Role of Free Flour Lipids in Batter Expansion in Layer Cakes. II. Effects of Heating[1]

R. L. CLEMENTS and J. R. DONELSON[2]

Cereal Chem. 59(2):125–128

ABSTRACT

Free lipids were extracted from unbleached flours and heated at 100°C for different periods, either unsupported or supported on diatomaceous earth. Cakes were then baked from defatted bleached and unbleached flours reconstituted with the heat-treated lipids. Heating unsupported lipids for up to 60 min usually resulted in oven expansion greater than that of unbleached controls. Heating supported lipids for shorter periods resulted in oven expansion equal to or exceeding expansion from bleached control flours. Differences in sensitivity to heating were noted among flours. Expansion was retained as volume when heat-treated lipids were added to defatted bleached flours, but cakes usually collapsed when lipids were added to defatted unbleached flours.

Kissell et al (1979) showed the importance of free flour lipids in chlorination responses and demonstrated that cake volume is dependent upon the lipids. In a study of the role of free flour lipids in oven expansion, flours that were aged (ie, exposed to moving air) gave batters that expanded in the oven. Interchange experiments established that the response was associated with the lipids (Clements and Donelson 1982).

Controlled heat treatment of flours results in increased batter expansion and improved texture and has been suggested as a possible alternative to chlorination (Doe and Russo 1968; Hanamoto and Bean 1978; Russo and Doe 1970a, 1970b). Presumably, improvement is a consequence of compositional and physical changes similar to those caused by chlorination. The purpose of the present study was to determine whether oven expansion could be induced in unbleached flour by reconstitution of defatted flours with heat-treated flour lipids.

MATERIALS AND METHODS

With the exception of one flour (a commercial soft red winter patent flour obtained in unchlorinated form), all flours were 50% patent flours milled in the Wooster Laboratory. Preparation and baking methods were described previously (Clements and Donelson 1982).

Heat Treatments

Free flour lipids equivalent to the flour for one cake (about 40 ml of hexane extract containing 0.7–0.8 g of lipid, depending on the flour) were added to 10 g of Celite 545 (a diatomaceous earth product of Johns Manville, from Fisher Scientific Co., Cleveland, OH). The hexane was then evaporated in the airstream of a hood, with stirring, to give a free-flowing powder. The Celite containing the lipid was spread on an aluminum pan (about 150 cm^2) and heated at 100°C in a mechanical convection oven for the specified time, with stirring at 5-min intervals. Lipids were eluted by sequential suspension, twice each in hexane (25 ml), chloroform (25 ml), and chloroform:methanol, 2:1 (25 ml), a total of six suspensions. Each suspension was heated to 60–70°C in a water bath (with stirring), allowed to settle, and decanted into a column containing a glass-wool plug. For the final washing, the suspension was transferred to the column and allowed to drain; the remaining solvent was forced out under pressure. Solvent was removed from the combined washings by vacuum distillation in a rotary evaporator (65°C). Reagent controls (Celite without lipids) were also run. Lipids heated without support on Celite were weighed into 100-ml beakers and heated at 100°C for the specified times, with stirring at 5-min intervals. Flours were spread in aluminum pans and heated at 100°C for the specified times, with stirring at 5-min intervals.

RESULTS AND DISCUSSION

In preliminary experiments, lipids from unbleached flours were heated at 100°C for periods up to 60 min without adsorption on a solid support. When the heat-treated lipids were added to defatted flours ("bases"), either chlorinated or unchlorinated, batter expansion was generally greater than from reconstitution with untreated lipids. We assumed that these responses were the result of oxidative changes. Therefore, to increase surface area, lipids were heated while supported on diatomaceous earth (ie, Celite 545). Under these conditions, more pronounced responses occurred after shorter heating periods (Fig. 1). Cakes made from Arthur flour lipids, eluted from the support after 15 min at 100°C and added to defatted bleached flour, had greater volume than did bleached-flour controls (Fig. 1). Reconstitution with lipids heated for 30 min gave cakes similar to cakes from bleached controls, but lipids heated for 60 min gave much lower volumes. Exposure of

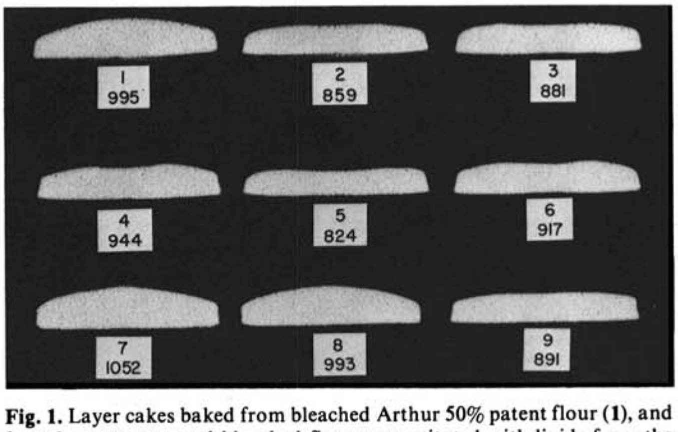

Fig. 1. Layer cakes baked from bleached Arthur 50% patent flour (**1**), and from hexane-extracted bleached flour reconstituted with lipids from the unbleached flour. Lipids were treated as follows: no heat-treatment (**2**); hexane extract evaporated at 25°C and redissolved (**3**); and lipids heated for 60 min at 100°C (**4**); lipids adsorbed on Celite and eluted after 0 min (**5**), 24 hr at 25°C (**6**), 15 min at 100°C (**7**), 30 min at 100°C (**8**), and 60 min at 100°C (**9**). Labels show volume in cubic centimeters.

[1]Cooperative investigation of the Soft Wheat Quality Laboratory, North Central Region, Agricultural Research Service, U.S. Department of Agriculture, and the Department of Agronomy, Ohio Agricultural Research and Development Center, Wooster 44691.

Approved for publication as Journal Article 48-80 of the Ohio Agricultural Research and Development Center, Wooster 44691.

Mention of a trademark or proprietary product does not constitute a guarantee or warranty of a product by the USDA and does not imply its approval to the exclusion of other products that may also be suitable.

[2]Research chemist and chemist, respectively, Soft Wheat Quality Laboratory, Ohio Agricultural Research and Development Center, Wooster 44691.

supported Arthur lipids to moving air at ambient temperature for 24 hr caused a slight response. Time studies verified that 15 min was optimum for Arthur lipids heated at 100°C while supported on Celite (Fig. 2). Unsupported lipids gave maximum reponse after being heated for 40 min at 100°C.

Nondefatted flours did not respond when heated for 15 min at 100°C (Fig. 3). Under these conditions, the lipids were on a granular support and therefore presented a relatively large surface area, but apparently 15 min was not adequate to produce a perceptible effect. Perhaps natural antioxidants retard oxidation. In this study, heated Arthur lipids did not respond when added to unbleached base, in contrast to the effects produced when they were added to bleached bases (Figs. 1 and 2).

Expansion caused by lipid treatments was generally retained as volume, but observations during baking indicated that final volume often was not a true measure of oven expansion. Therefore, in subsequent experiments, a scale was routinely employed for quantitative measurement of batter expansion during baking (Clements and Donelson 1981). Expansion curves resulting from the addition of treated lipids to their bleached Beau, Tecumseh and commercial flour bases were plotted (Fig. 4). Patterns from Beau and Tecumseh lipids were very similar, exhibiting maximum expansion after 45 min at 100°C (supported on Celite). Very slight responses were evident after 15 min. Responses after 60 min were somewhat less than after 45 min but were greater than expansions of cakes baked from the bleached control flours. Supported lipids from the commercial flour, however, gave maximum expansion after 15 min at 100°C (about the same expansion as in bleached-

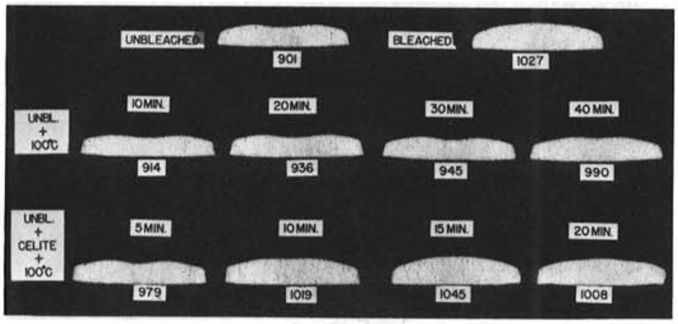

Fig. 2. Layer cakes baked from unbleached and bleached Arthur 50% patent flour (**top**) and from hexane-extracted bleached flour reconstituted with heat-treated lipids from the unbleached flour. **Center:** Lipids heated for 10, 20, 30, and 40 min at 100°C. **Bottom:** Lipids adsorbed on Celite, and eluted after 5, 10, 15, and 20 min at 100°C. Labels show volume in cubic centimeters.

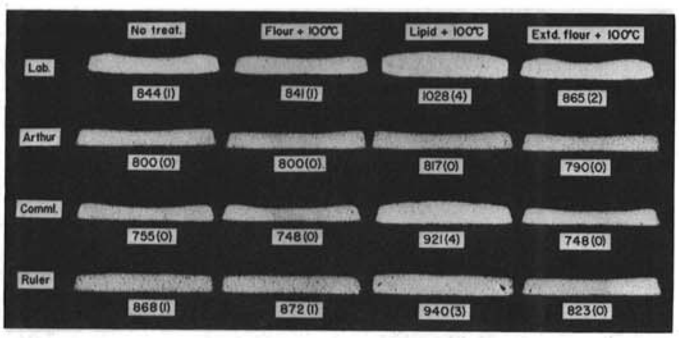

Fig. 3. Layer cakes baked from unbleached Arthur, Ruler, laboratory-milled blend, and commercial flours with various heat treatments. First column, control flour; second column, control flour heated 15 min at 100°C; third column, hexane-extracted flour reconstituted with lipids that had been adsorbed on Celite and eluted after 15 min at 100°C; fourth column, hexane-extracted flour heated 15 min at 100°C and reconstituted with unheated lipids. Labels show volume in cubic centimeters and expansion on a scale of 0–4 (4 = expansion judged to be equal to or exceeding expansion typical of bleached flour).

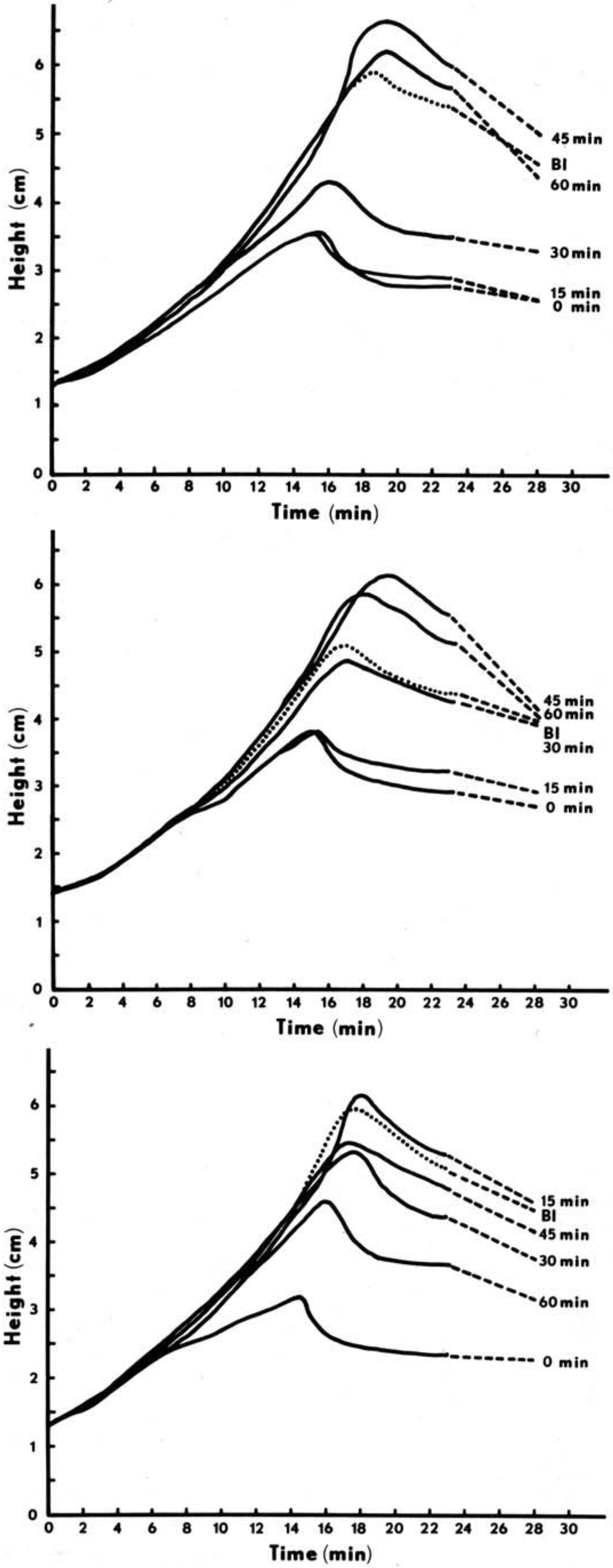

Fig. 4. Oven expansion in layer cakes baked from hexane-extracted bleached Beau (**top**), Tecumseh (**center**), and commercial (**bottom**) patent flours reconstituted with lipids from the unbleached flour. The lipids were adsorbed on Celite and eluted after 0, 15, 30, 45, and 60 min at 100°C. The dotted line shows response from nondefatted bleached flour. The dashed line shows shrinkage after removal from the oven.

flour control cakes). Heating for longer periods resulted in diminished effects. These experiments were performed on bleached bases; therefore, cake volumes reflect expansions (Fig. 5). Optimal treatments of lipids from each of the three flours resulted in cakes that had greater volume than did the bleached-flour control cakes.

When lipids were heated for 45 min at 100°C (supported on Celite) and added to their unbleached bases, batters expanded in the oven but collapsed upon cooling (Figs. 6 and 7). Volume was retained, however, in cakes that were dropped immediately after removal from the oven (Ohtsubo et al 1978).

In studies in this laboratory on effects of bleaching levels, flour chlorination level has been observed to affect physical properties of the lipids, ie, with increasing chlorination levels, the lipids become increasingly viscous and tacky. Similar properties developed in supported lipids during heating. Slight changes were noted after 15 min at 100°C, but when heated for 30–45 min, the lipids became quite viscous and dissolved quite slowly in hexane. Lipids heated for 60 min were only partially soluble in hexane and left a gummy residue that was soluble in chloroform. Lipids heated on Celite also were bleached to some extent and after 60 min were generally comparable to lipids from chlorinated flours. Lipids heated for 60 min at 100°C without support did not exhibit obvious physical changes. Because of the limited solubility of heated lipids in hexane, lipids were added back to flours in chloroform (after we established that chloroform did not introduce solvent effects).

The temperature (100°C) employed in this study was arbitrary, and, in view of the effects of aging, lower temperatures would probably be effective with supported lipids. As in aging studies (Clements and Donelson 1982), flours appear to vary in sensitivity to treatment. Lipids from the commercial flour, for example, gave maximum response after 15 min at 100°C, whereas lipids from Beau and Tecumseh flours required 45 min. The latter flours were freshly milled, but the commercial flour had been stored (4°C) for about four years. Further studies will be required to determine effects of treatment time and temperature in relation to storage time and conditions.

Although the potential value of heat treatment for flour improvement has been recognized for several years (Doe and Russo 1968; Russo and Doe 1970a, 1970b), little is known regarding the mechanisms involved. In a recent study, Johnson and Hoseney (1980) concluded that such improvement effects were not from changes in the free lipids but were the result of changes in the starch. Moreover, because their results indicated that improvement was accelerated when the flour was defatted before heating, the authors suggest that the free lipid fraction contains components that inhibit the changes brought about by heating. Our study has shown that heat treatment of isolated free lipids alters the lipids in such a manner that they behave like lipids extracted from a chlorinated flour, ie, they induce batter expansion when added to unbleached flours. Further studies must determine whether lipids in situ undergo these same changes when flour is heated under conditions normally used for flour improvement. Our study has shown that, in the system employed, the native lipids must be modified for expansion to occur. However, expansion is only one component of the improvement process (Clements and Donelson 1982), and the starch (and/or some other nonlipid fraction) must also be modified if the volume generated by expansion is to be retained. In view of the total improvement reported in heat-treated flours, such treatments probably also affect the starch, thereby resulting in volume retention. As pointed out previously (Clements and Donelson 1982), a potential source of conflict in results noted in improvement studies may be the inadvertent use of control flours in which the lipids have already been modified (eg, through prolonged exposure to air). If such modification has occurred, the lipids may appear to be unaffected by treatment because they have already been "improved." Or, if the lipids are in a functional state, perhaps further treatment may result in reduced expansion. In a study of bleaching levels, Kissell et al (1979) demonstrated that reconstitution of flours with lipids from highly chlorinated flour gave cakes of lower volume than did lipids from flours chlorinated at lower levels. Similarly, our study suggests that maximum expansion results when lipids are heated for a limited period; further heating results in reduced expansion. Therefore, a treatment (ie, heat, chlorination, or exposure to air) may have positive or negative effects on expansion, depending on the state of the lipids before treatment.

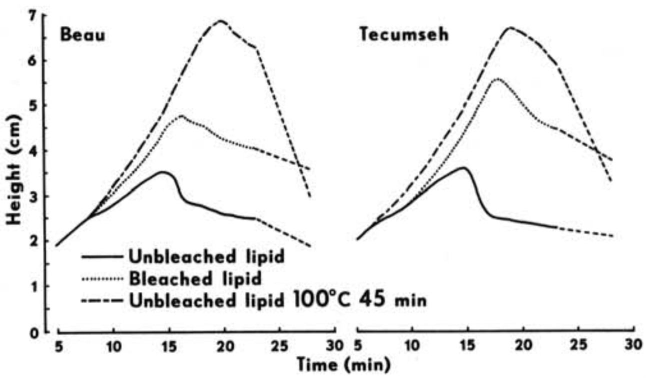

Fig. 6. Oven expansion in layer cakes baked from hexane-extracted unbleached Beau and Tecumseh 50% patent flours reconstituted with lipids extracted from the unbleached and bleached flours and with lipids from unbleached flour, adsorbed on Celite and eluted after 45 min at 100°C. The dashed line shows shrinkage after removal from the oven.

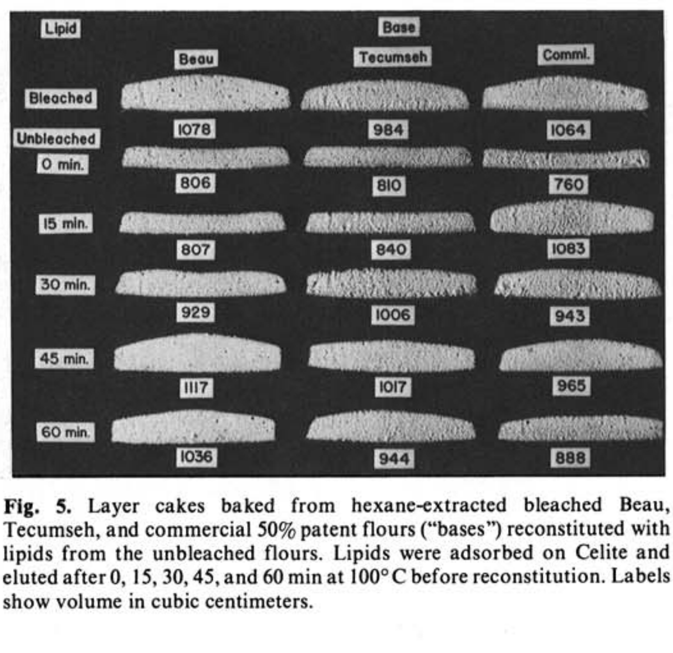

Fig. 5. Layer cakes baked from hexane-extracted bleached Beau, Tecumseh, and commercial 50% patent flours ("bases") reconstituted with lipids from the unbleached flours. Lipids were adsorbed on Celite and eluted after 0, 15, 30, 45, and 60 min at 100°C before reconstitution. Labels show volume in cubic centimeters.

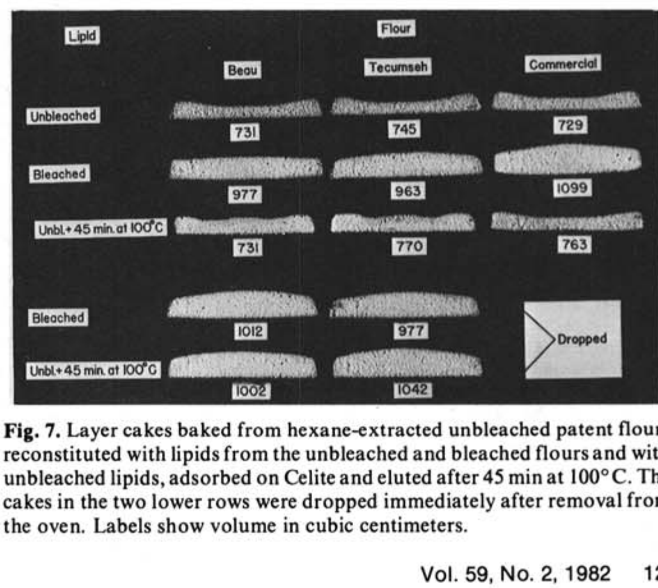

Fig. 7. Layer cakes baked from hexane-extracted unbleached patent flours reconstituted with lipids from the unbleached and bleached flours and with unbleached lipids, adsorbed on Celite and eluted after 45 min at 100°C. The cakes in the two lower rows were dropped immediately after removal from the oven. Labels show volume in cubic centimeters.

LITERATURE CITED

CLEMENTS, R. L., and DONELSON, J. R. 1981. Note on a simple device for monitoring batter expansion in layer cakes during baking. Cereal Chem. 58:153.

CLEMENTS, R. L., and DONELSON, J. R. 1982. Role of free flour lipids in oven expansion in layer cakes. I. Effects of aging. Cereal Chem. 59:121.

DOE, C. A. F., and RUSSO, J. V. B. 1968. Flour treatment process. British Patent 1,110,711.

HANAMOTO, M. M., and BEAN, M. M. 1978. Alternatives to chlorination for cake flours. Cereal Foods World 23:459. (Abstr.).

JOHNSON, A. C., and HOSENEY, R. C. 1980. Chlorine treatment of cake flours. IV. Effects of storing and heating nondefatted and defatted flours. Cereal Chem. 57:92.

KISSELL, L. T., DONELSON, J. R., and CLEMENTS, R. L. 1979. Functionality in white layer cake of lipids from untreated and chlorinated patent flours. I. Effects of free lipids. Cereal Chem. 56:11.

OHTSUBO, H., KANBE, T., KANEKO, Y., and NOMURA, S. 1978. Prevention of shrinkage after baking. Cereal Foods World 23:361.

RUSSO, J. V. B., and DOE, J. A. F. 1970a. Flour treatment process. U.S. Patent 3,490,917.

RUSSO, J. V. B., and DOE, J. A. F. 1970b. Heat treatment of flour as an alternative to chlorination. J. Food Technol. 5:363.

[Received October 27, 1980. Accepted September 14,1981]