Role of Free Flour Lipids in Batter Expansion in Layer Cakes. I. Effects of "Aging"[1]

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ABSTRACT

White layer cakes baked from unbleached patent flours that had been aged (exposed to moving air) for 9 or 14 weeks exhibited greater oven expansion than did cakes baked from bleached control flours. A measurable increase in expansion occurred in cakes baked from flours aged two weeks. Expansion in cakes baked from defatted unbleached and bleached flours reconstituted with free lipids from aged flours suggests that expansion induced by aging is a result of changes in free lipids. Cake volumes were retained when the lipids were added back to defatted bleached flours, but some degree of collapse usually resulted when the lipids were added back to defatted unbleached flours.

Many studies have concerned the effects of storage and "aging" on flour quality. Most of these studies were performed before 1940 and were reviewed in various reports of that period (Bailey 1925, Fisher et al 1937, Kozmin 1935, Shellenberger 1939). They generally support the statement by Fisher et al (1937) that "wheat flours improve in baking quality during storage." Since that period, most storage studies have been confined to changes in specific components, especially lipids (Pomeranz 1971). With few exceptions, the early storage studies were concerned with quality defined in terms of hard wheat flours, and "improvement" generally referred to mixing tolerance or other quality attributes associated with bread-baking potential.

Flour improvement has also been effected by subjecting flours to elevated temperatures. Such treatments (which, if mild, may be considered "accelerated aging") have been studied as a possible substitute for chlorination. In such experiments, "quality improvement" has been observed in soft wheat products (primarily cakes). A British patent (Doe and Russo 1968) describes a heat treatment for flour (or starch) to replace chlorination in the manufacture of cake flour, and Hanamoto and Bean (1978) described a combination of heat treatments of flour and starch as alternatives to chlorination. Johnson et al (1979) observed that reconstituted flour containing starch air dried during fractionation gave cakes of quality equal to that of cakes from Cl_2-treated flour. Recently, Johnson and Hoseney (1980) reported that storing flour for two months at room temperature resulted in cake improvement and concluded that the effects were due to changes in the starch.

The present study was stimulated by anomalous effects occasionally observed in our laboratory when cakes were baked from hexane-extracted unbleached flours to which the free lipids had been restored. Normally, white layer cakes baked from such reconstituted flours are essentially identical to controls baked from the original untreated flour, ie, they exhibit limited oven expansion, low volumes, and poor texture (Kissell et al 1979). On one occasion, a sample of unbleached flour was weighed into several cloth bags, which were tied and placed on a tray in the laboratory preparatory to lipid extraction (Clements 1977). However, circumstances resulted in a delay of several weeks before extraction could be performed. During subsequent baking studies, we noted that cakes made from defatted unbleached flours reconstituted with lipids from this batch exhibited oven expansions exceeding normal expansions in cakes from bleached flours. The objectives of the present study were to determine to what extent lipids are involved in such effects and to attempt to duplicate the effects under controlled conditions. This report is concerned with aging effects; a second report is concerned with the effects of heating (Clements and Donelson 1982).

MATERIALS AND METHODS

One flour, a soft red winter patent, was obtained in unchlorinated form from an Ohio mill. The remaining flours were 50% patent flours pinmilled in the Wooster Laboratory at 9,000 rpm (Alpine Kolloplex, type 160Z mill). All flours were stored at 4°C in metal cans containing about 15 kg of flour and covered with tight-fitting lids. Samples for controls and aging were taken from the cans without regard for location in the cans. Bleached controls were prepared by chlorination in the laboratory to pH 4.8 (Kissell and Marshall 1972). Free lipids were removed by extraction with hexane for 24 hr in a large Soxhlet extractor (Clements 1977). Lipids were returned to defatted flours, and cakes were baked using the AACC white layer cake method (1976) as previously described (Kissell et al 1979). The shortening was a mixture of Creamtex (92%) and DUR-EM 114 emulsifier (8%), both obtained from Durkee Famous Foods (SCM Corp., Cleveland, OH). Volumes were measured by rapeseed displacement. Batter height was measured at approximately 0.5-min intervals during baking (23 min) as described by Clements and Donelson (1981). All bakes were replicated at least twice. Least significant difference for volumes of cakes baked from bleached flours was 35 cc ($P = 0.05$).

Aging Experiments

Unbleached nondefatted flour was packed in 20–25 cloth bags (350 g each) that were tied and arranged upright 4–5 cm apart on a tray. The tray was placed in the air stream of a fume hood with constant circulation. At specified intervals, single bags were removed, sealed in polyethylene bags, and stored at 4°C until baking was done. At the end of the specified period (9 or 14 weeks), the flour in the bags under the hood was extracted with hexane. Cakes were baked from the unextracted aged samples and from defatted aged flours and defatted bleached and unbleached control flours reconstituted with lipids from these flours in various combinations. Lipid reconstitution was accomplished as described by Kissel et al (1979).

RESULTS AND DISCUSSION

Initial experiments (conducted with the flour that had given the anomalous results noted earlier) confirmed the supposition that exposure to air resulted in oven expansion. However, because final cake volumes did not provide a true measure of the effects of treatments, some means for objective measurement of oven expansion appeared to be essential to further studies. Therefore, a method was devised (Clements and Donelson 1981) and applied to subsequent experiments.

Expansion exhibited by Logan flour as a result of aging

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increased measurably in two weeks and after nine weeks exceeded expansion from bleached flour (Fig. 1). Volume increased with aging and after nine weeks was essentially the same as volume from bleached flour. When the commercial flour had aged two weeks, expansion was about the same as expansion of bleached flour (Fig. 2). A drastic increase occurred at four weeks, but no further increases were noted as aging continued (to nine weeks).

To determine whether nonlipid components contributed to the aging responses, lipids were interchanged on the base (ie, defatted flour) from Arthur flour that had been aged for 14 weeks. When lipids from the untreated unbleached flour were added back, expansion was about the same as expansion without lipids (Fig. 3). Expansion from lipids from the 14-week aged flour was much greater, exceeding the response from lipids from the bleached flour. However, volumes of cakes containing lipids from bleached flour were greater (Fig. 4). Because the same aged base was used for these cakes, lipids appeared to be solely responsible for expansion increases. We also performed experiments to determine whether mechanical shock would minimize collapse and thereby preserve the potential volume generated by the expansion (Ohtsubo et al 1978). Volume increase resulting from dropping a cake immediately after removal from the oven was more than 200 cc (Fig. 4).

Logan and commercial unbleached, bleached, and nine-week aged lipids interchanged on their respective unbleached and bleached bases further established the role of lipids in expansion responses and the importance of bases in batter stability. The Logan interchange gave predicted results: volumes of cakes baked from the bleached base reconstituted with bleached or aged lipids were substantially greater than volumes of cakes baked from the reconstituted unbleached bases (Fig. 5). When lipids from the commercial flour were interchanged, however, the bleached base

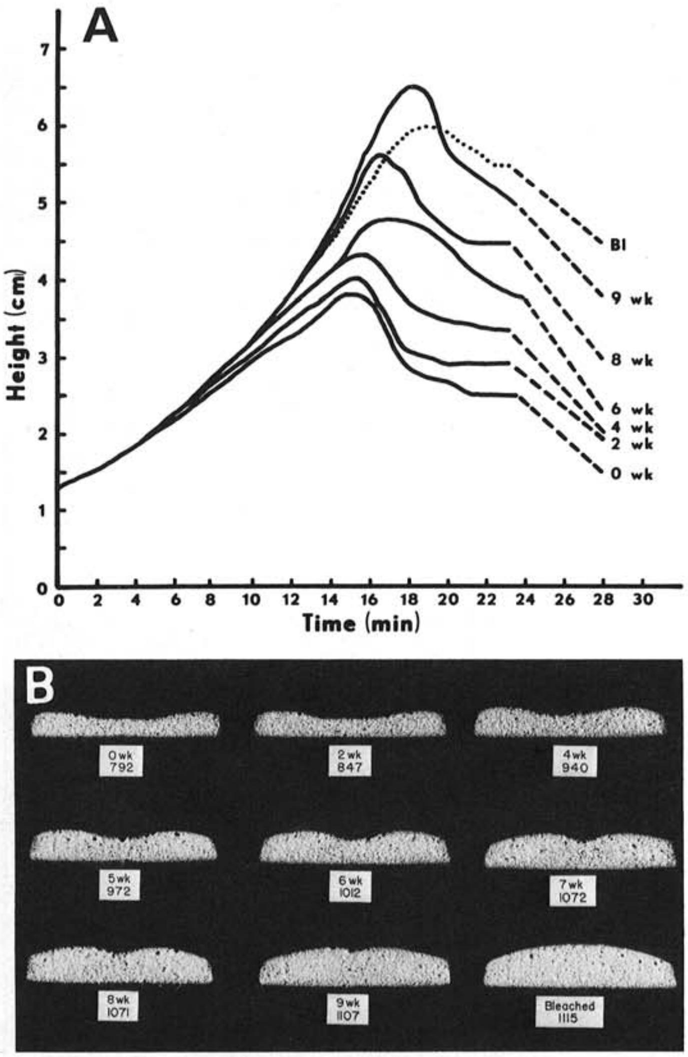

Fig. 1. Oven expansion (**top**) in layer cakes baked from unbleached Logan 50% patent flour exposed to moving air for periods of up to nine weeks compared with expansion in a cake baked from the bleached flour (dotted line). The dashed line shows shrinkage after removal from the oven. Cross sections (**bottom**) of the above cakes show contour and volume (in cubic centimeters).

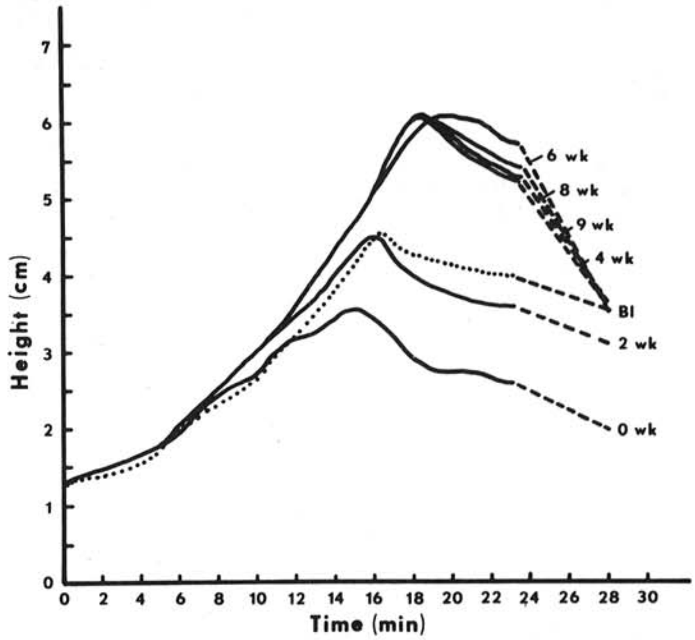

Fig. 2. Oven expansion in layer cakes baked from an unbleached commercial patent flour after exposure to moving air for periods of up to nine weeks compared with expansion in a cake baked from the bleached flour (dotted line). The dashed line shows shrinkage after removal from the oven.

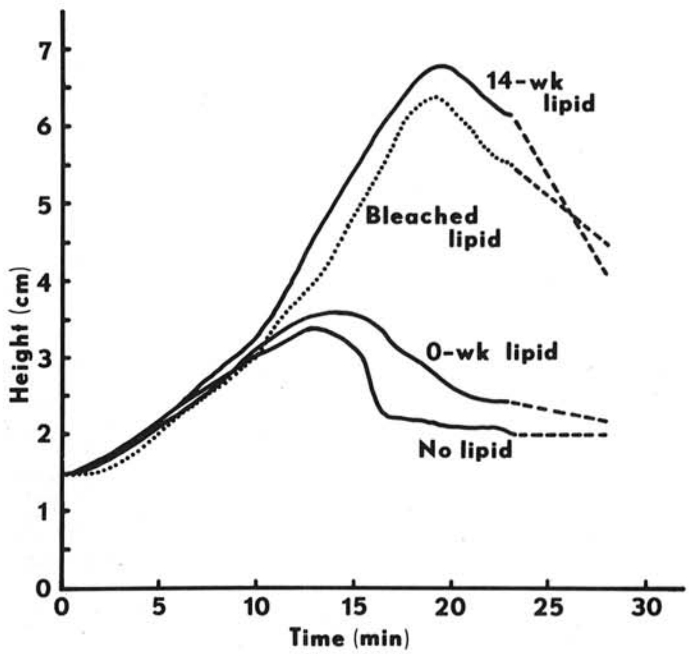

Fig. 3. Oven expansion in layer cakes baked from unbleached Arthur 50% patent flour exposed to moving air for 14 weeks. Cakes were baked from the flour after hexane extraction (**No lipid**) and after extraction and reconstitution with lipids from unbleached flour (**0-wk lipid**), from bleached flour (**Bleached lipid**), and from the aged flour (**14-wk lipid**). The dashed line shows shrinkage after removal from the oven.

reconstituted with lipids from nine-week aged flour gave cakes of very low volume (Fig. 6). Maximum volumes resulted from addition of bleached lipids to the unbleached and bleached bases, but volumes of cakes baked from unbleached base reconstituted with lipid from the nine-week aged flour were also high.

A three-way interchange of Arthur, Logan, and commercial lipids on bleached bases verified the unexpected lack of response in cakes baked from the commercial bleached base reconstituted with lipids from the aged flour (Fig. 7). Lipids from the aged Arthur and Logan flours gave about the same responses, resulting in substantial expansions with all three bases. Lipids from the aged commercial flour, on the other hand, responded only when added to the Logan base; negligible response resulted from addition of the lipids to the bleached commercial or Arthur bases. Cake volumes and contours reflect this lack of response (Fig. 8). Repeated reconstitutions and bakes gave the same results.

These experiments show that when an unbleached patent flour is exposed to moving air, cake batters containing the flour exhibit batter expansion that is not characteristic of the untreated flour. The degree of expansion depends on the flour and on the length of exposure to air. The expansion, like that caused by chlorination, appears to be a function of the lipids. In this laboratory, experience has shown that flours routinely stored in sealed containers at 4°C for extended periods (ie, years) do not develop this characteristic, nor do flours stored in sealed glass jars at room temperature for several months.

Interchange experiments showed that the degree to which expansion is translated into volume depends on the nonlipid flour components (base). Expansion of an unchlorinated base often results in a cake structure that cannot support the potential volume (Kissell et al 1979), whereas expansion generated on a bleached base is usually retained. However, lipid-base interactions may occur, leading to unpredictability of volume. Limited experiments indicate that collapse can be prevented in expanded batter by mechanical shock, which presumably opens the cells to admit air during cooling.

Flours included in this study varied in sensitivity to aging. The Logan flour showed maximum expansion at nine weeks (the end of the aging period), whereas the commercial flour gave maximum response after four weeks. Oven expansion from Arthur flour was not measured at intervals but appeared to reach a maximum in 10–12 weeks. The age of a flour (ie, elapsed time since milling) and storage conditions before "aging" (ie, exposure to air) can possibly influence susceptibility to aging. The Arthur and commercial flours had been stored for about three years at 4°C; the Logan flour had been stored for about one year. The relative freshness of the Logan flour may have been a factor in the oven response of Logan bleached base reconstituted with lipids from the aged commercial flour. The same lipids applied to Arthur and commercial bleached bases failed to respond (Fig. 7 and 8).

Cakes were not graded organoleptically, but casual inspection showed that when cakes baked from unbleached bases expanded and retained volume, they compared favorably with cakes baked from bleached flours. These cakes were quite moist, however, and did not exhibit the somewhat dry and brittle texture characteristic

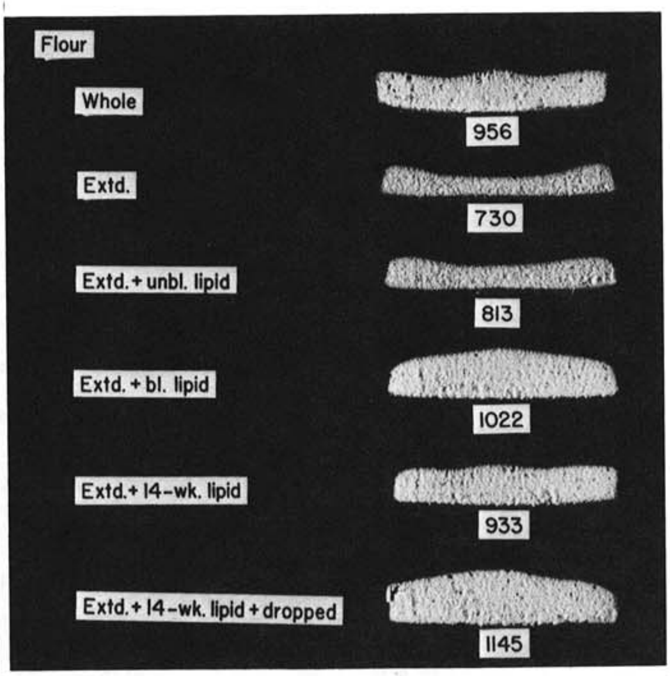

Fig. 4. Layer cakes baked from unbleached Arthur 50% patent flour exposed to moving air for 14 weeks. Cakes were baked from the flour before and after hexane extraction and after extraction and reconstitution with lipids from unbleached flour, from bleached flour, and from unbleached flour exposed to moving air for 14 weeks. Bottom cake was dropped immediately after removal from the oven. Labels show volume in cubic centimeters.

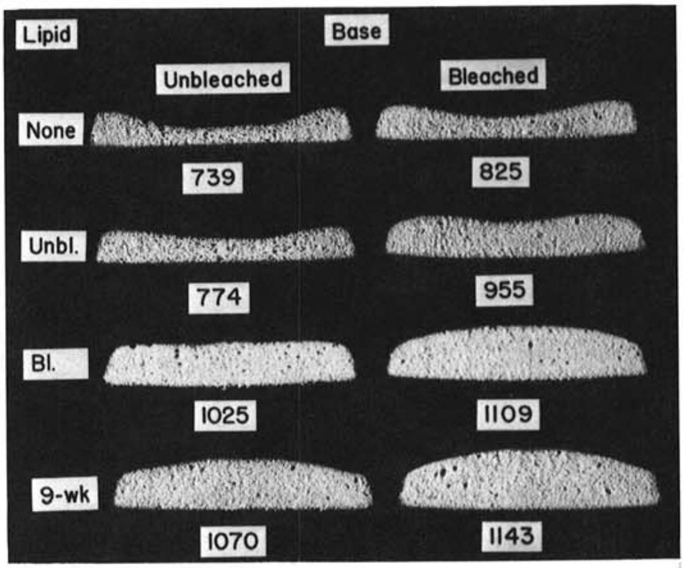

Fig. 5. Layer cakes baked from hexane-extracted bleached and unbleached Logan 50% patent flour. Cakes were baked without reconstitution and after reconstitution with lipids from unbleached flour, from bleached flour, and from unbleached flour exposed to moving air for nine weeks. Labels show volume in cubic centimeters.

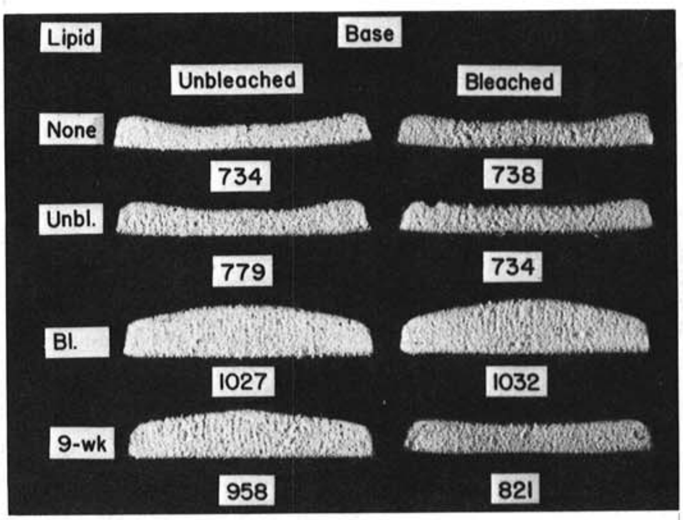

Fig. 6. Layer cakes baked from hexane-extracted unbleached and bleached commercial patent flour. Cakes were baked without reconstitution and after reconstitution with lipids from unbleached flour, from bleached flour, and from unbleached flour exposed to moving air for nine weeks. Labels show volume in cubic centimeters.

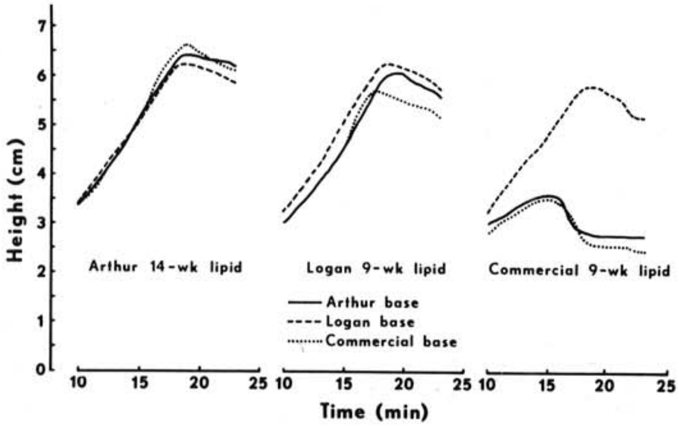

Fig. 7. Oven expansion in cakes baked from hexane-extracted bleached Arthur, Logan, and commercial patent flours ("bases"). Cakes were baked after reconstitution with lipids extracted from unbleached Arthur flour exposed to moving air for 14 weeks and with lipids extracted from unbleached Logan and commercial flours exposed to moving air for nine weeks.

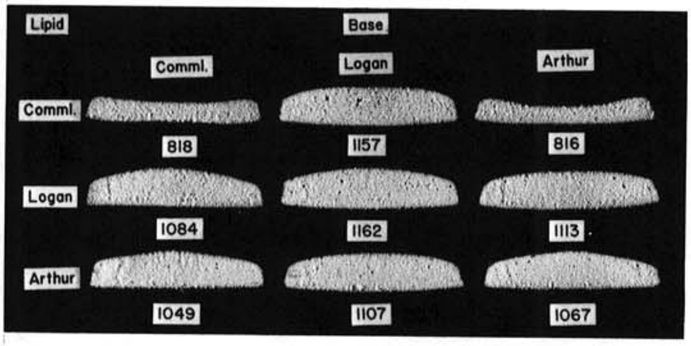

Fig. 8. Layer cakes baked from hexane-extracted bleached Arthur, Logan, commercial patent flours ("bases"). Cakes were baked after reconstitution with lipids extracted from unbleached Logan and commercial flours exposed to moving air for nine weeks and from unbleached Arthur flour exposed to moving air for 14 weeks. Labels show volume in cubic centimeters.

of cakes baked from bleached flours.

The implication of flour lipids in oven expansion induced by aging suggests possible approaches to cake flour improvement. Perhaps of greater importance, however, is the variability that these effects can introduce into baking studies. Kissell et al (1979), in lipid interchange experiments with chlorinated flours, demonstrated that free lipids from chlorinated flour were required for full volume response in AACC white layer cakes. The present study showed that batter expansion can also be induced by reconstitution with lipids from aged flours. These results are at variance with reports that free flour lipids are of little or no importance in the bleaching mechanism (Johnson et al 1979, Spies and Kirleis 1978), or in aging effects (Johnson and Hoseney 1980). This lack of agreement may be due to any of several factors. The AACC white layer cake was used as a medium in both studies from this laboratory. Other formulations, such as the lean-formula (Wooster formula) and starch cake formulations employed in the other studies, may not give the same response. Also, batter expansion may be influenced by shortening and emulsifiers and by physical factors such as pan size. We suggest, however, that an additional potential source of disagreement may be the inadvertent use of flours in which the lipids have been affected by storage. Our results suggest that lipids in an unbleached flour exposed to air for an extended period may undergo changes that cause them to behave like lipids from a bleached flour. If such an aged flour is chlorinated (or further aged), the lipids may appear to be unaffected by the treatment because they are already functional. (In this laboratory, an unbleached flour that gives cakes that expand significantly in the oven is regarded as suspect, regardless of the cake *volume.*) The lipids appear to be involved in expansion only, and if collapse occurs (as it often does if the lipids are not applied to a bleached base), volume is not a true measure of the effect. Therefore, oven expansion must be monitored in such studies.

These results substantiate our previous studies, which show that the free flour lipids are directly involved in flour improvement (Kissell et al 1979). Further evidence of lipid involvement is that batter expansion can be induced by addition of heat-treated flour lipids (Clements and Donelson 1982). The modified lipids probably are involved in foam formation and stabilization, a process basic to development of cake structure. Studies are now in progress to determine the degree to which such lipid effects may be exhibited by other formulations and systems and to isolate and characterize the functional lipids.

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