects of Fats on Crumb Color

Table 21 shows the total effect of different fats on

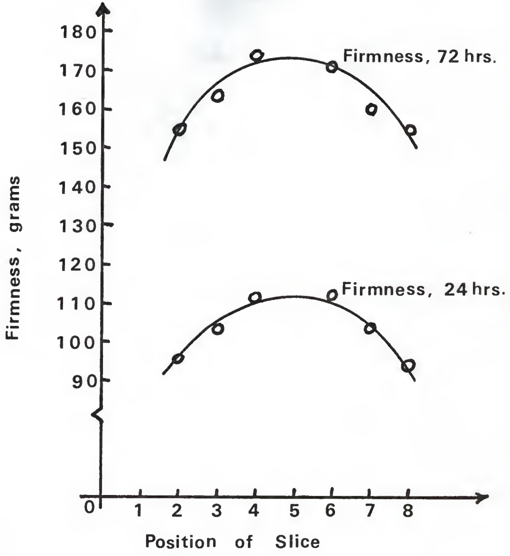

FIG.1. FIRMNESS PATTERN WITHIN BREAD

Table 16

Effects of SSL, P60-MDG-39, P60-MDG-23, SMG-MG, and Palm Oil and Combinations of Them on Bread Crumb Color

SSL %	P60-MDG-39 %	P60-MDG-23 %	SMG-MG %	Palm Oil %	Agtron Rd.
0	0	0	0	0	1.83
0.25	0	0	0	0	23.72
0.25	0	0	0	1.0	24.52
0.25	0	0	0	3.0	22.58
0.50	0	0	0	0	15.00
0.50	0	0	0	1.0	16.28
0.50	0	0	0	3.0	26.05
0	0.25	0	0	0	14.02
0	0.25	0	0	1.0	6.93
0	0.25	0	0	3.0	10.07
0	0.50	0	0	0	14.73
0	0.50	0	0	1.0	15.08
0	0.50	0	0	3.0	11.42
0	0	0.25	0	0	17.37
0	0	0.25	0	1.0	7.17
0	0	0.25	0	3.0	15.48
0	0	0.50	0	0	25.00
0	0	0.50	0	1.0	25.08
0	0	0.50	0	3.0	18.18
0	0	0	0.25	0	6.27
0	0	0	0.25	1.0	21.18
0	0	0	0.25	3.0	12.12
0	0	0	0.50	0	11.68
0	0	0	0.50	1.0	23.78
0	0	0	0.50	3.0	13.15
0	0	0	0	1.0	15.37
0	0	0	0	3.0	21.98

Table 17

Effects of SSL, P60-MDG-39, P60-MDG-23, SMG-MG, and Lard and Combinations of Them on Bread Crumb Color

SSL %	P60-MDG-39 %	P60-MDG-23 %	SMG-MG %	Lard %	Agtron Rd.
0	0	0	0	0	1.83
0.25	0	0	0	0	23.72
0.25	0	0	0	1.0	16.95
0.25	0	0	0	3.0	16.10
0.50	0	0	0	0	15.00
0.50	0	0	0	1.0	27.33
0.50	0	0	0	3.0	18.40
0	0.25	0	0	0	14.02
0	0.25	0	0	1.0	19.68
0	0.25	0	0	3.0	18.22
0	0.50	0	0	0	14.73
0	0.50	0	0	1.0	21.88
0	0.50	0	0	3.0	17.97
0	0	0.25	0	0	17.37
0	0	0.25	0	1.0	20.58
0	0	0.25	0	3.0	19.27
0	0	0.50	0	0	25.00
0	0	0.50	0	1.0	17.47
0	0	0.50	0	3.0	11.77
0	0	0	0.25	0	6.27
0	0	0	0.25	1.0	19.70
0	0	0	0.25	3.0	18.22
0	0	0	0.50	0	11.68
0	0	0	0.50	1.0	7.48
0	0	0	0.50	3.0	14.03
0	0	0	0	1.0	14.12
0	0	0	0	3.0	21.07

Table 18

Effects of SSL, P60-MDG-39, P60-MDG-23, SMG-MG, and Fluid Shortening and Combinations of Them on Bread Crumb Color

SSL %	P60-MDG-39 %	P60-MDG-23 %	SMG-MG %	Fluid Short. %	Agtron Rd.
0	0	0	0	0	1.83
0.25	0	0	0	0	23.72
0.25	0	0	0	1.0	11.38
0.25	0	0	0	3.0	20.17
0.50	0	0	0	0	15.00
0.50	0	0	0	1.0	21.15
0.50	0	0	0	3.0	14.55
0	0.25	0	0	0	14.02
0	0.25	0	0	1.0	22.27
0	0.25	0	0	3.0	11.42
0	0.50	0	0	0	14.73
0	0.50	0	0	1.0	14.45
0	0.50	0	0	3.0	17.83
0	0	0.25	0	0	17.37
0	0	0.25	0	1.0	17.92
0	0	0.25	0	3.0	21.32
0	0	0.50	0	0	25.00
0	0	0.50	0	1.0	9.70
0	0	0.50	0	3.0	20.42
0	0	0	0.25	0	6.27
0	0	0	0.25	1.0	15.20
0	0	0	0.25	3.0	5.62
0	0	0	0.50	0	11.68
0	0	0	0.50	1.0	12.53
0	0	0	0.50	3.0	24.80
0	0	0	0	1.0	8.82
0	0	0	0	3.0	10.43

Table 19

Effects of SSL, P60-MDG-39, P60-MDG-23, SMG-MG, and Soya Oil and Combinations of Them on Bread Crumb Color

SSL %	P60-MDG-39 %	P60-MDG-23 %	SMG-MG %	Soya Oil %	Agtron Rd.
0	0	0	0	0	1.83
0.25	0	0	0	0	23.72
0.25	0	0	0	1.0	22.95
0.25	0	0	0	3.0	18.80
0.50	0	0	0	0	15.00
0.50	0	0	0	1.0	14.60
0.50	0	0	0	3.0	19.02
0	0.25	0	0	0	14.02
0	0.25	0	0	1.0	21.82
0	0.25	0	0	3.0	18.22
0	0.50	0	0	0	14.73
0	0.50	0	0	1.0	19.30
0	0.50	0	0	3.0	10.45
0	0	0.25	0	0	17.37
0	0	0.25	0	1.0	15.77
0	0	0.25	0	3.0	9.78
0	0	0.50	0	0	25.00
0	0	0.50	0	1.0	18.40
0	0	0.50	0	3.0	18.60
0	0	0	0.25	0	6.27
0	0	0	0.25	1.0	21.82
0	0	0	0.25	3.0	18.22
0	0	0	0.50	0	11.68
0	0	0	0.50	1.0	19.30
0	0	0	0.50	3.0	10.45
0	0	0	0	1.0	3.47
0	0	0	0	3.0	8.37

Table 20

Total Effects of SSL, P60-MDG-39, P60-MDG-23, and SMG-MG on Bread Crumb Color

SSL %	P60-MDG-39 %	P60-MDG-23 %	SMG-MG %	Agtron Rd.
0	0	0	0	11.72
0.25	0	0	0	19.69
0	0.25	0	0	15.86
0	0	0.25	0	16.07
0	0	0	0.25	13.48
0.50	0	0	0	19.15
0	0.50	0	0	15.90
0	0	0.50	0	18.36
0	0	0	0.50	15.76

Table 21

Total Effects of Palm Oil, Lard, Fluid Shortening, and Soya Oil on Bread Crumb Color

Palm Oil %	Lard %	Fluid Short. %	Soya Oil %	Agtron Rd.
0	0	0	0	14.47
1.0	0	0	0	17.27
0	1.0	0	0	18.36
0	0	1.0	0	14.82
0	0	0	1.0	15.19
3.0	0	0	0	16.78
0	3.0	0	0	17.23
0	0	3.0	0	16.28
0	0	0	3.0	15.58

bread crumb color (combining all the effects of surfactants). All fats improved the crumb color compared to the contro. Bread made with lard was slightly brighter than bread made with the other fats. However, the differences were small.

Pattern of Crumb Color Within the Loaf of Bread

Figure 2 showed the pattern of crumb color within the loaf of bread. The loaf centers were darker in color than their ends. This might be explained by the presence of solids in the center loaf.

Effects of Surfactants on Amylograph Properties of Crumb

Table 22 shows the effects of the four surfactants on amylograph properties of the crumb of the bread made with 3.0% soya oil. In general, all surfactants increased the peak height compared to the control. Bread made with 0.50% SMG-MG did not increase the peak height. This might be explained by the fact that SMG-MG was not optimum when added in the dough stage. This point will be duscussed later.

Bread made with surfactants increased the pasting temp. slightly.

Bread made with 0.50% P60-MDG-23 did not show any difference in amylograph properties of the crumb, from bread made with 0.50% P60-MDG-23.

Effects of Fats on Amylograph Properties of Crumb

Table 23 shows the effects of the four fats on amylograph

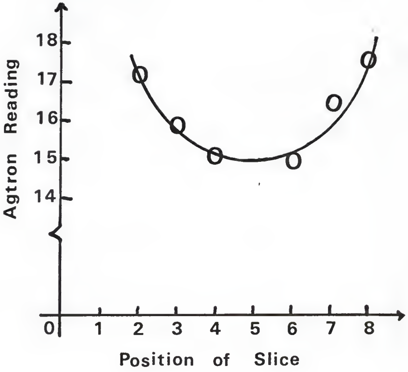

FIG. 2. CRUMB COLOR PATTERN WITHIN BREAD

Table 22

Effects of SSL, P60-MDG-39, P60-MDG-23, and SMG-MG On Amylograph Properties of the Crumb[b]

SSL %	P60-MDG-39 %	P60-MDG-23 %	SMG-MG %	Peak Height	Peak Time min.	Pasting Temp. °C
0	0	0	0	394	45.50	86.63
0.50	0	0	0	549	46.00	89.63
0	0.50	0	0	432	45.75	87.94
0	0	0.50	0	433	45.75	88.88
0	0	0	0.50	364	46.00	90.38

[b]All loaves were made with 3.0% soya oil.

Table 23

Effects of Palm Oil, Lard, Fluid Shortening, and Soya Oil on Amylograph Properties of the Crumb[a]

Palm Oil %	Lard %	Fluid Short. %	Soya Oil %	Peak Height	Peak Time min.	Pasting Temp. °C
0	0	0	0	430	45.46	87.50
3.0	0	0	0	516	35.75	89.26
0	3.0	0	0	521	45.75	89.44
0	0	3.0	0	536	45.75	89.10
0	0	0	3.0	549	46.00	89.63

[a]All loaves were made with 0.50% SSL.

properties of the crumb of the bread made with 0.50% SSL. All fats increased the peak height compared to the control. Bread made with fats increased the pasting temp. slightly.

Effects of Various Methods of Adding SMG-MG on Bread Quality

Table 24 shows three ways of adding SMG-MG in breadmaking and their effects on bread quality. All loaves were made with 3.0% lard and 0.50% SMG-MG (on flour basis). There was no differences in loaf volumes among the three methods. When SMG-MG was added either dry in sponge or hydrated in dough, the bread was softer than if SMG-MG was added dry in dough. Grain and external characteristics of the bread did not show any differences among the three methods.

Fat-Surfactant Interactions on Bread Quality

One of the objectives of this study was to determine whether or not there were any interactions between fats and surfactants during breadmaking.

Tables 25-28 summarize the analysis of variance performed on the data to ascertain whether fat-surfactant interactions had occurred.

Assuming no time effect, the analysis of variance showed that there were no interactions between fats and surfactants to affect loaf volume, firmness (24 and 72 hrs.), and grain. Therefore, the effects of fats and surfactants are additive.

Table 24

Effects of Various Methods of Adding SMG-MG on Bread Quality[a]

	Dry in Dough	Dry in Sponge	Hydrated and added to dough
Avg. Sp. Loaf-Vol. cc/g	6.27	6.33	6.27
24 hr., firmness	116.03	104.83	112.58
72 hr., firmness	183.48	156.22	161.81
Rate	77.45	51.39	49.23
Grain	7.8	7.75	7.85
External	7.6	7.75	7.53

[a]All loaves were made with 3.0% lard.

Table 25

Analysis of Variance
Dependent Variable: Specific Loaf-Volume

Source	D.F.	Sum Square	Mean Square	F Value	PR>F
Replicate	1	0.851	0.851	18.54	0.0001
Fat	8	1.380	0.173	3.76	0.0009
Surfactant	8	2.267	0.283	6.15	0.0001
Fat *Surfactant	64	2.562	0.040	0.87	0.7136
Error	80	3.672	0.046	1.90	0.0023
Corrected Total	161	10.732	-	-	-

Table 26

Analysis of Variance
Dependent Variable: Firmness, 24 hrs.

Source	D.F.	Sum Square	Mean Square	F Value	PR>F
Replicate	1	252.43	252.43	3.65	0.0598
Fat	8	1689.68	211.21	3.05	0.0048
Surfactant	8	3182.78	397.85	5.75	0.0001
Fat *Surfactant	64	4831.46	75.49	1.09	0.3545
Error	80	5538.32	69.23	1.78	0.0054
Corrected Total	161	15494.67	-	-	-

Table 27

Analysis of Variance
Dependent Variable: Firmness, 72 hrs.

Source	D.F.	Sum Square	Mean Square	F Value	PR>F
Replicate	1	4007.50	4007.50	21.27	0.0001
Fat	8	5310.74	663.84	3.52	0.0015
Surfactant	8	15605.77	1950.72	10.35	0.0001
Fat *Surfactant	64	14524.38	226.94	1.20	0.2140
Error	80	15074.45	188.43	2.58	0.0001
Corrected Total	161	54522.84	-	-	-

Table 28

Analysis of Variance
Dependent Variable: Grain

Source	D.F.	Sum Square	Mean Square	F Value	PR>F
Replicate	1	1.142	1.142	24.30	0.0001
Fat	8	0.188	0.024	0.51	0.8547
Surfactant	8	1.139	0.142	3.02	0.0052
Fat *Surfactant	64	3.814	0.060	1.28	0.1612
Error	80	3.778	0.047	1.64	0.0137
Corrected Total	161	10.061	-	-	-

SUMMARY AND CONCLUSIONS

It is well-known that the addition of fat system to white bread formulation results in several benefits, including better texture, volume, machining properties, and keeping quality of the bread (10). Regardless of the exact mechanism by which softeners exert their effect, because they do retard crumb firming, so they are very important to the baker for extending the shelf-life of his products.

The mixing process weakened the gluten to the extent that the resulting doughs could not withstand the shaking and jarring of the conveyor belts and early oven stages of baking (16). Bread made with soya oil and SSL produced bread of a higher loaf-volume and the bread was softer compared to the other fats and surfactants used.

Addition of fats and/or surfactants did not change the pattern of firmness within the loaf. The loaf centers were firmer and darker in color than their ends.

Bread made with either fats or surfactants increased amylograph peak heights and pasting temperature slightly compared to the control. Bread made with 3.0 percent soya oil and 0.50 percent SSL showed the highest peak height compared to the other fats and surfactants used.

When SMG-MG was added either dry in sponge or hydrated in dough, the bread was softer than if SMG-MG was added dry in dough. Loaf volumes, grain, and external characteristics of the bread did not show any differences among the three methods.

Assuming no time effect, the analysis of variance showed that there were no interactions between fats and surfactants to affect loaf volume, firmness (24 and 72 hrs.), and grain. Therefore, the effects of fats and surfactants are additive.

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LITERATURE CITED

1. Food Fats and Oils. Institute of Shortening and Edible Oils, Inc. August, 1974.

2. Baeurlen, R.J. Trends and development in bakery fats and oils. Bakers Digest. 47(5):91 (1973).

3. Tsen, C.C. and Hoover, W.J. The shortening-sparing effect of sodium stearoyl-2-lactylate and calcium stearoyl-2-lactylate in bread-making. Bakers Digest. 45(3):38-40, 42 (1971).

4. Jackel, S.S. New trend in breed, buns: Vegetable oils, conditioners. Bakery Production. November: 118 (1975).

5. Shortening products, Chapter 10 in Baking Science and Technology, Vol. 1, ed. by E. Pyler. Siebel Publishing Co., Chicago, Ill. (1973).

6. Swanson, C.O. and Andrews, A.C. Factors which influence the physical properties of dough. IV. The effects of surface-active agents on the characteristics of the curves made by the recording dough mixer. Cereal Chem. 19:102 (1942).

7. Green, F.C. On the mechanism of the functionality of surfactant dough conditioners. Bakers Digest. 49(3):16 (1975).

8. Jackson, G.R. and Landfried, B.W. The effect of various glycerides on the baking properties of starch doughs. Cereal Chem. 42:323 (1965).

9. Birnbaum, H. The relationship of the physical state of emulsifiers and their efficacy in bread-making. Bakers Digest. 45(3):22 (1971).

10. Baldwin, R.R., Johansen, R.C., Keough, W.J., Titcomb, S.T. and Cotton, R.H. Special report: Continuous bread-making. The role that fat plays. Cereal Science Today. 8:273 (1963).

11. Bayfield, E.G., and Young, W.E. Fluid shortenings for white bread. Cereal Science Today 9:363 (1964).

12. Baker, J.C. and Dize, M.D. The relation of fats to texture, crumb, and volume of bread. Cereal Chem. 19: 84 (1942).

13. Bell, B.M., Daniels, D.G.H., and Fisher, N. Physical aspects of the improvement of dough by fat. Food. Chem. 2:57 (1977).

14. Keeping properties of bread, Chapter 20 in Baking Science and Technology, Vol. 2, ed. by E.J. Pyler. Siebel Publishing Co., Chicago, Ill. (1973).

15. Cookson, M.A., Ritchic, M.L. and Coppock, J.B.M. The role of lipids in baking. IV. Some further properties of flour lipids and defatted flours. J. Sci. Fd. Agric. 8:105 (1957).

16. Sullivan, B., Near, C., and Foley, G.H. The role of the lipids in relation to flour quality. Cereal Chem. 13: 318 (1936).

17. Pomeranz, Y., Shogren, M., and Finney, K.F. Natural and modified phospholipids: Effect on bread quality. Food Technol. 22:897 (1968).

18. Cookson, M.A., and Coopock, J.B.M. The role of lipids in baking. III. Some bread-making and other properties of defatted flours and of flour lipids. J. Sci. Food. Agric. 7:72 (1956).

19. Mecham, D.K. Lipids, p. 393 in: Wheat: Chemistry and technology, ed. by Y. Pomeranz. Amer. Ass. Cereal Chem.: St. Paul, Minn. (1971).

20. Baker, J.C. and Dize, M.D. Effect of temperature on dough properties, II. Cereal Chem. 16:682 (1939).

21. Daniels, N.W.R., Richmond, J.W., Eggitt, P.W.R., and Coppock, J.B.M. Studies on the lipids of flour. IV. Factors affecting lipid binding in bread-making. J. Sci. Fd. Agric. 20:129 (1969).

22. Baldwin, R.R., Titcomb, S.T., Johansen, R.G., Keough, W.J., and Koedding, D. Fat systems for continuous mix bread. Cereal Science Today 10:452 (1965).

23. DeStefanis, V.A., and Ponte, J.G., Jr. Studies on the bread-making properties of wheat-flour nonpolar lipids. Cereal Chem. 53:636 (1976).

24. Tsen, C.C. and Mlynka, I. Flour lipids and oxidation of sulfhydryl group in dough. Cereal Chem. 40:145 (1963).

25. Charmerlain, N., Collins, T.H., and Elton, G.A.H. The chorleywood bread process: Improving effect of fat. Cereal Science Today 10(8):415 (1965).

26. Pomeranz, Y., Rubenthaler, G.L. and Finney, K.F. Studies on the mechanism of bread-improving effect of lipids. Food Technol. 20:1485 (1966).

27. Pomeranz, Y. and Hays, E.R. Hydrogenated corn oils effect on bread baked from flours of single wheat varieties. Food Technol. 22:1446 (1968).

28. Pomeranz, Y., Rubenthaler, G.L. and Finney, K.F. Polar vs. nonpolar wheat flour lipids in bread-making. Food Technol. 19:1724 (1965).

29. Pomeranz, Y., Rubenthaler, G.L., Deftary, R.D. and Finney, K.F. Effects of lipids on bread baked from flours varying widely in bread-making potentialities. Food Technol. 20: 1225 (1966).

30. Daniels, D.G.H. and Fisher, N. Release of carbon dioxide from dough during baking. J. Sci. Fd. Agric. 27:351 (1976).

31. Burhens, M.E. and Clapp, J. A microscopic study of bread and dough. Cereal Chem. 19:196 (1942).

32. Sandstedt, R.M., Schaumburg, L. and Fleming, J. The microscopic structure of bread and dough. Cereal Chem. 31:43 (1954).

33. Baker, J.C. The structure of the gas cell in bread dough. Cereal Chem. 18:34 (1941).

34. Standing, M.A. The microstructure of dough and bread using histophysical technique. J. Sci. Fd. Agric. 24: 984 (1973).

35. Daniels, N.W.R., Frazier, P.J. and Wood, P.S. Flour lipids and dough development. Bakers Digest. 45(4):20 (1971).

36. Petrieca, T. Fluid bakery shortenings. Bakers digest. 50(5):39 (1976).

37. Elton, G.A.H. and Fisher, N. A technique for the study of the baking process and its application to the effect of fat on baking dough. J. Sci. Fd. Agric. 17:250 (1966).

38. Newbold, M.W. Crumb softeners and dough conditioners. Bakers digest. 50(4):37 (1976).

39. Cotton, R.H., and Ponte, J.G., Jr. Baking industry, Chapter 11 in: Wheat: Production and Utilization, ed. by G.E. Inglett, AVI Publishing Co., Inc. (1973).

40. Ponte, J.G., Jr. Bread, Chapter 13 in: Wheat: Chemistry and Technology, ed. by Y. Pomeranz. Amer. Ass. Cereal Chem., St. Paul, Minn. (1971).

41. Wren, J.J. Importance of physical state in the application of fat-derived emulsifiers. S.C.I. monograph 32:158-170, London, 1968.

42. Morrison, W.R. Lipids in flour, dough and bread. Bakers Digest. 50(4):29-36, 47 (1976).

43. Chung, O.K. and Tsen, C.C. Distributions of lipids in acid-soluble protein components as affected by dough-mixing and surfactants. Cereal Chem. 52:823 (1975).

44. DeStefanis, V.A., Ponte, J.G., Jr., Chung, F.H., and Ruzza, N.A. Binding of crumb softeners and dough strengtheners during bread-making. Cereal Chem. 54:13 (1977).

45. Zobel, H.F. A review of bread staling. Bakers Digest. 47(5):52 (1973).

46. Knightly, W.H. The evolution of softeners and conditioners used in baked goods. Bakers Digest 47(5):64 (1973).

47. Knightly, W.H. In: Surface-active lipids in foods. Soc. Chem. Ind. (London) Monograph No. 32 (1968).

48. Cornford, S.J., Axford, D.W.E. and Elton, G.A.H. The elastic modulus of bread crumb in linear compression in relation to staling. Cereal Chem. 41:216 (1964).

49. Cookson, M.A. and Coppock, J.B.M. The effects of added glycerinated fats in bread and flour confectionery. J. Sci. Fd. Agric. 5:129 (1954).

50. Betchel, W.G. and Meizner, D.F. Staling studies of bread made with flour fractions. IV. Effect of gluten and wheat starch. Cereal Chem. 31:182 (1954).

51. Marston, P.E. and Wannan, T.L. Bread-baking: The transformation from dough to bread. Bakers Digest 50(4): 24 (1976).

52. Kulp, K. Physiochemical properties of wheat starch as related to bread. Bakers Digest. 47(5):34 (1973).

53. Sandsted, R.M. The function of starch in the baking of bread. Bakers Digest 35(3):36 (1967).

54. Jongh, G. The formation of dough and bread structures, and the improving effect of glyceryl monostearate. Cereal Chem. 38:140 (1961).

55. Katz, J.R. X-ray investigation of gelatinization and retrogradation of starch in its importance for bread research. Bakers weekly 81:34-37, 46 (March 24, 1934).

56. Helman, N.N., Fairchild, B. and Senti, F.R. The bread staling problem: Molecular organization of starch upon aging of concentrated starch gels at various moisture levels. Cereal Chem. 31:495 (1954).

57. Zobel, H.F. and Senti, F.R. The bread staling problem: X-ray diffraction studies on bread containing a cross-linked starch and a heat-stable amylase. Cereal Chem. 36:441 (1959).

58. The mixing process, Chapter 14 in: Baking Sciences and Technology, Vol. 2, ed. by E.J. Pyler. Siebel Publishing Co., Chicago, Ill. (1973).

59. Anker, C.A. and Geddes, W.F. Gelatinization studies upon wheat and other starches with the amylograph. Cereal Chem. 21:335 (1944).

60. Yasunaga, T., Bushuk, W., and Irvine, G.N. Gelatinization of starch during bread-making. Cereal Chem. 45:269 (1968).

APPENDIX

REP. #1, day 1

Fat	---	3% Lard	1% Fluid Short.	1% Palm Oil	1% Soya Oil	1% Lard	3% Fluid Short.	3% Soya	3% Palm
	0.25% P60-MDG-23	0.25% SSL	0.5% P60-MDG-23	0.5% SSL	0.5% P60-MDG-39	0.5% SMG-MG	0.25% P60-MDG-39	0.25% SMG-MG	--
Proof time (min.)	44	42	42	40	41	41	40	41	40
Sp. Vol. (cc/gm)	5.63	6.10	6.32	6.04	6.02	5.90	6.04	6.07	5.80
Firmness, 24 hr. (gm)	113.34 ± 3.73	103.42 ± 12.51	103.78 ± 5.76	96.32 ± 8.88	100.34 ± 8.92	111.13 ± 6.74	99.17 ± 11.04	99.34 ± 6.97	102.80 ± 9.73
Firmness, 72 hr. (gm)	183.45 ± 15.11	171.47 ± 10.72	163.82 ± 8.57	162.72 ± 11.37	178.26 ± 18.12	200.13 ± 14.57	167.64 ± 7.76	184.40 ± 9.38	194.36 ± 10.68
Rate/48 hr.	70.11	68.05	60.04	66.40	77.92	89.00	68.47	85.06	91.56
Grain	7.55	8.05	7.8	8.1	7.7	7.5	7.25	7.85	7.7
External	7.63	7.60	7.68	7.75	7.83	7.75	7.63	5.58	7.35

REP. #1, day 2

Fat	1% Soya Oil	3% Palm Oil	1% Fluid Short.	1% Palm Oil	3% Fluid Short.	1% Lard	3% Lard	--	3% Soya Oil
Surfactant	0.25% P60-MDG-23	0.25% SMG-MG	0.25% SSL	--	0.50% P60-MDG-39	0.25% P60-MDG-23	0.50% SMG-MG	0.25% P60-MDG-39	0.50% SSL
Proof time (min.)	46	45	44	47	45	47	49	46	48
Sp. Vol. (cc/gm)	5.90	5.89	6.07	5.77	6.19	6.14	5.93	5.70	6.21
Firmness, 24 hr. (gm)	114.34 ± 7.42	109.74 ± 6.79	116.09 ± 12.80	118.08 ± 10.84	94.62 ± 9.40	117.16 ± 11.39	96.83 ± 12.34	118.72 ± 7.91	74.12 ± 8.63
Firmness, 72 hr. (gm)	173.66 ± 24.16	159.09 ± 9.86	152.98 ± 8.70	183.76 ± 9.16	161.56 ± 5.12	155.80 ± 5.65	165.77 ± 12.29	205.25 ± 12.94	132.08 ± 5.79
Rate/48 hr.	59.32	49.35	36.89	65.68	66.94	38.64	68.94	86.53	37.96
Grain	8.0	7.8	8.2	8.0	7.9	7.8	8.1	8.1	8.5
External	7.67	7.37	7.47	7.37	7.60	7.47	7.37	7.33	7.77

REP. #1, day 3

Fat	0	3% Soya Oil	1% Palm Oil	3% Lard	1% Soya Oil	3% Fluid Short.	3% Palm Oil	1% Lard	1% Fluid Short.
Surfactant	0.50% P60-MDG-39	0	0.25% SMG-MG	0.50% P60-MDG-23	0.25% P60-MDG-39	0.25% P60-MDG23	0.50% SSL	0.25% SSL	0.50% SMG-MG
Proof time (min.)	39	41	41	42	40	39	42	41	43
Sp. Vol. cc/g	5.71	6.10	5.80	6.00	6.07	6.01	5.89	6.13	5.79
Firmness, 24 hr. g	98.49 ± 10.97	97.27 ± 7.33	94.41 ± 10.50	92.63 ± 8.14	104.00 ± 10.75	101.00 ± 10.30	93.69 ± 14.75	98.01 ± 14.64	95.72 ± 11.58
Firmness, 72 hr. g	161.57 ± 9.73	165.76 ± 16.64	161.09 ± 15.21	170.58 ± 12.86	160.30 ± 19.15	173.29 ± 9.02	149.36 ± 8.23	150.56 ± 16.97	163.84 ± 6.44
Rate/48 hrs.	63.08	68.49	66.68	77.95	56.30	72.29	55.67	52.55	68.12
Grain	7.8	7.9	7.8	8.5	7.5	8.0	8.3	8.1	8.3
External	7.70	8.1	7.73	7.87	7.77	7.90	7.83	8.17	7.50

REP. #1, day 4

Fat	3% Palm Oil	1% Salad Oil	1% Palm Oil	0	3% Lard	3% Fluid Short.	3% Salad Oil	1% Fluid Short.	1% Lard
Surfactant	0.25% SSL	0.50% SSL	0.50% P60-MDG-23	0	0.25% P60-MDG-23	0.25% SMG-MG	0.50% SMG-MG	0.50% P60-MDG-39	0.25% P60-MDG-39
Proof time (min.)	42	47	37	39	36	38	39	39	38
Sp. Vol. cc/g	5.97	6.19	5.98	5.45	5.89	5.84	6.01	6.03	5.78
Firmness, 24 hrs. g	88.78 ± 6.64	99.87 ± 8.21	101.82 ± 8.94	104.48 ± 8.71	95.79 ± 6.49	99.02 ± 6.10	89.09 ± 8.56	95.23 ± 7.19	98.21 ± 5.32
Firmness, 72 hrs. g	140.47 ± 9.34	146.48 ± 8.84	156.78 ± 17.08	168.70 ± 15.33	163.07 ± 11.77	162.71 ± 7.82	148.53 ± 14.72	157.22 ± 18.43	175.43 ± 13.58
Rate/48 hrs.	51.69	46.61	54.96	64.22	67.28	63.69	59.44	61.99	77.22
Grain	8.2	8.0	7.9	8.5	7.9	7.9	7.9	7.5	8.5
External	7.7	7.73	7.73	7.60	7.80	7.50	7.67	7.70	7.60

REP. #1, day 5

Fat	0	1% Fluid Short.	3% Salad Oil	3% Lard	1% Palm Oil	1% Lard	1% Salad Oil	3% Palm Oil	3% Fluid Short.
Surfactant	0.25% SMG-MG	0.25% P60-MDG-23	0.50% P60-MDG-23	0.25% P60-MDG-39	0.25% SSL	0.50% P60-MDG-39		0.50% SMG-MG	0.50% SSL
Proof time (min.)	42	41	45	45	42	41	41	42	46
Sp. Vol. cc/g	5.72	5.91	6.41	6.14	6.05	5.97	5.96	6.14	6.59
Firmness, 24 hrs. g	99.12 ± 17.92	98.23 ± 11.13	93.95 ± 7.58	99.56 ± 10.11	97.43 ± 10.69	93.78 ± 8.85	108.90 ± 15.62	99.68 ± 8.70	82.39 ± 4.91
Firmness, 72 hrs. g	168.86 ± 3.91	152.38 ± 10.56	134.04 ± 14.46	151.99 ± 10.18	151.97 ± 12.94	133.88 ± 8.09	167.20 ± 10.50	146.09 ± 9.39	117.08 ± 8.07
Rate/48 hrs.	69.74	54.15	40.09	52.43	54.54	40.10	58.30	46.41	34.70
Grain	8.3	8.0	8.3	7.8	8.1	7.9	7.8	7.6	8.0
External	7.67	7.87	7.70	7.73	7.63	7.60	7.50	7.80	8.50

REP. #1, day 6

Fat	1% Fluid Short.	1% Lard	3% Fluid Short.	3% Soya Oil	3% Lard	3% Palm Oil	1% Soya Oil	1% Palm Oil	0
Surfactant	0.25% P60-MDG-39	0.25% P60-MDG-23	0	0.25% SSL	0.50% P60-MDG-39	0.50% P60-MDG-23	0.25% SMG-MG	0.50% SMG-MG	0.50% SSL
Proof time (min.)	38	37	36	41	46	38	40	39	36
Sp. Vol. cc/g	6.33	6.18	5.92	6.47	6.79	6.23	6.20	6.25	6.39
Firmness, 24 hrs. g	101.47 ± 8.61	112.38 ± 12.66	97.17 ± 8.47	90.10 ± 5.74	94.54 ± 11.47	102.75 ± 6.16	105.11 ± 10.33	117.41 ± 4.86	96.63 ± 9.20
Firmness, 72 hrs. g	139.45 ± 12.71	154.15 ± 11.39	150.98 ± 11.22	135.17 ± 5.13	134.29 ± 9.72	141.70 ± 10.39	150.82 ± 11.66	160.96 ± 10.92	138.62 ± 12.36
Rate/48 hrs.	37.98	41.77	53.81	45.07	39.75	38.95	45.71	43.55	41.99
Grain	7.7	7.5	7.5	7.6	7.6	7.6	7.8	8.0	8.2
External	8.07	7.87	7.63	8.10	7.83	7.93	7.37	7.60	7.73

REP. #1, day 7

Fat	3% Fluid Short.	1% Palm Oil	1% Soya Oil	1% Lard	3% Lard	3% Palm Oil	3% Soya Oil	1% Fluid Short.	0
Surfactant	0.50% SMG-MG	0.50% P60-MDG-39	0.50% P60-MDG-23	0.25% SMG-MG	0	0.25% P60-MDG-23	0.25% P60-MDG-39	0.50% SSL	0.25% SSL
Proof time (min.)	47	45	47	46	47	49	47	51	46
Sp. Vol. cc/g	5.78	6.13	6.35	5.98	6.32	6.43	6.39	6.68	6.37
Firmness, 24 hrs. g	107.30 ± 11.93	96.01 ± 7.51	89.20 ± 12.50	108.66 ± 15.76	112.80 ± 7.83	93.08 ± 7.79	96.42 ± 8.68	87.76 ± 7.48	95.61 ± 12.08
Firmness, 72 hrs. g	156.86 ± 16.08	147.73 ± 12.47	141.83 ± 13.91	160.25 ± 29.75	171.91 ± 7.69	150.21 ± 15.56	146.73 ± 10.58	130.38 ± 11.01	157.41 ± 7.58
Rate/48 hrs.	51.56	51.72	52.63	51.59	59.11	57.13	50.31	42.62	61.80
Grain	7.0	7.4	8.0	7.8	7.9	7.9	7.8	8.0	8.0
External	7.83	7.70	7.83	7.77	7.67	7.57	7.67	8.37	7.77

REP. #1, day 8

Fat	3% Lard	3% Fluid Short.	1% Soya Oil	3% Palm Oil	0	1% Palm Oil	1% Fluid Short.	1% Lard	3% Soya Oil
Surfactant	0.25% SMG-MG	0.50% P60-MDG-23	0.25% SSL	0.25% P60-MDG-39	0.50% SMG-MG	0.25% P60-MDG-23	0	0.50% SSL	0.50% P60-MDG-23
Proof time (min.)	43	44	54	45	42	46	49	52	57
Sp. Vol. cc/g	6.08	6.52	6.46	6.30	6.14	6.16	6.38	6.84	6.99
Firmness, 24 hrs. g	119.23 ± 9.58	98.05 ± 16.59	98.72 ± 13.92	106.40 ± 17.97	102.65 ± 12.22	102.93 ± 7.46	114.20 ± 8.29	87.40 ± 12.27	83.20 ± 10.03
Firmness, 72 hrs. g	179.84 ± 22.34	133.24 ± 17.37	139.85 ± 19.97	162.43 ± 16.23	154.39 ± 17.16	152.66 ± 27.68	168.86 ± 11.89	132.76 ± 19.61	130.64 ± 8.00
Rate/48 hrs.	60.61	35.19	41.13	56.03	51.74	49.73	54.66	45.36	47.44
Grain	7.7	7.8	7.9	7.8	7.5	7.4	7.7	8.0	8.0
External	7.87	7.87	7.67	7.93	7.5	7.73	7.87	8.10	8.23

REP. #1, day 9

Fat	1% Fluid Short.	1% Soya Oil	3% Palm Oil	3% Fluid Short.	0	3% Soya Oil	1% Palm Oil	3% Lard	1% Lard
Surfactant	0.25% SMG-MG	0.50% SMG-MG	0.50% P60-MDG-39	0.25% SSL	0.50% P60-MDG-23	0.25% P60-MDG-23	0.25% P60-MDG-39	0.50% SSL	0
Proof time (min.)	45	44	48	43	48	45	42	46	44
Sp. Vol. cc/g	6.07	6.24	6.58	6.38	6.28	6.36	6.07	6.47	6.25
Firmness, 24 hrs. g	117.21 ± 8.42	110.96 ± 12.63	102.86 ± 15.39	102.28 ± 10.07	109.60 ± 6.72	109.36 ± 10.76	133.64 ± 17.13	102.89 ± 9.41	124.45 ± 16.31
Firmness, 72 hrs. g	171.27 ± 25.25	159.16 ± 7.77	153.74 ± 17.01	158.49 ± 13.92	162.44 ± 14.98	143.30 ± 16.92	187.3 ± 24.90	133.22 ± 13.39	195.83 ± 21.25
Rate/48 hrs.	54.06	48.10	50.88	56.21	52.84	33.94	53.39	30.33	71.38
Grain	7.9	7.9	7.7	8.0	7.9	7.8	7.9	7.6	7.8
External	7.87	7.73	7.73	7.90	7.77	7.87	7.83	7.80	8.00

REP. #2, day 1

Fat	0	3% Fluid Short.	3% Soya Oil	3% Palm Oil	1% Palm Oil	1% Lard	1% Fluid Short.	1% Soya Oil	3% Lard
Surfactant	0.50% P60-MDG-23	0.50% SMG-MG	0.25% SMG-MG	0.50% SSL	0.25% 0	0.25% P60-MDG-39	0.25% P60-MDG-23	0.25% SSL	0.50% P60-MDG-39
Proof time (min.)	38	40	42	43	40	45	48	47	49
Sp. Vol. cc/g	5.95	6.17	6.29	6.55	5.96	6.15	6.20	6.48	6.43
Firmness, 24 hrs. g	100.27 ± 14.02	97.47 ± 7.58	90.45 ± 8.99	87.42 ± 12.31	99.84 ± 8.22	101.42 ± 16.25	91.89 ± 6.85	93.12 ± 12.95	99.87 ± 8.62
Firmness, 72 hrs. g	173.12 ± 11.35	164.79 ± 10.90	166.92 ± 13.48	143.03 ± 11.56	191.12 ± 16.42	151.77 ± 18.35	177.88 ± 11.14	183.00 ± 16.64	147.01 ± 12.97
Rate/48 hrs.	72.85	67.30	76.47	55.61	91.28	50.35	85.99	89.88	47.14
Grain	7.80	7.90	8.00	8.20	7.60	7.40	7.50	7.50	7.50
External	7.50	7.67	7.93	7.87	7.43	7.83	7.80	7.57	7.63
Crumb Color	25.58 ± 3.51	25.80 ± 2.58	19.12 ± 2.35	26.05 ± 1.51	15.37 ± 2.02	19.68 ± 2.41	17.92 ± 1.83	22.95 ± 2.34	17.97 ± 2.12

REP. #2, day 2

Fat	3% Soya Oil	3% Lard	1% Soya Oil	1% Lard	0	3% Fluid Short.	1% Palm Oil	1% Fluid Short.	3% Palm Oil
Surfactant	0.50% SSL	0.25% P60-MDG-23	0.50% SMG-MG	0.50% P60-MDG-39	0.25% SSL	0.50% P60-MDG-23	0.25% SMG-MG	0.25% P60-MDG-39	0
Proof time (min.)	52	52	51	52	47	49	53	52	52
Sp. Vol. cc/g	6.62	5.96	6.16	6.28	6.17	6.43	6.22	6.26	6.18
Firmness, 24 hrs. g	107.04 ± 4.78	126.29 ± 10.62	117.64 ± 12.81	116.81 ± 7.36	115.61 ± 16.78	108.40 ± 9.22	119.40 ± 14.12	113.94 ± 11.35	127.18 ± 10.24
Firmness, 72 hrs. g	145.30 ± 11.01	196.61 ± 20.34	175.40 ± 11.89	180.54 ± 14.99	205.51 ± 43.53	167.42 ± 14.71	198.84 ± 7.32	187.18 ± 14.47	192.49 ± 15.36
Rate/48 hrs.	38.26	70.32	57.76	63.73	89.90	59.02	79.70	73.24	65.31
Grain	7.90	7.60	7.80	7.40	7.70	7.70	7.70	7.80	7.60
External	7.77	7.63	7.47	7.57	7.70	7.80	7.70	7.47	7.43
Crumb Color	19.02 ± 1.99	19.27 ± 3.34	16.48 ± 3.64	21.88 ± 3.03	23.72 ± 3.78	20.42 ± 2.28	21.18 ± 2.29	22.27 ± 2.93	21.98 ± 3.11

REP. #2, day 3

Fat	3% Palm Oil	0	1% Palm Oil	3% Fluid Short.	1% Lard	3% Soya Oil	1% Soya Oil	3% Lard	1% Fluid Short.
Surfactant	0.25% SMG-MG	0.50% SMG-MG	0.50% SSL	0.25% SSL	0.25% P60-MDG-23	0	0.50% P60-MDG-23	0.25% P60-MDG-39	0.50% P60-MDG-39
Proof time (min.)	50	47	55	52	50	52	49	54	52
Sp. Vol. cc/g	6.18	6.05	6.67	6.54	6.47	6.47	6.52	6.66	6.29
Firmness, 24 hrs. g	111.96 ± 6.84	111.85 ± 7.26	95.67 ± 8.48	100.50 ± 13.95	107.78 ± 12.60	107.02 ± 7.80	101.45 ± 11.47	106.26 ± 6.69	109.58 ± 7.26
Firmness, 72 hrs. g	175.12 ± 14.86	182.25 ± 19.23	151.75 ± 10.39	162.47 ± 23.39	175.44 ± 14.73	163.70 ± 10.39	160.45 ± 8.64	176.60 ± 14.18	188.35 ± 12.11
Rate/48 hrs.	63.16	70.40	56.08	61.97	67.66	56.68	59.00	70.34	78.77
Grain	7.70	7.50	7.80	7.50	7.60	7.80	7.60	7.40	7.40
External	7.93	7.73	7.67	8.07	7.77	7.73	7.73	8.00	8.03
Crumb Color	12.12 ± 3.14	11.68 ± 2.17	16.28 ± 2.43	20.17 ± 2.69	20.58 ± 3.94	8.37 ± 1.50	18.40 ± 3.55	18.22 ± 4.10	14.45 ± 2.09

REP. #2, day 4

Fat	3% Lard	1% Fluid Short.	3% Palm Oil	0	1% Lard	1% Soya Oil	3% Soya Oil	1% Palm Oil	3% Fluid Short.
Surfactant	0.50% SSL	0	0.50% P60-MDG-23	0.50% P60-MDG-39	0.25% SMG-MG	0.25% P60-MDG-23	0.50% SMG-MG	0.25% SSL	0.25% P60-MDG-39
Proof time (min.)	53	56	54	55	50	51	50	49	51
Sp. Vol. cc/g	6.33	6.03	6.55	6.38	6.45	6.42	6.29	6.43	6.32
Firmness, 24 hrs. g	111.79 ± 4.61	111.05 ± 6.59	93.99 ± 9.76	98.31 ± 12.17	103.72 ± 16.06	98.50 ± 7.35	100.09 ± 5.38	96.44 ± 9.03	138.12 ± 15.37
Firmness, 72 hrs. g	159.64 ± 13.35	200.69 ± 19.66	165.86 ± 20.24	150.58 ± 9.35	177.63 ± 14.96	153.30 ± 8.48	197.42 ± 14.52	151.66 ± 14.03	172.03 ± 9.89
Rate/48 hrs.	47.85	89.64	71.87	52.27	73.91	54.80	97.33	55.22	33.91
Grain	7.70	7.80	7.60	7.50	7.50	7.60	7.90	7.70	8.00
Crumb Color	18.4 ± 2.08	8.82 ± 1.18	18.18 ± 2.31	14.73 ± 3.13	19.70 ± 1.30	15.77 ± 0.76	17.87 ± 2.29	24.52 ± 2.08	11.42 ± 2.54

REP. #2, day 5

Fat	1% Fluid Short.	0	1% Palm Oil	3% Lard	3% Fluid Short.	1% Soya Oil	3% Palm Oil	1% Lard	3% Soya Oil
Surfactant	0.25% SMG-MG	0.25% P60-MDG-23	0.50% SMG-MG	0	0.50% P60-MDG-39	0.25% P60-MDG-39	0.25% SSL	0.50% SSL	0.50% P60-MDG-23
Proof time (min.)	53	52	50	51	54	49	53	52	50
Sp. Vol. cc/g	6.12	5.72	6.16	5.98	6.53	6.27	6.45	6.27	6.13
Firmness, 24 hrs. g	96.22 ± 9.13	106.53 ± 13.20	102.90 ± 8.82	112.54 ± 10.17	86.99 ± 9.34	100.64 ± 11.05	98.81 ± 8.24	97.80 ± 7.67	98.00 ± 15.96
Firmness, 72 hrs. g	163.77 ± 23.08	177.39 ± 13.53	160.75 ± 9.37	164.97 ± 12.61	160.69 ± 6.94	155.50 ± 16.00	146.69 ± 11.34	133.18 ± 15.22	138.67 ± 12.97
Rate/48 hrs.	67.55	70.86	57.85	52.43	73.70	54.86	47.88	35.38	40.67
Grain	7.60	7.80	7.70	7.70	8.00	7.80	8.00	8.00	7.70
Crumb Color	15.20 ± 2.85	17.37 ± 3.11	23.78 ± 1.80	21.07 ± 1.65	17.83 ± 2.57	21.82 ± 1.98	22.58 ± 2.73	27.33 ± 2.94	18.60 ± 2.73

REP. #2, day 6

Fat	1% Lard	3% Palm Oil	1% Fluid Short.	1% Soya Oil	3% Soya Oil	0	3% Lard	3% Fluid Short.	1% Palm Oil
Surfactant	0	0.50% SMG-MG	0.50% SSL	0.50% P60-MDG-39	0.25% SSL	0.25% P60-MDG-39	0.25% SMG-MG	0.25% P60-MDG-23	0.50% P60-MDG-23
Proof time (min.)	5	52	52	57	51	52	54	50	49
Sp. Vol. cc/g	6.23	6.17	6.55	6.78	6.34	6.15	6.25	6.56	6.32
Firmness, 24 hrs. g	124.19 ± 15.84	111.96 ± 6.56	96.26 ± 14.92	97.66 ± 15.25	84.16 ± 6.29	109.32 ± 12.36	111.29 ± 9.05	99.50 ± 4.88	115.33 ± 19.09
Firmness, 72 hrs. g	182.75 ± 16.39	157.91 ± 7.96	142.19 ± 10.32	144.66 ± 10.48	153.13 ± 18.11	177.46 ± 13.50	182.45 ± 26.26	156.79 ± 7.70	157.29 ± 4.56
Rate/48 hrs.	58.56	45.95	45.93	47.00	68.97	68.14	71.16	57.29	41.96
Grain	7.80	7.60	7.90	7.70	7.90	7.80	8.00	7.70	
External	7.73	7.53	7.80	7.77	7.63	7.63	7.67	7.63	7.47
Crumb Color	14.12 ± 2.00	13.15 ± 2.26	21.15 ± 1.44	19.30 ± 2.43	18.80 ± 2.49	14.02 ± 3.18	18.22 ± 2.04	21.32 ± 2.53	25.08 ± 2.33

REP. #2, day 7

Fat	1% Palm Oil	3% Soya Oil	3% Palm Oil	1% Soya Oil	1% Fluid Short.	0	1% Lard	3% Fluid Short.	3% Lard
Surfactant	0.25% P60-MDG-23	0.25% P60-MDG-39	0.50% P60-MDG-39	0	0.25% SSL	0.50% SSL	0.50% SMG-MG	0.25% SMG-MG	0.50% P60-MDG-23
Proof time (min.)	50	52	48	47	49	51	48	50	41
Sp. Vol. cc.g	6.06	6.18	6.06	5.81	6.36	6.40	6.16	6.42	6.33
Firmness 24 hrs. g	108.89 ± 8.13	102.31 ± 12.25	114.92 ± 10.40	109.81 ± 10.09	98.72 ± 7.72	94.97 ± 8.47	109.79 ± 12.04	97.20 ± 7.14	106.33 ± 11.18
Firmness, 72 hrs. g	173.16 ± 18.54	151.25 ± 12.09	182.07 ± 12.05	181.41 ± 11.94	148.88 ± 12.05	152.02 ± 10.50	172.29 ± 10.24	186.68 ± 18.76	149.15 ± 6.30
Rate/48 hrs.	64.25	48.94	67.15	71.60	50.16	57.05	62.50	89.48	42.82
Grain	7.80	7.60	7.60	7.80	7.80	8.10	7.60	7.80	8.20
Crumb Color	7.17 ± 1.52	18.22 ± 3.77	11.42 ± 3.02	3.47 ± 1.24	11.38 ± 2.49	15.00 ± 2.14	7.48 ± 3.25	5.62 ± 2.56	10.86 ± 1.83

REP. #2, day 8

Fat	3% Fluid Short.	1% Soya Oil	1% Palm Oil	3% Soya Oil	1% Lard	3% Palm Oil	0	3% Lard	1% Fluid Short.
Surfactant	0.50% SSL	0.25% SMG-MG	0.25% P60-MDG-39	0.50% P60-MDG-39	0.50% P60-MDG-23	0.25% P60-MDG-23	0	0.25% SSL	0.50% SMG-MG
Proof time (min.)	55	52	55	52	50	49	51	49	48
Sp. Vol. cc/g	6.46	6.09	6.12	6.31	6.30	6.32	5.75	6.29	6.17
Firmness, 24 hrs. g	87.94 ± 6.09	106.33 ± 4.64	103.11 ± 7.39	95.79 ± 6.17	111.26 ± 12.44	100.32 ± 8.50	122.17 ± 7.52	108.54 ± 9.91	108.72 ± 7.30
Firmness, 72 hrs. g	128.66 ± 6.94	161.21 ± 15.12	182.01 ± 12.33	151.12 ± 6.77	170.16 ± 14.87	165.45 ± 12.50	212.84 ± 18.96	191.26 ± 22.73	174.75 ± 12.99
Rate/48 hrs.	40.72	54.88	78.90	55.37	58.90	65.13	90.67	82.72	66.03
Grain	7.90	7.90	7.80	7.60	7.60	7.80	7.40	8.10	7.70
External	8.07	7.77	7.77	7.83	7.70	7.83	7.73	7.70	7.70
Crumb Color	14.55 ± 1.41	3.88 ± 0.83	6.93 ± 2.08	9.78 ± 2.82	17.52 ± 2.46	15.48 ± 3.08	1.83 ± 0.38	16.10 ± 3.81	12.53 ± 1.11

REP. #2, day 9

Fat	0	1% Palm Oil	3% Lard	1% Lard	3% Palm Oil	3% Soya Oil	3% Fluid Short.	1% Fluid Short.	1% Soya Oil
Surfactant	0.25% SMG-MG	0.50% P60-MDG-39	0.50% SMG-MG	0.25% SSL	0.25% P60-MDG-39	0.25% P60-MDG-23	0	0.50% P60-MDG-23	0.50% SSL
Proof time (min.)	48	47	45	50	50	50	49	50	48
Sp. Vol. cc/g	6.01	6.14	6.21	6.41	6.16	6.51	6.54	6.24	6.43
Firmness, 24 hrs. g	102.07 ± 5.95	105.67 ± 3.88	107.26 ± 8.30	94.98 ± 8.18	99.12 ± 6.80	102.25 ± 21.35	88.51 ± 5.12	110.62 ± 8.12	93.72 ± 3.09
Firmness, 72 hrs. g	179.60 ± 12.71	203.93 ± 20.53	173.57 ± 10.74	137.27 ± 13.87	157.61 ± 8.07	159.75 ± 9.89	143.92 ± 12.51	174.53 ± 15.46	157.34 ± 25.09
Rate/48 hrs.	77.53	98.26	66.31	42.29	58.49	57.50	55.41	63.91	63.62
Grain	8.00	8.00	7.70	7.80	7.70	7.90	7.80	7.60	7.80
External	7.47	7.63	7.53	7.67	7.77	7.67	7.93	7.80	7.87
Crumb Color	6.27 ± 1.45	15.08 ± 2.65	14.03 ± 31.8	16.95 ± 2.33	10.07 ± 4.99	9.78 ± 1.30	10.43 ± 2.94	9.70 ± 1.82	14.60 ± 3.10

STUDIES OF FAT AND SURFACTANT SYSTEMS IN BREAD-MAKING

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ABSTRACT

The purpose of this study reported here was to investigate the effects of four fats, used at three levels, in various combinations with four commercial surfactants also at three levels. The fats used were: lard; unhydrogenated soybean oil (soya oil); lightly hydrogenated soybean oil (fluid shortening); and palm oil. The surfactants employed were succinylated monoglycerides with monoglycerides, sodium stearoyl-2-lactylate and 2 types of polysorbate 60-Mono- and diglyceride combinations. Observations were made on bread firmness (1 and 3 days), loaf volume, and overall bread quality.

Bread made with 3.0% soya oil had a higher loaf volume, and the bread was softer than bread made with other fats. On the other hand, bread made with 0.50% SSL had a better loaf volume, better grain, and the bread was softer compared to the other surfactants used.

All fats and surfactants increased the peak heights and pasting temperatures slightly of the crumb. Bread made with 3.0 percent soya oil and 0.50 percent SSL had the highest peak height compared to the other fats and surfactants used.

Comparison among methods of incorporating SMG-MG in bread-making indicated that there was no differences in loaf-volume among the three methods used. However, SMG-MG was either added dry in sponge or hydrated in dough, the bread was softer than if it was added dry in dough.

Our study also indicated that the loaf centers were firmer and darker in color than their ends.

Assuming no time effect, the analysis of variance showed that there were no interactions between fats and surfactants to affect loaf volume, firmness (24 and 72 hrs.), and grain. Therefore, the effects of fats and surfactants are additive.