Use of Oil in Baked Products — Part I: Background and Bread[1]

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ABSTRACT

The benefits of fat systems in yeast-raised and chemically leavened baked goods are reviewed. The effects of rising ingredient costs and competition on ingredient technology are described, leading to a discussion concerning the trend in the United States to switch from the standard shortenings – lard and partially hydrogenated vegetable shortening – to oil in baked products. Problems associated with the incorporation of oil in bread formulations follow. Test work has shown that surfactants are effective additives in overcoming these negatives and in promoting the production of quality products. A comparison of oil versus lard as the shortening medium in bread is described. Evaluation of emulsifiers with oil in bread are discussed.

INTRODUCTION

Twenty years ago, the probability that the baking industry would someday use vegetable oil as a replacement for plastic shortening was very unlikely, for, as Pyler says: "It was accepted as a fact that vegetable oil could not be used as a shortening in baked foods with optimum results. Dough weakness, dull crumb color, and poor volume were obtained" (1). Many workers researched this area and studied the causal factors contributing to these negative results.

Baker and Mize showed that there was a direct relationship between the ratio of solid and liquid fractions of fat to the performance of that fat in baked goods. As the solid fraction increased to a point, performance also improved (2). Pyler explains this in the following way: "Plastic fats, when mixed into a batter or a dough, are extended into streaks and films which lubricate large surfaces in the dough and thereby produce a maximum shortening effect for a given quantity of fat. Plastic fats are further able, during the mixing or creaming process, to entrap and retain considerable quantities of air. This produces an important leavening effect, particularly in cakes of high sugar content. Liquid oils, on the other hand, are dispersed on mixing throughout the dough in the form of minute globules which are far less effective in their shortening and aerating actions than are fat films" (1).

Regardless of these views held 20 years ago, the trend is now to replace the plastic fats in baked goods with liquid vegetable oil. This can be clearly illustrated by examining some figures (Table I) published by the U.S. Department of Commerce, Census of Manufacturers on the Utilization of Fats and Oils in Foods for 1950-1975. These figures show that while the use of lard is decreasing in foods, the use of other fats and oils is on the upward swing.

A number of factors are responsible for this growing trend to oil. These factors include: (a) availability and cost of edible oil base stocks; (b) baker's need to reduce raw material costs; (c) bulk handling requirements; and (d) consumer preference for "all vegetable" and "polyunsaturated" labeling.

The purpose of this paper is to discuss this trend to oil in the production of bread.

[1]Presented at the American Oil Chemists' Society, San Francisco, CA, April 29-May 3, 1979.

TABLE I

Food use of Fats and Oils (Millions of lbs.)

	1950	1960	1970	1975
Butter	1327	1112	890	815
Lard	1906	1361	940	616
Shortening	1705	2302	3556	3666
Margarine	764	1367	1787	1908
Other fats and oils	1314	2094	3635	4299
TOTAL	7,016	8,241	10,808	11,304

USE OF OIL IN BREAD

It is only natural that our discussion begin with white pan bread and rolls, as annual production of these products amounts to over 13 billion pounds. Utilizing an average fat level of 2.5%, total shortening requirements for these products amount to 325 million pounds per year (3).

Until a few years ago, lard was the preferred shortening in bread. It was plentiful in supply, economical, and it provided good flavor. In addition, its approximate 70:30 liquid to solid fat ratio at room temperatures provided a slip point of 94-96 F. This was ideal for conventionally prepared bread having a dough out temperature of 86 F, as best results are obtained with a shortening having sufficient solids to provide a slip point approximately 8 F higher than the dough out temperature. Further, Baker and Mize pointed out that this particular liquid to solid fat ratio in lard was significant in contributing to lard's superior performance in bread over other shortenings (2). Their work showed that the two-thirds oil phase provided the lubrication qualities necessary to promote tenderness in the finished product. The one-third solid phase entrapped the oil fraction in a matrix, keeping it from leaking into the dough during mixing and proofing and thereby providing strength during proofing and baking. As a result, volume, symmetry, and crumb structure were improved. Baker and Mize concluded in their studies that the absence or reduction of solids in shortening caused poor quality bread characteristics. The baking industry refers to this as shortening failure (2). Specifically, it results in slow proof, poor oven spring, open grain, dull crumb, weak sidewalls, and low volume.

Examples of shortening failure can be better described by examining data resulting from some laboratory bakings. As can be seen in Table II, all bread containing soya oil produced a lower specific volume (volume cc/wt. g) than bread made with equivalent levels of lard. In addition, dough containing oil was sticky during make-up, and the finished bread was firmer and contained a more open grain and dull crumb color than bread made with equivalent levels of lard. It should be noted, however, as Bayfield and Young also pointed out in their work, that all breads containing some form of fat were superior in quality when compared to bread containing no fat (4).

In the 1950s, the introduction of the continuous mixing process for bread production prompted the development of new ingredient technology. In the first place, the new automated operations required bulk handling of ingredients to maintain production speed while keeping costs down. Pumpable fluid shortenings were, therefore, requested. Second, the continuous mixer exerted extreme shear during mixing, thereby weakening the dough and causing a dough

TABLE II

Performance of Lard vs. Soya Oil in Bread

Shortening type	%	Dough handling properties	% Specific volume increase volume/weight	Average softness index @ 3-6 days	Grain/crumb
---	0	Poor	—	1.00	Fair, open
Lard	1	Fair	8.0	.86	Fair, even
Soya oil	1	Poor	3.0	.96	Fair, open
Lard	2	Good	10.0	.87	Fair
Soya oil	2	Poor, sticky	4.0	.90	Fair, open
Lard	3	Good	11.0	.80	Fair
Soya oil	3	Poor, sticky	6.0	.77	Fair
Lard	4	Good	11.0	.79	Fair
Soya oil	4	Poor, sticky	6.0	.78	Fair

out temperature of 104-106 F. Even the solids contained in the lard were insufficient to strengthen the dough sufficiently enough so that it could withstand the punishment associated with the proofing and baking aspects of the bread operation. The lard melted during the mixing and proofing stages and functioned as a liquid oil. Signs of shortening failure were evident as finished bread had low volume and poor grain. However, it was found that these problems could be resolved with the addition of hard fat to the lard. Workers such as Baldwin et. al. confirmed this report by conducting a study using 3% lard containing 0-18% shortening hard fat flakes in the continuous mixer (5). Their results showed that the addition of hard fat at ca. 15% (shortening weight) greatly improved the quality of the bread. However, it was also shown that the same negatives caused by too low a solid level were also caused by too high a solid level. As the percent of solids varied in the lard and bakers had no way to measure it, a trial and error process was used to determine the amount of hard fat to be added with the lard; hence, variability in bread quality resulted. In addition to a fluid, pumpable shortening, bakers also requested one that remained consistent in composition.

As a result, fat and oil technologists designed fluid shortenings that met the requirements of the industry. Bayfield and Young found that when hard fat and emulsifier, such as saturated mono- and diglycerides, were added to liquid oil, improvements in the bread's internal structure and crumb color resulted (4). The data shown in Table III, originally presented by Koren, exemplifies these findings for bread made in the continuous mixer (6). Products containing liquid oil or no shortening at all have characteristics induced by shortening failure: low volume, fair softness, and poor grain. The addition of hard fat and emulsifier to the oil improves the volume, softness, and overall quality of the bread, thus confirming Bayfield and Young's work.

While new and improved fluid shortenings were being developed, studies in the areas of dough conditioner and softener blends were being conducted. By definition, a conditioner is a surface active agent that has the ability to complex with the protein in flour and impart strengthening properties to a bread dough. Test work showed that a conditioner can enhance the following aspects of a bread system: (a) dough strength and mixing tolerance; (b) gas retention; (c) proof time; (d) hydration and absorption; (e) oven spring; (f) dough extensibility; (g) bread volume; (h) bread symmetry; (i) bread grain and crumb.

In theory, it seemed that the conditioner performed the same functions as the shortening solids. A detailed comparison, however, (Fig. 1) showed that the conditioner provides several additional benefits to bread dough: these include increased absorption, improved mixing tolerance, and improved extensibility (7).

These findings, in combination with reports from the industry attesting to the success of the oil plus certain conditioner-softener blends, encouraged us to study the concept in more depth. Our subsequent laboratory and pilot plant studies have confirmed these reports that a conditioner can overcome the negative effects associated with lack of shortening solids. Bread prepared with liquid oil plus a conditioner has the structural strength necessary for a quality end product. The following examples sum-

TABLE III

Effects of Shortening Type on Bread Mixed in Continuous Mixer

	Volume cc	Softness[a] grams	Grain
No shortening	2590	320	Coarse, open grain
4% oil (fl. wt.)	2640	338	Poor
4% Fluid shortening commercial (oil + hard fat + emul.)	2960	373	Even

[a]As measured by a compressimeter.

FUNCTIONS OF

SHORTENING SOLIDS	VERSUS	CONDITIONER
		IMPROVED MIXING TOLERANCE
		IMPROVED WATER ABSORPTION
		IMPROVED EXTENSIBILITY
IMPROVED GAS RETENTION		IMPROVED GAS RETENTION
a. BETTER OVENSPRING		a. BETTER OVENSPRING
b. FASTER PROOF		b. FASTER PROOF
IMPROVED VOLUME		IMPROVED VOLUME
BETTER SYMMETRY		IMPROVED SYMMETRY
a. STRONGER SIDEWALLS		a. STRONGER SIDEWALLS
CLOSER GRAIN		CLOSER GRAIN
BRIGHTER CRUMB		BRIGHTER CRUMB

FIG. 1.

TABLE IV

Effect of Shortening Solids vs. Conditioner in Bread

Shortening type @ 3% (fl. wt.)	% Mono/poly 60 blend (fl. wt.)	Handling	Proof time min.	Average volume increase cc	Average softness index @ 7 days	Average reflectance reading %	Grain
Lard	---	Good	65	---	1.00	59.34	Good
Lard	0.5	Good	64	136	.78	61.32	Good
Soya oil	0.5	Weak, soft	64	225	.72	60.80	Good
Cottonseed oil	0.5	Weak, soft	63	148	.70	60.90	Good
Soya oil	---	Weak, soft	65	73	.94	57.18	Good

TABLE V

Effect of Reduced Oil Levels on Conventional Prepared Bread

% and type fat	% Mono/poly 60 blend (fl. wt.) (50% ACTIVE)	Handling	Increased volume cc	Average softness index 3-6 days	Grain
3% Lard	---	Good	---	1.00	7.0
3% Lard	1.0	Good	19	.81	7.25
3% Soya oil	1.0	Good	32	.80	7.25
2% Soya oil	1.0	Good	58	.76	7.25

marize data on this subject.

In the study shown in Table IV, a conditioner-softener containing 40% polysorbate 60 and 60% mono- and diglycerides was evaluated in combination with 3% soya and cottonseed oil (percentages are based on flour weight (fl. wt.)) and compared to 3% lard, fl. wt. In general, doughs containing salad oil were slightly weaker and softer than the lard counterparts. However, these characteristics had no drastic or significant effect on proof time. Major improvements were noticed, however, on volume and softness. Breads containing oil plus the conditioner-softener exhibited superior volume and softness to the bread containing only lard and equivalent characteristics to bread containing the lard and the conditioner-softener. Evaluation of the grain showed lower reflectometer readings on the oil alone bread, which is indicative of a darker crumb. Addition of the conditioner-softener blend, however, overcame this defect and produced crumb brightness approximately equal to the lard counterpart. Subjective evaluations of the grain showed little variation.

As was mentioned previously, approximately one-third of lard is comprised of a solid fraction. It was therefore felt that if a substitution were made with vegetable oil, only the liquid fraction of the fat should be replaced. Thus, a reduction in one-third total fat should be considered in the conversion.

The data in Table V represent work performed to determine the effect of reduced oil levels on finished bread quality.

The conditioner-softener used in these bakings was a 50% active hydrate containing a 3:1 ratio of mono- and diglycerides to polysorbate 60. Because of the lower fat ratio, it was theorized that the crumb would be firmer. Contrary to this, though, bread containing the 2.0% soya + the polysorbate 60/monoglyceride hydrate had improved softness and volume than both its soya oil and lard counterparts used at higher levels. Thus, the data indicate a reduction in one-third total fat can be realized when switching from plastic shortenings to liquid oils.

The data in Table VI represent a baking study performed on a continuous mixer.

The mono- and diglyceride used in this study contained 55% alpha mono. The conditioner-softener was a 40:60 blend of polysorbate 60 and mono- and diglycerides. All doughs handled well; however, dough containing soya oil and mono- and diglycerides had poor strength, as exhibited by collapsed volume after the shock test. The addition of hard fat or conditioner-softener into the soya oil overcame the dough weakness. Loaves tested by shock were affected very rapidly. Again, by examining results of these finished bread loaves, it can be demonstrated that the conditioner-softener compensated for the absence of shortening solids and facilitated the production of quality bread.

Table VII describes some laboratory and pilot plant data on a production scale. Here, 3% soya oil (fl. wt.) plus 0.5% (fl. wt.) of a 100% active polysorbate 60/mono product were used to replace 3% commercial fluid shortening + 0.2% added softener (fl. wt.). Results indicate equivalent dough handling and grain characteristics and improved softness were obtained by the use of oil plus the conditioner-softener. Thus, it can be seen that a conditioner-softener consisting of mono- and diglycerides and polysorbate 60 can replace the need for the hard fat which, at one time, was thought to be so necessary for the production of quality bread.

In making the switch from plastic shortening to vegetable oil, bakers have realized several benefits other than the reduction of total fat. First, it has been noted that when the total fat level is reduced and the hydrophilic polysorbate 60 is incorporated into the dough, there is often a need to increase absorption by 1-2% (fl. wt.). This need is quite evident and is characterized by drier, more viscous doughs. This phenomenon can be explained possibly by the findings of two studies: Bayfield and Young (8), and Langhans and Thalheimer (9). Bayfield and Young showed that shortening acts as a lubricating agent permitting dough to slide more easily over itself. To a certain extent, water acts in a similar fashion and, therefore, should be interchangeable with the fat. They showed that reduction of absorption could be compensated for with an

TABLE VI

Effect of Shortening Solids vs. Conditioner on Continuous Mixed Bread

Percent and type fat (fl. wt.)	Type emulsifier @ 0.5%	Dough handling	Dough stability index	Softness index @ 2 days	Grain
2% Soya oil	Mono (55%)	Good	.77	1.00	Open, dense, thick cell walls
2% Soya oil with 10% Cottonseed Flakes	Mono (55%)	Good	.93	.57	Good, silky
2% Soya oil	Poly 60/mono 40/60 blend	Good	.98	.70	Good, silky
3% Lard	Poly 60/mono 40/60 blend	Good	.99	.75	Good, silky

TABLE VII

Effect of Oil Plus Conditioner in Industry Tests

	Dough handling	Softness index			Grain
		3 Days	5 Days	Average	
3% Commercial fluid shortening + added softener	Good	1.00	1.00	1.00	Good
3% Soya oil + 0.5% Mono/ polysorbate 60 blend 100% Active	Good	.76	.78	.77	Closer grain

increase in shortening. Therefore, the opposite would also be true in that the reduction of shortening can be compensated for with an increase in absorption (8). Langhans and Thalheimer performed work on the farinograph showing that polysorbate 60 is an excellent dough strengthener. It increases the rate of moisture pick-up of the flour and other moisture-absorbing ingredients; this promotes a drier dough which requires increased absorption to readjust the consistency of the dough to the standard of 500 BU (9). Thus, reduction of total fat and addition of polysorbate 60 generally mandates an increase in absorption. A second benefit associated with the replacement of lard by vegetable oil is that the elimination of all shortening solids provides improved bread softness. Both Cooley (10) and Bayfield and Young (8) showed that the solid component in the plastic shortening promotes firmness of bread crumb, while the liquid component produces softness. Thus, there is a distinct advantage to using a fat that has a low solid fat index at room temperature. Third, as oil contains no solids, it can be pumped and stored through the plant without heating. If it should solidify in colder temperatures, it will regain clarity and fluidity as it approaches room temperature, and there is no problem with separation of components. Fourth, there is no need for trial and error to determine the % solids necessary to eliminate shortening failure. The conditioner-softener blends are consistent and established by specifications. Fifth, the oil and conditioner (softener) can be incorporated into the brew, liquid sponge, yeast slurry, or dough. In regard to this, the monoglyceride-polysorbate 60 products are available in several forms – solid, plastics, and liquids. In addition, oil level is independent of conditioner-softener levels. Sixth, a cost savings is realized with the reduced shortening levels. In addition, salad oil is readily available from many sources. This means greater competitive activity, closer sources of supply with more rapid delivery and lower freight costs and no fear of loss of supply. Seventh, baked goods can be labeled as "all vegetable" and containing "polyunsaturated" fats. This will meet the needs of the nutritionally conscious consumer.

Results of this study show that vegetable oil, when used with the proper conditioner-softener, can produce quality bread.

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[Received May 24, 1979]