

# Flour Lipids: Theoretical Aspects and Functional Properties<sup>1</sup>

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## ABSTRACT

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Baking variables such as loaf volume and texture are very sensitive to changes in lipid content and composition. Polar lipids have favorable effects in baking, but the nonpolar lipid fraction has detrimental effects, which have been identified mainly with free fatty acids. The unusual loaf volume-lipid content curve may be used quantitatively to assess the effects

of lipids. This curve is unaffected by interchanging the nonstarch lipid or starch of different flours but is modified by interchanging the gluten protein. The function of lipids in baking can be related to their effects on the formation and stability of the gas cell structure of dough.

Wheat flour lipid, although only constituting about 2% by weight of flour, makes important contributions to dough properties, baking behavior, and bread staling. Because dough properties and staling are considered in other papers of this symposium, the present discussion will focus on the effects of flour lipid in bread baking and will be restricted mainly to recent results from the author's laboratory.

The baking test was a short-time procedure using 30.2 g (dry weight) of flour (MacRitchie and Gras 1973). Optimum water addition, mixing time, and bromate level were established for each flour before the baking test. General conclusions were checked by other baking procedures, both long (3 hr) and short-time fermentation, employing 120 g of flour and 400 g of dough per loaf, respectively.

Lipid is the component of wheat flour which, when varied, produces the greatest changes, on a weight basis, in characteristics such as loaf volume and texture. Figure 1 illustrates the effects on loaf volume (MacRitchie 1978) when comparable amounts of lipid and gluten protein are removed from a flour. Loaf volume decreases as both lipid and protein contents are decreased from their natural values. The decrease for protein is linear (Finney and Barmore 1948); however, the lipid curve reaches a minimum, thereafter increasing on further removal of lipid (MacRitchie and Gras 1973). Changes in volume are accompanied by parallel changes in texture. The minimum often corresponds to a negligible expansion of the loaf in the oven. For the flour represented in Fig. 1, the volume increment was 6.5 cc per percent of gluten protein, whereas the volume increment for lipid in the steep parts of the curve on either side of the minimum was about 50 cc per percent of lipid, a factor of eight greater. On the other hand, complete removal of protein from a flour destroys its dough-forming properties and bread-baking capacity whereas removal of lipid does not. Dough properties and bread-baking capacity are retained by a defatted flour.

The starch lipids, which comprise roughly one-fourth of the total lipid of a flour, do not play a role in bread baking (MacRitchie and Gras 1973, Morrison 1978), although they may be important in staling. The following discussion will be concerned with the nonstarch lipids only. A defatted flour will be understood to mean a flour that has had its nonstarch lipid removed by exhaustive extraction with chloroform. Whole flour refers to the original, untreated flour and whole lipid to the unfractionated chloroform extract.

## EFFECTS OF LIPID COMPONENTS

Analytical data for the composition of the complex mixture of lipids in wheat flour is available (Morrison 1978). For evaluation in breadmaking, separation of lipid fractions is usually effected by

utilizing differences in the ease of elution of components from activated silica gel (Ponte and DeStefanis 1969). This allows a convenient classification of lipids into nonpolar and polar fractions. The major components of the more easily eluted nonpolar fraction are steryl esters, monoglycerides, diglycerides, triglycerides, and free fatty acids. The polar fraction contains mainly galactolipids and phospholipids. The favorable effects of the polar fraction and detrimental effects of the nonpolar fraction in breadmaking have been well documented (Daftary et al 1968, MacRitchie and Gras 1973, Ponte and DeStefanis 1969). Among the nonpolar components, the free fatty acids have been shown to be mainly responsible for depressing loaf volume (DeStefanis and Ponte 1976). Although the unsaturated linoleic acid depressed volume when added to a defatted flour, the saturated palmitic acid (which occurs in much smaller amounts in flour) had little effect. When the baking test was carried out on whole flour with 3% lard in the formulation, the ill effects of the free fatty acids were greatly reduced.

Some polar lipid fractions and fractions of intermediate polarity, added to defatted flour in small amounts, depress loaf volume, and the volume depression per unit weight is greater than when nonpolar fractions are added (MacRitchie 1977, MacRitchie and Gras 1973). This may be due to the presence of compounds of intermediate polarity, such as the free fatty acids, which could become bound during fractionation. The more nonpolar components such as the triglycerides have been shown to exert little effect on the volume of loaves made from defatted flour (DeStefanis and Ponte 1976). Galactolipids and phospholipids, components of the polar fraction, have generally beneficial effects.

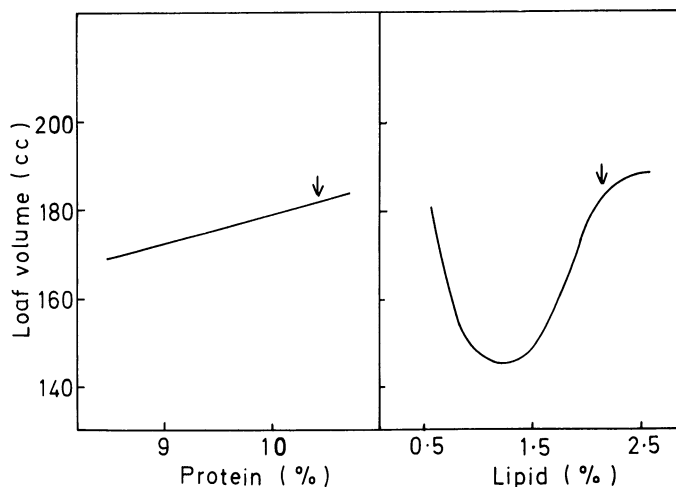


Fig. 1. Variation of loaf volume with changing protein (left) and lipid (right) contents of the same flour, redrawn from results of MacRitchie (1978). Arrows indicate natural values for the flour. Lipid is expressed as hydrolysate lipid. Starch contains approximately 0.5% hydrolysate lipid; curve shows effects of additions of chloroform-extracted lipid.

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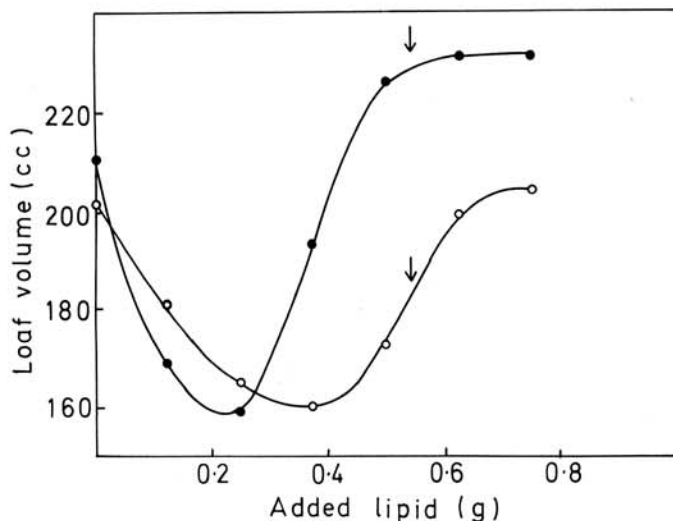
## LIPID-PROTEIN INTERACTION IN FLOUR QUALITY

The unusual form of the loaf volume-lipid content curve has not been explained. To gain insight into the theoretical basis for the curve, one can examine how it is quantitatively affected by different variables. First, for a given flour, the curve is very sensitive to the lipid composition. Altering the polar-nonpolar balance in favor of the polar lipid displaces the minimum to a lower lipid content (MacRitchie and Gras 1973). However, studies have shown that the curve for a given flour is usually unaffected by replacing the lipid with the whole lipid from another flour (MacRitchie 1978) of different baking performance. From this result, one may deduce that for the flours examined in this way to date, no significant differences in composition of the lipid exist that could affect breadmaking. This is in agreement with conclusions reached in a detailed study by Fisher et al (1966). Similarly, interchanging starch fractions of different average granule size gave identical curves indicating no starch-lipid interaction.<sup>2</sup>

However, flours that differ in baking performance give rise to different loaf volume-lipid content curves, and this effect can be related to the gluten protein component (MacRitchie 1978). Figure 2 illustrates this effect. When the gluten protein from a good baking flour was replaced by that from a poor flour (at the same protein level), all other components being kept constant, the loaf volume-lipid curve was modified. The minimum was displaced to a higher lipid content. As a result, the loaf volume was relatively low at the natural lipid content and corresponded to a point on the steeply rising part of the curve, whereas the loaf volume of the good flour had approached its maximum value.

This effect is often observed when flours of varying baking performance are compared. At times, a poor flour may approach a good one in loaf volume at sufficiently high lipid contents. This explains the fat response of certain flours and justifies the general use of shortening in commercial no-time baking processes. Once a flour contains an appreciable amount of natural lipid, additions of shortening appear to be equally as effective in increasing loaf volume as the natural lipid is. In certain cases, as in the example of Fig. 2, the poorer flour does not attain the volume of the better one even at high lipid additions. Interchange experiments have shown this to be due to a deficiency in gluten protein quality. For the flours used in the experiment of Fig. 2, the amounts of lipid bound by dough making were approximately the same. No relation between flour performance and bound lipid has been found in previous experiments (MacRitchie 1978), and the lipid-protein interaction appears to be of a more subtle nature.

<sup>2</sup>Unpublished results.

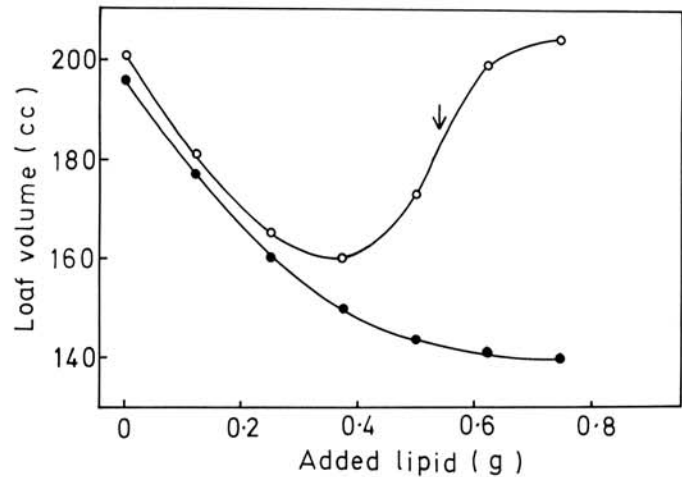


**Fig. 2.** Loaf volume-lipid content curves for a good baking flour (●) and for the same flour with its gluten protein replaced, at the same protein level, by gluten protein from a poorer baking flour (○). Arrows indicate natural lipid level of flour. Lipid additions refer to the weight of whole lipid added to a defatted flour of 30.2 g dry weight.

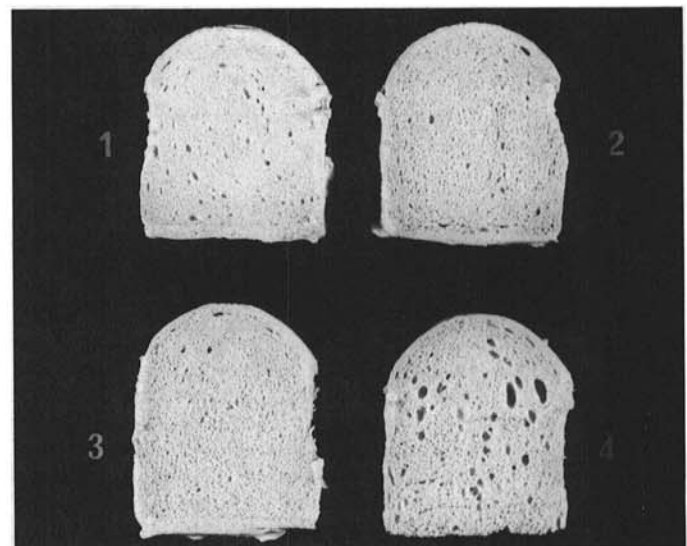
## ROLE OF LIPIDS IN STABILITY OF GAS CELL STRUCTURE OF DOUGH

Omission or inclusion of an intermediate molding step during proofing may have a very great effect on the loaf volume-lipid curve as shown in Fig. 3 (MacRitchie 1977). The present results refer to a short-time baking process. When the molding step is omitted, loaf volume continuously falls with increasing lipid content of the flour and does not show the recovery above an intermediate lipid content, as is found in the normal baking procedure in which dough pieces are molded after a 20-min fermentation. Changes of lipid content were not found to change mixing or rheological properties of doughs in ways that can be related to baking performance. On the other hand, molding is known to modify gas cell structure (Baker and Mize 1941), and the marked interrelation between the flour lipid content and molding (Fig. 3) suggests that lipid plays a role in the formation of a stable gas cell structure in dough.

Gas cell structure of doughs may be followed by freezing dough



**Fig. 3.** Loaf volume-lipid content curves for a flour in which a remodeling step after 20-min fermentation has been included (○) and omitted (●). Arrow indicates natural lipid content of flour. Lipid additions refer to the weight of whole lipid added to a defatted flour of 30.2 g dry weight (from MacRitchie 1976).



**Fig. 4.** Photographs of freeze-dried slices of fermented doughs taken at the end of the proofing stage, just before oven baking. 1, Defatted flour, remolded; 2, flour with lipid content corresponding to minimum in the loaf volume-lipid content curve, remolded; 3, whole flour, remolded; 4, whole flour, remodeling step omitted. An average quality baker's flour (11.2% protein) and the standard short-time baking procedure (30.2 g, dry weight, of flour) were used.

pieces at different stages of proofing, cutting slices from the hardened dough, and freeze-drying them. In this way, gas cell structure is preserved and may be conveniently examined and photographed if required. Figure 4 shows photographs of the gas cell structure of dough pieces that have had different lipid additions and molding treatments, taken at the end of the proofing stage, just before oven baking. At this point, no differences in volume are found. Comparisons between the gas cell structure and the final loaf volume can be made using the graphs of Fig. 3.

Figure 4 clearly shows that the gas cell structure of the dough piece from whole flour that has not been remolded is greatly inferior to the corresponding one that has been remolded. Deterioration of the gas cell structure of doughs from defatted flours to which increasing additions of lipid are made is evident early in the fermentation. At this stage, doughs from defatted flour have a distribution of small and uniformly sized bubbles. With increasing lipid, this changes to a more heterogeneous dispersion with numerous large bubbles. During proofing, the larger cells tend to grow at the expense of the smaller ones because of gas transfer caused by the excess pressure within the smaller cells (Davies and Rideal 1961). During the critical initial oven stage of baking, such a gas cell structure tends to collapse, giving a loaf of low volume and poor texture.

In the case of dough pieces that have been remolded (Fig. 4), subtle differences are apparent in the structure as lipid content is increased, but the quality of the dispersion appears to be maintained. However, variations in the final loaf volume reflect differences in the stability of the gas cells. This in turn may be related to a changing composition of the stabilizing protein-lipid film at the air-aqueous interface. When dough pieces are molded after an initial fermentation, the high pressure causes a momentary decrease in size of the cells and their interfaces. The more readily desorbable components in the stabilizing film (eg, the more unsaturated free fatty acids) may be forced out of the interface at this

stage. The role of the molding step could thus be twofold, the forming of a more uniform gas cell distribution and the improvement of the stabilizing properties of the film. Gaining better understanding of bread-making processes and the role of lipids may require more studies of gas cell distributions in dough and of how foam stability is related to the composition of adsorbed films containing protein and specific lipids.

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## Theoretical Aspects of Surfactants in Relation to Their Use in Breadmaking

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The physical chemistry of food grade surfactants used in breadmaking is discussed in relation to their functionality as dough conditioners and crumb softeners. A general survey of surface activity of surfactants and their ability to form lyotropic, mesomorphic phases in water is followed by a discussion

Surfactants in the form of monoglycerides and diglycerides have been used in the food industry since about 1921, and some industrial production of food grade surfactants has taken place for more than 50 years. Today the food industry annually uses approximately 100,000 tons of fat-derived surfactants, of which monoglycerides and their derivatives total about 75% on a volume basis.

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of how surfactants may interact with the components of flour: starch, proteins, and lipids. The formation of ordered surfactant-water structures in the dough may play a vital part in the function of dough conditioners and crumb softeners.

Cereal-based foods produced in the industrialized parts of the world are one of the major markets for surfactants, which are used as dough conditioners; as crumb softeners in bread, buns and rolls; and as aerating agents in cake systems. Furthermore, surfactants are used as emulsifiers in emulsions (coffee whiteners, margarines, spreads), as amylose-complexing agents in starch-based foods (processed potatoes), as aerating agents in toppings and whipping creams, or as crystal-modifiers in fats.

#### CHEMICAL STRUCTURE

Most surfactants consist of hydrophobic fatty acid chains esterified to a hydrophilic polar group that can originate from different types of polyvalent alcohols, such as propylene glycol,