EFFECTS OF INTERACTIONS AMONG FLOUR LIPIDS, OTHER FLOUR FRACTIONS, AND WATER ON COOKIE QUALITY[1]

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ABSTRACT

Soft wheat flour was fractionated into five components—free lipids, gluten, tailings, starch, and water solubles. Cookies baked from a blend of these fractions were identical to those baked from the parent flour. The good quality of cookies baked from blends of fractions indicated that a composite structure obtained by doughing fractions is not necessary for the production of normal cookies. The interaction of free lipids with tailings and water had an adverse effect on the internal structure of cookies, and this effect was intensified when gluten was added as an interactant. Inclusion of starch as a further interactant moderated the effect and also controlled the spread of cookies.

The effect of flour lipids on quality of test sugar-snap cookies was studied by Cole *et al.* (1) and by Kissell *et al.* (2). Both groups found that cookies baked from a flour previously extracted with a lipid solvent were of poorer quality than those from that flour plus the extracted lipids, or those from the parent flour. In neither study was a significant varietal or class difference found among the flour lipids tested. Moreover, the latter study showed that the mode of return of lipids did not affect their quality-restorative effect.

One of the problems in the fractionation and reconstitution studies of soft wheat flour has been to prepare (from fractions obtained with water as the only reagent) cookies identical with those from the parent flour. Yamazaki (3) found that such cookies had satisfactory spread but poor top grain. Using fractions from an acetic acid extraction procedure, Sollars (4) obtained cookies closely resembling those from the parent flour. In both these endeavors, reconstitution to a "flour" by doughing, drying, and grinding was found to be vital.

We report herein results of studies on interactions among flour fractions, flour lipids, and water as they affect cookie quality. As part of this study, we developed a flour fractionation procedure using only water and hexane as reagents, which enabled the direct use of the fractions—without their reconstitution into a "flour"—for the preparation of cookies practically identical with those made from the parent flour. The key to this procedure was the extraction of free lipids from flour prior to fractionation.

MATERIALS AND METHODS

The Flour

A soft wheat flour (protein content 10.4% on 14% mb), a blend of various laboratory-milled, straight-grade, untreated flours of satisfactory cookie quality, was used.

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Lipid Extraction

Untreated flour (3000 g) was extracted in a laboratory all-glass Soxhlet-type extraction apparatus with hexane. The extract was concentrated in the same apparatus, filtered, and diluted to desired volume with hexane. Extracted lipids were determined gravimetrically after evaporation of an aliquot and drying of the residue for 1 hr at 100° C (in our work, 1.0 ml of solution contained lipids from 1.6 g flour).

Flour Fractionation

Parent or extracted flour (500 g) and distilled water (1000 ml) were mixed at low speed for 3 min in a paddle-type mixer. The slurry was centrifuged for 15 min at 1000 $\times$ g, and the supernatant, which contained the water solubles, was lyophilized. The sedimented dough was mixed with 700 ml distilled water in a blender at high speed for 1 min, then centrifuged as above. The supernatant was decanted, and each of the three sedimented layers—the top starch tailings, middle gluten, and bottom prime starch—was separated mechanically. The gluten was washed with the supernatant, kneaded for removal of starch and tailings, chilled, and lyophilized. The wash water was centrifuged and the supernatant discarded. The tailings, starch, and wash-water centrifugate were combined, slurried with distilled water, and centrifuged. The supernatant was discarded, and the top tailings and bottom prime starch were separated. The starch was then air-dried. The tailings were resuspended in distilled water, shelled, and lyophilized. The dried fractions were ground at a moderately fine setting of a grinder. Too close a setting would damage the fractions and could thus reduce cookie baking performance.

Fraction Blending

The fractions were blended, in proportion to their recovery yields, into 50-g lots at 14% moisture content. If the moisture content was low, the blend was rehydrated to 12 to 13% moisture. Lipids were added to fractions or blends as required by contact wetting with an appropriate volume of lipid solution and evaporation of the solvent in an air stream.

Preliminary Baking Trials with Defatted Flour and Defatted Fractions

To link a previous study (2) with ours, we prepared cookies from parent flour, the blended fractions of parent flour with and without extra lipids, defatted flour, and the latter plus extracted lipids. Further, to illustrate the effect of the interactions between flour and water on cookie quality, we prepared cookies from parent flour that was wetted, dried, and ground, and with free flour lipids equal in quantity to that normally extracted added after the flour was ground.

Cookies were also baked from a dry blend of fractions from defatted flour with and without lipids, from fractions which had been doughed together before lipids were restored, and from fractions to which lipids had been restored before doughing. Thus, we were able to study the interactions among the four flour fractions, water, and lipids.

Fraction Interaction with Lipids and Water

For study of a single component interaction, the quantity of gluten, prime starch, or tailings normally present in 50 g of blend was wetted with a hexane solution containing flour lipids normally extracted from 50 g of flour. The solvent was evaporated, the lipid-treated fraction hand-mixed with enough water to form a cohesive mass, and further mixed on a small pin-type mixer for 2 min. The product was then dried and ground. Quantities of the other three fractions in recovered proportions were then added, the blend was rehydrated to about 13% moisture, and cookies were baked therefrom.

Controls for this test were prepared in the same manner, except that each fraction was first mixed with water only, and the lipids were added to the dried and ground dough.

For study of the two- and three-component interactions, the same procedure as above was followed, except that two or three of the four fractions were used for both the control and lipid-interaction doughings. In this manner, six two-component and four three-component combinations were interacted.

Cookie Baking

All cookies were baked according to the Micro Method III procedure of Finney *et al.* (5) and were evaluated on spread or diameter, top grain, and internal appearance. Thus, three scores were used to characterize the products in Figs. 1–7. The first score shown is the sum of diameters of two cookies (in cm). The second is the top grain score, which ranged from 9 for a well-broken grain, which is considered desirable, to 0 for a bald surface. The third score is for the

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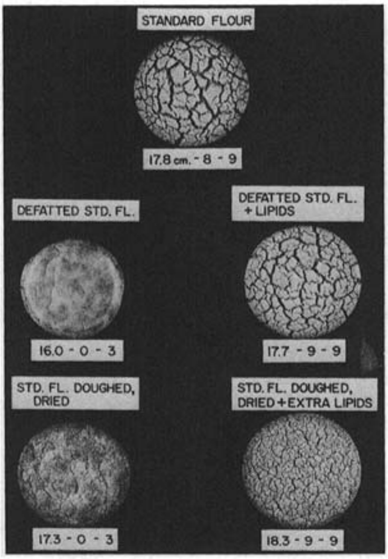

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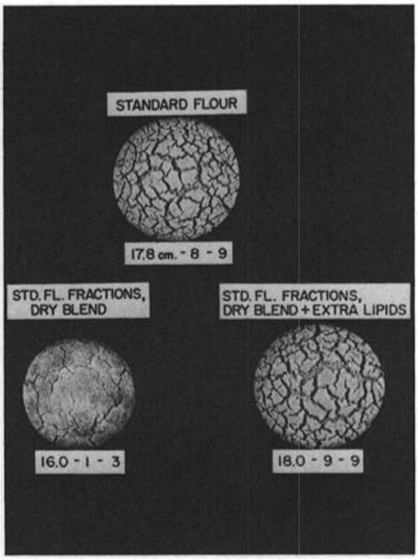

Fig. 1. Cookies from parent soft wheat flour (top), from defatted residue of the flour (2nd row left), from same after lipid restoration (2nd row right), from parent flour doughed, dried, and ground (3rd row left), and from same with additional lipids (3rd row right).
Fig. 2. Cookies from parent flour (top), from a blend of fractions obtained from the parent flour (bottom left), and from the same blend to which extra lipids had been added (bottom right).

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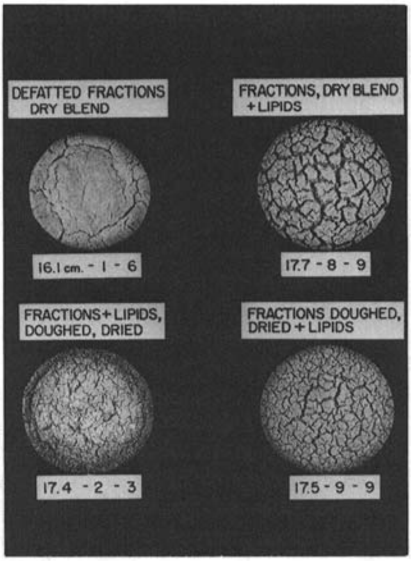

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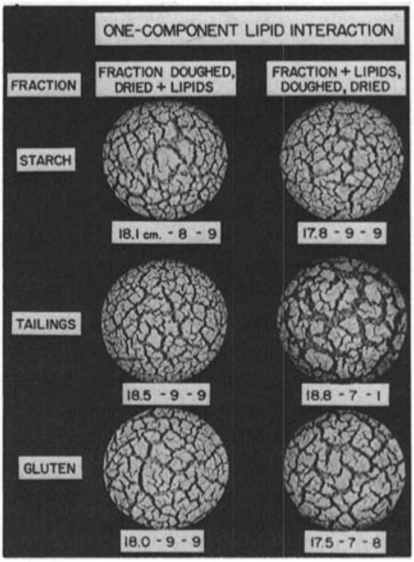

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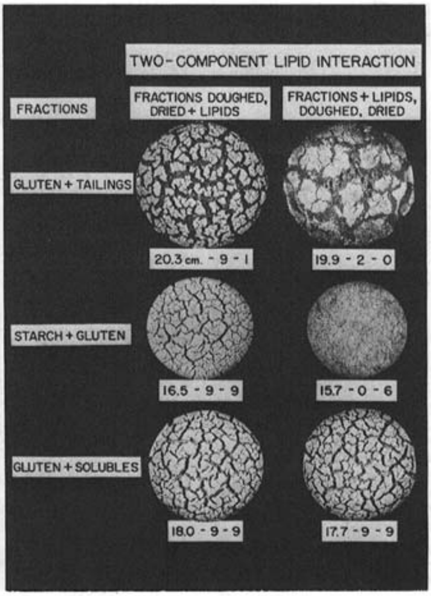

Fig. 3. Cookies from dry blend of fractions obtained from defatted flour (top left), from same with lipids restored (top right), from fractions doughed with lipids, dried, and ground (bottom left), and from fractions doughed, dried, ground, and lipids restored (bottom right). Fig. 4. Cookies from one-component doughing without lipids (component-water interaction) (left column) and with lipids (component-water-lipids interaction) (right column). Fig. 5. Cookies from two-component doughing without lipids (left column) and with lipids (right column).

internal appearance, and ranged from 9 for a light-colored, well-layered crumb, through 6 for one which was somewhat dark and greasy, through 3 for one with large, coalesced gas pockets, and walls which were dark and greasy, to 0 for one which appeared to consist only of top and bottom surfaces, and was dark and greasy in appearance. Top grain and internal appearance scores were subjective but were useful as proximate indexes.

All cookie data are means of at least two distinct flour or fraction treatments or recombinations. Least significant difference in diameter at the 5% level of probability was 0.28 cm.

RESULTS AND DISCUSSION

The importance of free flour lipids in quality of sugar-snap cookies has been reported (2) and was confirmed in our study (Fig. 1, top two rows). Wetting of flour is known to cause lipid binding (6). Thus, cookies baked from flour that was wetted, dried, then ground were of poor quality (Fig. 1, bottom left). However, cookies were of good quality if baked from that flour with extra free flour lipids added after the flour was ground (Fig. 1, bottom right).

Flour wetting is an integral part of our fractionation procedure. The blend of fractions from parent flour did not produce normal cookies (Fig. 2, bottom left). But when extra flour lipids were added to the dry blend, cookies comparable to those from the parent flour were obtained (Fig. 2, bottom right).

For some tests, we prevented the interaction between free flour lipids and other

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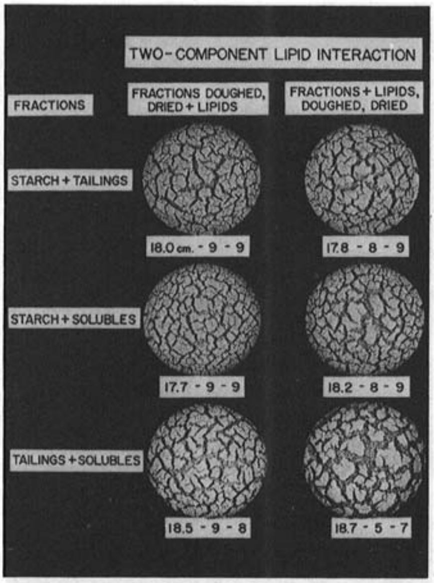

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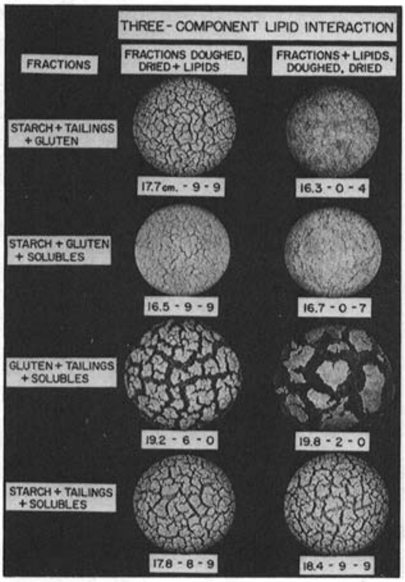

Fig. 6. Cookies from two-component doughing without lipids (left column) and with lipids (right column). Fig. 7. Cookies from three-component doughing without lipids (left column) and with lipids (right column).

components in the wet state by removing the free lipids before fractionating the flour. A blend of fractions from defatted flour (without lipids) did not bake into normal cookies (Fig. 3, top left), but the same blend to which lipids had been restored produced cookies (Fig. 3, top right) identical in all respects to those from the parent flour (Fig. 1, top). When lipids were added to the doughed blend of fractions from defatted flour and the product baked into cookies, their top grain and internal structure were good (Fig. 3, bottom right). However, if the lipid restoration was made prior to doughing, the cookies were poor (Fig. 3, bottom left). This is the four component-lipid-water interaction which is referred to later in the paper.

Apparently, the relation between dry fractions and lipids could be reestablished by addition of the latter to the fractions. By doughing various combinations of fractions, we could selectively induce interactions between lipids and other fractions with water. Thus, we were able to determine a) the fraction or fractions with which lipids and water interacted to alter the structural integrity and/or size of cookies, b) the extent of this interaction, and c) the functionality of the several flour components with respect to cookie diameter and structure.

Single Component-Lipid Interactions

Interactions of gluten or starch, singly, with lipids and water were such that the cookies produced closely resembled those from the parent flour (Fig. 4, top and bottom right). These results indicated that at least some of the free lipids involved in the doughing did not bind with either the starch or gluten, but remained free. The normal appearance of the product from the gluten-lipid-water interaction was unexpected in view of some past suggestions that a lipoprotein complex may result from flour doughing (6). Cookies made from a blend containing rewetted, dried, and ground tailings had normal internal structure but were significantly larger than those of the parent flour (Fig. 4, middle left). These treatments apparently changed the fraction slightly—perhaps decreased its hydrophilicity (3). Some instability in the fraction is thus implied. Cookies made from blends containing tailings doughed with lipids before drying and grinding had almost no internal structure (Fig. 4, middle right).

Two Component-Lipid Interactions

Even without the involvement of flour lipids, the doughing of gluten plus tailings and of gluten plus starch showed contrasting effects on cookies (Fig. 5, top and middle left). The former produced large cookies with poor internal structure, whereas the latter yielded small cookies with excellent internal qualities. In the preparation of cookie doughs, these blends also showed contrasting properties. Considerably less water than normally used was needed for the blend with gluten-tailings interaction, whereas much more water than normally used was needed for the blend with gluten-starch interaction.

The inclusion of lipids in the respective interactions (Fig. 5, top and middle right) appeared to enhance the trends already shown: for the gluten-tailings interaction, a complete loss of internal structure; for the gluten-starch interaction, a further decrease in cookie size but with the retention of considerable internal structure.

Cookies made from a blend having starch or gluten interaction with water solubles were similar to those from the corresponding blends having the one-component interaction of starch or gluten whether with or without lipids. These results suggest that the water solubles fraction is not a major determinant in cookie diameter or top grain properties (compare Fig. 5, bottom row, and Fig. 6, middle row, with Fig. 4, bottom and top rows, respectively). The solubles, however, appeared to interact with tailings and lipids to prevent deterioration of internal structure (compare Fig. 6, bottom row, with Fig. 4, middle row).

Three Component-Lipid Interactions

Of the four systems, the three that included the water solubles were like the corresponding two-component systems without the water solubles in regard to cookie quality (compare Fig. 7, second, third, and fourth rows, respectively, with Fig. 5, second and top rows, and Fig. 6, top row). Hence, the effect of the solubles appeared to be minor in the three-component systems also.

When gluten, starch, and tailings were doughed without lipids and baked, the product (Fig. 7, top left) resembled closely that resulting from the four-component doughing (Fig. 3, bottom right). Here again, the water solubles appeared to have little effect on cookie characteristics. When lipids were interacted with the three insoluble fractions and water, the baked product was small and of inferior internal structure (Fig. 7, top right). But the structure was not as poor as that of the product with the gluten-tailings-solubles-lipid interaction (Fig. 7, third row right). Reduced internal structural quality may be attributed to the interaction between tailings and lipids, with considerable involvement of gluten as seen in a previous photograph (Fig. 5, top right). The starch fraction apparently moderated both spread and structure when it participated with gluten, tailings, and lipids (Fig. 7, top right, compared with Fig. 5, top right), as it did with tailings and lipids only (Fig. 6, top right, compared with Fig. 4, middle right).

In all of these interactions, the roles of the variable quantities of the fractions—and therefore the ratios of quantities—may have been important. Thus, tailings, which appeared to be important, comprised only 9.2% of the blend, whereas starch comprised 74.5%. This and similar disparities in fraction proportions may have affected the mixing action during doughing, and influenced cookie size and structure.

Cookies baked from extracted flour to which lipids had been restored were of good quality. The organization of flour components (that is, the relations among gluten, starch, tailings, and solubles) had apparently not been disturbed; hence, normal cookies would be expected if lipid surface activity were the only consideration. However, we also obtained good cookies from a dry blend of fractions plus lipids. The organization of flour components had been completely disrupted. The short mixing time for a cookie dough, the severely limited water available in a cookie dough, and the presence of shortening and sugar in relatively large quantities would appear to inhibit the restoration of the component relationship originally present in the flour. The flour components contributing to normal cookie structure thus apparently functioned whether or not a pre-organized flour structure was present. Bernardin and Kasarda (7) showed that when flour particles are wetted, the protein immediately sends out fibrils which have cohesive and adhesive properties. Starch (and presumably other solid components as well) will adhere, and fibrils may join to form a network. If this action could take place among isolated gluten fractions in a sugar solution (and some preliminary work shows this to be possible), then gluten perhaps could form a network that gives structure to cookies. Such a possibility may explain why both unfractionated flour and fractionated components can form a good cookie structure under appropriate conditions.

The formation of normal cookies from a dry blend of fractions may result, in part, from the effect of the lipids on all the components, not only on the dry fraction to which they were applied. Kissell *et al.* (2) showed that normal cookies could be produced whether the lipids were added to the shortening phase of the cookie mix or added directly to the extracted flour. Thus, lipids added to the dried fractions appear to be taken up by the shortening in the cookie dough during the mixing stage and redistributed so that the functionality of the lipids as surfactant would be extended to all the fractions.

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