Wrap-Up of Symposium on Theory and Application of Lipid-Related Materials in Breadmaking: Today and Tomorrow (Not Yesterday)[1]

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ABSTRACT

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An ideal surfactant should increase mixing stability and fermentation tolerance, stabilize loaf volume, improve crumb grain, and slow down staling. This requires that its hydrophilic-hydrophobic interactions with gluten proteins enhance selective aggregation and interaction with amylose and the linear fraction of amylopectin without adversely affecting panary fermentation or allowing excessive protein aggregation. The possible selection of a single material that meets all of those requirements and does not adversely affect any of those functions is wrought with many difficulties. The effectiveness of any surfactant must be considered in the context of the total of the effects of all ingredients, their balance in various stages of baking, and their interactions. In addition, the contributions of natural flour lipids, shortening, and additives and their interactions with each other and with major flour components must be considered.

I hope that in this wrap-up I can provide a connecting link between the presentations in this symposium, a necklace to tie things together.

The first presentation, from Australia, concerned theoretical aspects and functional properties of flour lipids (MacRitchie 1981). Studies that employed various baking methods indicated that as a result of an initial decrease in lipids, due to their extraction from a flour, loaf volume of bread baked from the flour decreases, but after additional removal of lipids loaf volume increases. One of the possible explanations is that in the original untreated flour, lipids contribute beneficially by interacting with proteins. Once the lipids are removed, that mechanism is inoperative. Consequently, after removal of about half of the free lipids the system has reduced chemical interaction between lipids and proteins and/or reduced lipid-mediated interaction among proteins themselves. Subsequent removal of lipids possibly contributes to aggregation among proteins, an aggregation that is not lipid mediated. The comment that adding a free saturated fatty acid to defatted or nondefatted flour is less damaging to loaf volume than adding an unsaturated fatty acid is correct. The opposite may be true, however, when, for instance, the fatty acid (saturated or unsaturated) is acylated to

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glycerol, especially in complex lipids such as glycolipids, phosphohipids, or surfactants (Pomeranz and Wehrli 1969).

The statement was made that differences in the breadmaking contributions of lipids from different flours could not be related to genetic effects. I'm referring not to contributions of specific lipid components but to contribution of total free lipids from flours that vary in breadmaking potential. Recent findings indicate that lipids in flours that vary in breadmaking quality differ in their contribution to breadmaking (Chung et al 1979). Consequently, for any given flour, assessing the effect of its lipid on potential loaf volume may be possible by determining the polar lipid content, the polar to nonpolar lipid ratio, or the galactose content of the lipids extracted from the flour. That study has shown that previous negative results for attempts to correlate genetic differences in breadmaking with contribution of lipids may have resulted from inadequate methodology, or from inadequate selection of testing material (eǵ, material that was extremely variable or affected by too many factors), or from a combination of both. Consequently, the test may have to be applied to a more "homogeneous" group of samples, such as sound hard red winter wheats grown in the Great Plains of the United States.

Several times in this symposium loaf volume was depicted as a criterion of breadmaking. Although this is correct, we must recognize that loaf volume is the total result of numerous factors. These factors include the contribution of types and amounts of lipids, the contribution of levels and quality of proteins—quality of proteins being independent sometimes from interaction with lipids, and possibly processing factors including bakeshop operations and schedules, formulation, and addition of materials not present in wheat flour. Consequently, although loaf volume determination is the most powerful single and quantitative yardstick (or better, meterstick) of breadmaking potential, we must recognize its limitations. First, tracing analytically which of the factors has the greatest impact may be difficult; second, in acquiring the power to measure interaction we may sacrifice some power of analytical discernibility.

For quite some time I have been occupied with developing a unified theory on the contribution of lipids to breadmaking. We have many pieces that do not seem to fit well at times into the large jigsaw puzzle of the combined role of flour lipids, shortening, and surfactants in breadmaking. We also have many fragmentary reports that frequently evoke the comment "So what?" or "What do these results mean?" Consequently, I have toyed with the idea of a model. The objective is not necessarily to be scientifically precise but to combine or reconcile all those fragmentary data and come up with a broad picture and unified theory. The picture I visualize is that the structure or skeleton of the dough is formed by gluten proteins, which can be reinforced by interaction with lipids. In that structure, the glutenins are required to develop the dough and the gliadins to retain the gas formed in the developed and fermented dough (Finney 1978). The starch is a major, yet temporarily relatively inert, component of the system. Up to the stage of oven proof, strength and stability of the dough structure depends on mixing and interaction of lipids and proteins. The overall quality of that structure depends on the amounts, types, and quality of the protein structure and on the amounts and types (quality) of the strengthening lipid elements. Not enough proteins and/or free lipids results in not enough cement for the desired structure and/or not enough strengthening elements to impart the desirable coherence. Similarly, if the proteins or lipids are damaged by sprouting or adverse storage conditions, protein-protein and protein-lipid (reinforcement) interactions can be impaired (Daftary et al 1970, Pomeranz 1971). The starch granules in the dough are basically a silent, but interested and potentially responsive, majority. They become a truly active partner mainly at the baking stage. Only at the oven spring stage of breadmaking does major interaction with starch take place (Wehrli and Pomeranz 1970). The extent of that interaction is significant both in imparting a desirable structure to the final bread and in contributing to the qualities that give overall consumer acceptance, including freshness retention.

Free flour lipids are involved in the interaction among macromolecules in the dough and bread and are essential in lipid-mediated effects. The bound lipids, on the other hand, are essential in maintaining the structure of those macromolecules (proteins and starch) (Pomeranz 1973). They are bound, difficult to remove without damaging the macromolecules, and, once removed, difficult to restore to their original form and function. In some instances, that restoration may be facilitated by surfactants.

Where do surfactants fit in that picture? Our data indicate that they can strengthen the framework of the protein-lipid interaction both at the mixing and the oven stages. Several studies indicate that shortening also can make a significant contribution. At low shortening levels, that contribution involves, in part at least, interaction that is mediated by flour lipids or surfactants. Consequently, it is affected by the numerous factors that govern breadmaking quality—protein content and quality, lipid content and quality, and surfactant contribution. Up to a certain point, that contribution is apparently a mechanical rather than a chemical strengthening of the dough or bread framework. Excessive amount of shortening, however, may possibly prevent interaction and thus prevent flour lipids from contributing maximally to dough and bread structure.

Baking then "sets" the dough structure and fixes the bread texture and volume. The properties of that structure can be modified by additives such as surface-active agents, enzymes, etc. Similarly, the size (loaf volume) and quality (crumb grain, freshness retention) can be affected by optional added ingredients (sugar, shortening, milk solids, malt) and by the manner in which the structure was produced (water absorption, reduction-oxidation relations, dough development, fermentation schedules and levels, etc.).

The article from Denmark on theoretical aspets of surfactants is useful in extrapolating what has been learned in physical chemistry to what is happening in breadmaking (Krog 1981). Like any extrapolation and generalization, it has its limitations. The other, potentially equally powerful, approach would be to use the data from baking studies to develop a theoretical basis for, and critical assessment of, the role of surfactants. The baking results cannot be an indiscriminate compilation of data from tests that employ various methods. The most meaningful data would be those obtained from baking tests that employ optimized conditions with regard to mixing time, water absorption, and oxidation level. In addition, none of the added ingredients should be limiting. Such baking tests were developed and are used in our laboratories (Finney 1978).

The statement has been made that in some surfactants C_{18} fatty acids are best. Again, we should ask: best for what? The effects of fatty acid chain length and saturation (in the lipid) may vary depending on their contribution to dough development or stability, loaf volume and crumb grain, or rate of staling. We have found that in surfactants and glycolipids unsaturated fatty acids are preferable to saturated acids (Pomeranz and Wehrli 1969). Up to a certain degree, short-chain fatty acids are preferable to long ones. The data that were reported at this symposium on the effects of fatty acids in sucroesters in breadmaking (Chung et al 1981) expand our previous findings and add an interesting dimension.

The article by Chung et al (1981) on acyl esters of sucrose and ascorbic acid examined the significance of fatty acid chain length, conformation, and position within the esters in breadmaking. A small difference in the fatty acid position may have a large effect. An additional factor that should be considered is the length of the carbohydrate chain in the sugar ester because the carbohydrate may be a monosaccharide, disaccharide, or oligosaccharide. Fatty acid chain length affects the hydrophilic-hydrophobic balance of the sucrose ester, its overall properties, and its contribution to breadmaking potential. Desired carbohydrates might be tailor-made by selective chemical-enzymic hydrolysis and fractionation of corn starch. Another factor that must be clearly identified in the use of sucrose esters in breadmaking (if and when that use is permitted by law) is the large adverse effect of very small amounts of impurities, such as residual solvents from synthesis. Such impurities may affect gas production and/or gas retention and may interfere with panary fermentation. Although the magnitude of the effect might be predicted solely on the basis of proof height, at the critical stage of oven spring the effect may possibly be made greater than predicted and be expressed in loaf volume, crumb grain, and overall bread quality. The caution about the adverse effect of small amounts of impurities is equally applicable and relevant to all the surfactants and chemically processed additives. In addition, some impurities may be beneficial rather than detrimental. Thus, for instance, the presence of small amounts of short-chain or unsaturated fatty acids in sucrose monopalmitate makes the surfactant superior to a highly purified sucrose ester (Pomeranz and Wehrli 1969).

The article on shortening systems, fats, oils, and surface-active agents impressed me by its consistent comparison between the role of shortening and oil in their contribution to cake and bread structure (Knightly 1981). Although we have found that operative mechanisms in both are different, we have also found incorrect the notion that what is good for bread is invariably bad for cake and vice versa. I was interested to learn that the contribution of shortening in both bread and cake has a common denominator. This might be attributed to the role of shortening in mechanically strengthening the structures of both products. Surfactants enhance the stability of the structures, even though those structures are obtained by various mechanisms and involve different basic components. Shortening apparently can contribute mechanically to gas retention in the baked bread. However, to impart certain desirable rheological properties, the addition of surfactants, is required, especially to liquid oil. Those rheological properties, in turn, affect the quality of the final bread as a result of interaction among surfactants, flour lipids, and proteins. The large surge in the use of liquid oil without concern for the solids index seems to have been made possible by surfactants imparting to the oil, in part at least, the properties of polar lipids. That could be attributed to surfactants with a high hydrophilic-lipophilic balance, which would lower the nonpolar-polar ratio of the total flour system. Although the latest fluid bread shortenings offer rather impressive advantages, however, they are not without their limitations (Smith 1979).

The role of lipoxygenase in dough mixing (Faubion and Hoseney 1980), apart from its contribution to the study of bleaching, is quite exciting. The contribution of lipoxygenase to mixing tolerance appears to warrant additional studies. Although mixing tolerance per se is of significance, to demonstrate its effects in the baked bread, controlled rheological studies on elasticity, extensibility, and related variables would be required. The role of lipoxygenase in dough systems, in general, and in the production of satisfactory bread from weak wheats, in particular, was reported in recent years by Frazier and co-workers (Frazier 1979, Frazier et al 1979). Their studies concerned the contributions of lipoxygenase, ascorbic acid, and azodicarbonamide (singly or in combination) to dough structure, rheological properties, work input, and bread quality. Maybe, rather than complex systems, simple model systems that are both effective and easy to interpret should be used. Thus, for instance, fats could be replaced by free fatty acids in combinations with lipoxygenase. Wheat proteins containing sulfhydryl groups could be replaced by cysteine, glutathione, or proteins with selected molecular weights and amounts of sulfhydryl groups, such as in commercially available thiolated gelatins. Maybe a combination of free fatty acids plus lipoxygenase can provide a controlled balance with regard to mixing tolerance and overall bread processing attributes. A combination of cysteine plus oxidants in a buffered system has been shown to provide such a balance with regard to loaf volume, crumb grain, and overall bread quality (Henika and Zenner 1960). Other fragmentary data from various laboratories are numerous enough to indicate that the hypothesis is more than just wishful thinking.

Although the effects of surfactants on dough properties and proof time of yeasted doughs (Tsen and Weber 1980) are of interest, two requirements should be met before the impact of those findings can be evaluated: first, the determination of whether the potential benefits are operative in actual breadmaking, and second, evaluation of the economics of all the factors combined in terms of their practical significance.

The best articles are the ones that not only answer questions but pose new and challenging questions. The presentation from England on recent studies on the effects of flour quality and shortening addition on some dough properties (Bell et al 1980) is certainly in this category. It demonstrated the contribution of shortening to gas retention in different flours and posed the question of whether heat is essential to the action of shortening. The mechanism by which shortening is beneficial when added to strong, weak, and poor flours remains still somewhat elusive. The definitive work in this area is yet to come. Interpretation of the results of changes in storage as they relate to shortening requirement and breadmaking strength is difficult. Those findings must be analyzed and interpreted before we can determine the extent to which reported changes in breadmaking properties during storage depended on the type of flour, the storage conditions, or the baking formulation and precedure. I was interested to learn that heat treatment was not a prerequisite to demonstrating shortening effects. At this time, the proposed dough expansion method is a precise, yet somewhat capricious, analytical tool. Inasmuch as the preliminary results agree with baking data and make possible the pinpointing of the stage at which shortening contributes to breadmaking, it is a useful tool that makes possible limited interpretations. At the same time, obviously, any time dough is taxed at elevated temperatures by carbon dioxide expansion, shortening is helpful in retaining the gases and in strengthening the structure of the gas-retaining dough (Bell et al 1980).

The presentation on bread staling (D'Appolonia and Morad 1981) clearly shows that even though we have learned a lot about bread staling, we still have much to learn. Unlike dough mixing and bread quality, the term staling is used to denote the total effects of a great number of changes that take place in the crumb and crust of baked bread. We haven't even defined specifically what we are measuring. This is partly because staling is so many things to so many people. If we speak about the combined contribution of lipids, surfactants, and shortening to dough mixing, we immediately think of dough development time and dough stability. If we speak about contribution of flour components to loaf volume, we think of a specific measurement. Even if we speak about effects on crumb grain we can point to specific variables and criteria. If we speak, however, about staling, we should define first whether we are interested in changes in the crumb or in the crust, whether we are concerned with moisture relations, whether we wish to measure a host of ill-defined rheological properties (crispness of crust, crumb hardness, and crumbliness) and related consumer assessments and preferences, or whether we mean changes in flavor, taste, etc. How to measure each of those and how to assign significance to each factor needs to be established before we can tackle the problem of slowing down the rate of staling.

This symposium is devoted to "Today and Tomorrow in the Theory and Application of Lipid-Related Materials in Breadmaking." Predicting the Tomorrow while we still have a limited picture of Today would be presumptuous (and dangerous). I would like to limit my concluding remarks to the things I believe are needed to help us find the right answers Tomorrow; 50% of the answer lies in good questions, so let's have a try at those questions.

1. The foremost need is better analytical tools that enable us to measure the changes we are observing.

2. Those analytical tools must permit a continuous recording of a dynamic rather than of a static system.

3. We pride outselves that in recent years we have been able to take components apart and put them together without damage to functional properties so that we can trace analytically the significance of each componenet in the breadmaking or cake-making process. That is a major accomplishment. What is necessary now is to study the roles of those components without taking them apart—only in this manner will we be in a position to follow their interaction in the actual system.

4. Most of our studies are conducted on a relatively large scale. Even when we examine loaves or cakes baked from a hundred or ten grams of flour we deal with and measure gross changes. What we need are tools and methods of continuously measuring and recording those changes by putting the whole dough mixing,

fermentation, and breadmaking process on the stage of a microscope (for instance, a scanning electron microscope) so that we can follow what is happening in the individual membrane of a dough or bread cell.

5. Once we obtain the results from microscopic studies (and maybe computerize them), we will be faced with the task of interpreting and, most importantly, evaluating their relevance to actual practice.

In enumerating all those needs, I have proposed some unconventional approaches to studying conventional foods. The picture becomes even more complicated if we consider the use of unconventional food sources (ie, corn, rice, triticale, etc. in addition to wheat) and unconventional food types (ie, high-temperature-short-time extrusion products in addition to bread, cakes, cookies, etc.). In summary, the Theory and Application of Lipid-Related Materials in Breadmaking has a tomorrow and a future. That tomorrow will be a very challenging one.

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