The Use of Some Oilseed Flours in Bread

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ABSTRACT

The effects of adding oilseed flours such as cottonseed, peanut, safflower seed, and soy on doughs and breads were investigated. Readings on the farinograph, extensigraph, amylograph, and various histological staining techniques were used as indices of performance of oilseed flours with wheat flour. Breads made with the customary straight-dough method had poor loaf volume at the 25% level of replacement of wheat flour. Changes in the formulation or the mixing time of doughs, or both, usually improved the volume of breads made at this replacement level. Oilseed flours increased absorption and usually decreased mixing tolerance of doughs concomitantly with increases in replacement level of wheat flour. Some soy flours, however, increased mixing tolerance of doughs. Strongest to weakest doughs at the 25% replacement level were safflower seed, glanded cottonseed, peanut flour from roasted peanuts, glandless cottonseed, and peanut flour from raw peanuts.

Much research has been devoted to developing oilseed flours for human consumption in order to effectively upgrade the nutritive well-being of people around the world (1). Oilseed flours have acceptable flavor and are relatively free of toxic materials. Fundamental research on developing basic principles for the optimum use of oilseed products in combination with cereal products, however, has not been undertaken. This information is vitally needed for scientists such as nutritionists, cereal chemists, oil chemists, and food scientists to improve protein nutrition.

Research was conducted in the Human Nutrition Research Division, U.S. Department of Agriculture, Beltsville, Maryland, to develop principles for incorporating optimum amounts of these high-protein oilseed flours and concentrates in breads. Physical, chemical, and histochemical techniques were used to evaluate and compare performance of cottonseed, peanut, safflower seed, and soy flours.

It is well known that oilseed flours change the properties of absorption, mixing tolerance, and other physical properties of doughs (2,3,4,5,6). Only small amounts (5 or 8%) of flour (7) or isolate (8) were satisfactory and gave good volume in the finished breads. Higher amounts of oilseed flour in the dough system caused markedly reduced loaf volume, which was the main reason for poor acceptability of breads made with higher levels of replacement. Some previous work in the Division[2] showed that up to 20% replacement of the wheat flour could be used in breads mixed by hand methods.

MATERIALS AND METHODS

The oilseed flours investigated included cottonseed, both glanded and glandless, peanut from raw and from roasted peanuts, safflower seed, and full-fat soy of the

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TABLE I. NITROGEN AND LIPID VALUES OF OILSEED FLOURS

Oilseed Flour	Nitrogen %	Lipid %
Cottonseed, glanded liquid-cyclone	10.7	0.64
Cottonseed, glandless	9.5	1.42
Peanut (raw)	9.3	0.20
Safflower seed	11.8	0.62
Soy, full-fat	6.8	24.40

village (9) and extrusion processes (10). The cottonseed flours and one sample of peanut flour were obtained from the Southern Utilization Research and Development Division; the other sample of peanut flour from raw peanuts and a sample from roasted peanuts were obtained from a commercial source; the safflower seed flour was from the Western Utilization Research and Development Division; and the soy flours came from the Northern Utilization Research and Development Division. Except for the full-fat soy flours, all oilseed flours were very low in fat by hexane extraction. Nitrogen and lipid values for these flours are given in Table I.

Research on dough-making properties was carried out with specialized instruments of the cereal laboratory including the farinograph and extensigraph according to methods of the AACC (11). The heating-holding-cooling method for starch slurries was used for measuring stability of oilseed-wheat flour suspensions (12,13). Histochemical studies were made with 10-μ cryostat sections of doughs. Sections were fixed in formalin vapor overnight and stained with safranin and fast green. Unfixed cryostat sections were heated on the microscope stage, and extent of gelatinization of starch granules at various temperatures was observed under polarized light.

Preparation of samples was in a laboratory with a controlled temperature of 24°C. and a relative humidity of 60%. Doughs were mixed in a Hobart mixer (Model C-100). Straight doughs were mixed for 3.5 min. at 144 r.p.m., fermented for 90 min., moulded by mechanical methods, and proofed for 60 to 70 min. Soft doughs were mixed for 2 min. at 258 r.p.m. with all ingredients except half of the flour; after the remaining flour was added the doughs were mixed for 1.5 min. at 144 r.p.m. After being fermented for 30 min., soft doughs were stirred down, weighed into the pans, and patted into a flat surface before proofing for about 60 min. Fermentation and proofing were at 30°C. and 85% r.h. Breads were baked in a rotary-hearth experimental baking oven at 375°F. for 40 min.

Formula

Ingredient	*Percent (See Note 1)*
Flour (wheat and oilseed) (see Note 2)	
Fat (hydrogenated)	7
Sugar (sucrose)	7
Salt (NaCl)	2
Yeast (active dry)	2
Water (distilled) (see Note 3)	variable

Note 1. Percent based on total weight of flours.

Note 2. A total weight of 0.75 kg. flour used in all samples; 3.60 kg. flour used when selected lots of glanded cottonseed, peanut, or soy flours were in ample supply.

Note 3. For straight doughs. the amount of water used was determined by farinograph absorption; for soft doughs, an additional amount of 20% was added (based on weight of flour).

RESULTS AND DISCUSSION

Typical farinograms when 11% protein, family-type flour (the control) was used as well as when some oilseed flours were used at the 25% level of replacement are shown in Fig. 1. Absorption rate for the control was 58.5% (Table II). For oilseed flours at the 25% level of replacement, absorption was higher (range 61.6 to 68.4%) than for wheat flour alone. The mixing tolerance of the oilseed flour doughs was usually less than for the wheat flour alone. The 80-mesh soy flours increased mixing tolerance of doughs slightly, however. In general, the soy, safflower seed, roasted peanut, and glanded cottonseed doughs were stronger than the raw peanut or glandless cottonseed flour doughs.

The shorter mixing tolerance values of the oilseed doughs indicate that several

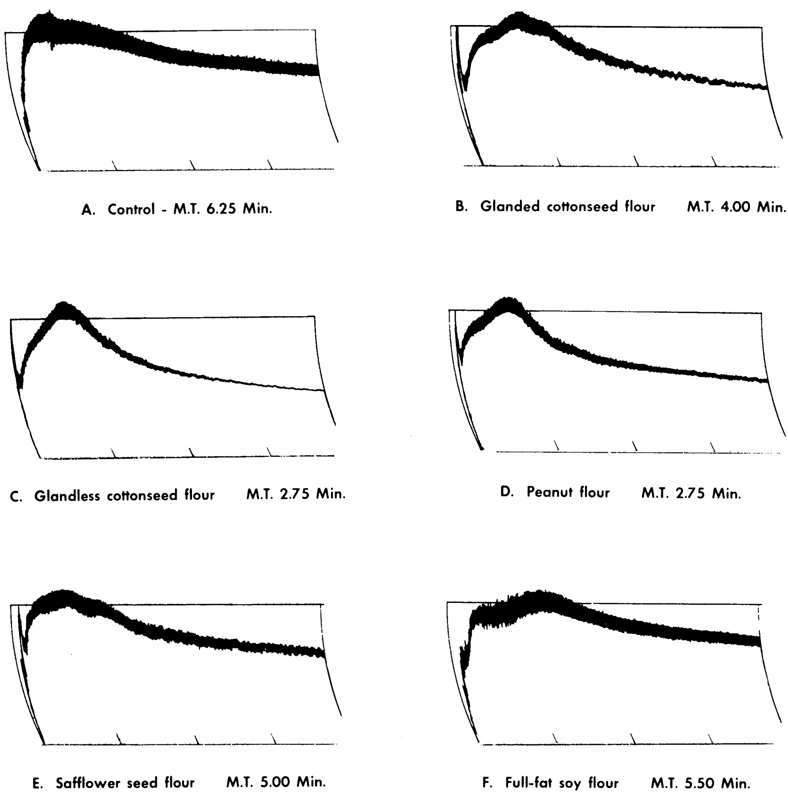


Fig. 1. Farinograms of some oilseed flours at the 25% level of replacement of wheat flour.

TABLE II. DOUGH PROPERTIES OF OILSEED FLOURS IN COMBINATION WITH WHEAT FLOUR (25% LEVEL OF REPLACEMENT)

Oilseed Flour	Absorption %	Mixing Tolerance min.	Mixing Peak min.	20-min. Drop B.U.
Cottonseed, glanded	63.2	4.00	4.25	210
Cottonseed, glandless	65.0	2.75	3.75	260
Peanut, raw, SURDD	63.2	2.75	3.75	230
Peanut, raw, commercial	61.6	1.50	4.25	200
Peanut, roasted, commercial	63.6	4.50	3.25	135
Safflower seed	64.6	5.25	3.25	160
Soy (full-fat), Village process				
100-mesh	68.4	5.50	5.25	130
80-mesh	69.3	7.00	5.00	120
Soy (full-fat), Extrusion Process				
100-mesh	63.4	4.00	6.25	130
80-mesh	63.8	6.50	7.00	80
Wheat, control	58.5	6.25	2.75	140

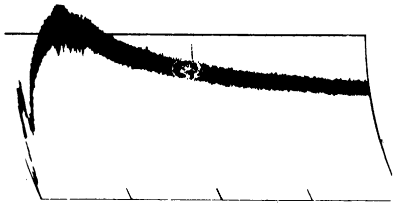
modifications in preparation must be made to compensate for this weakness. Doughs must be made more fluid and extensible for holding the gas bubbles produced during fermentation. Less severe or shorter mixing times must be adopted to minimize damage to the gluten structure. Both steps can prevent excessive stretching and tearing of the gluten.

Oilseed flour breads prepared by the straight-dough method were low in volume (Table III). Marked increases in loaf volume (between 11 and 33%) were usually evident when the soft-dough method was used. The 80-mesh soy flours of the village and extrusion processes showed minor decreases in volume when doughs were made softer. These soy doughs of longer mixing tolerance did not benefit by being made more fluid. Variation in granulation size of oilseed flours other than soy was not studied.

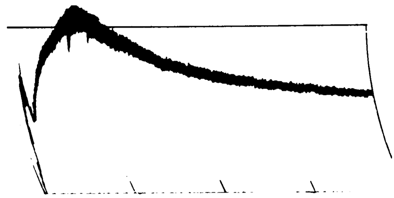
Effects of increasing the level of replacement of wheat flour on farinograms can be seen in Fig. 2. For glandless cottonseed flours, dough breakdown was most rapid at the 35% level of replacement as shown by the mixing tolerance of 2.25 min., compared to 4.00 min. at the 5% level of replacement. From 5 to 35% replacement,

TABLE III. LOAF VOLUME OF OILSEED BREADS (25% LEVEL OF REPLACEMENT OF WHEAT FLOUR)

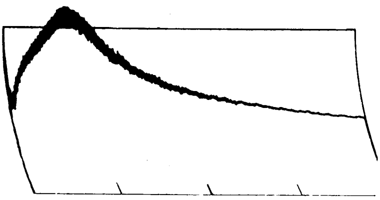
Oilseed Flour	Straight-Dough ml.	Soft-Dough ml.	Increase %
Cottonseed, glanded	1,482	1,875	26
Cottonseed, glandless	<1,400	1,825	33
Peanut, raw, SURDD	1,594	1,894	19
Peanut, raw, commercial	1,576	1,750	11
Peanut, roasted	1,725	2,065	18
Safflower seed	<1,400	1,750	30
Soy (full-fat), Village process			
100-mesh	1,538	1,788	16
80-mesh	1,756	1,738	−1
Soy (full-fat), Extrusion process			
100-mesh	1,474	1,720	17
80-mesh	1,644	1,607	−2
Wheat, control	1,925	1,950	1



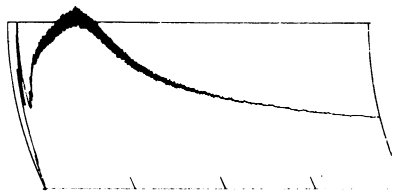
A. 5% - M.T. 4.00 Min.



B. 15% - M.T. 3.00 Min.



C. 25% - M.T. 2.75 Min.



D. 35% - M.T. 2.25 Min.

Fig. 2. Farinograms of wheat flour replaced with various levels of glandless cottonseed flour.

absorption increased from approximately 60 to more than 65%. The narrow farinograph band width at the higher levels of replacement shows poor dough stability.

Dough extensibility decreased when wheat flour was replaced with oilseed flour. The family-type flour control of 11% protein content gave dough extensibility values of 87 to 89 sq. cm. between 45 and 135 min. after mixing. In contrast, 100-mesh soy flour at the 25% level of replacement gave energy values ranging from 32 to 34 sq. cm. at the same time intervals. Extensibility measurements on other oilseed flour doughs should be continued. Procedures for measuring extensibility should be modified to accommodate doughs of all consistencies.

The amylograph viscosity of suspensions at the 25% replacement level varied dramatically among the oilseeds when suspensions were held for 1 hr. at 95°C., cooled to 50°C., and held for 1 hr. at 50°C. The temperature of initial swelling was raised from 1° to 5°C. because of the presence of oilseed flour at the 25% level of replacement (Table IV). Highest temperature for peak viscosity was that for the glanded cottonseed flour mixture, 76°C. compared to 71° to 73°C. for the others. Safflower seed flour suspensions were most stable to holding at 95°C. for 1 hr.

Cooling and holding the suspensions at 50°C. produced some marked differences among the oilseed flours. The safflower seed mixture was the most viscous, followed by the raw peanut, glanded cottonseed, and the 80-mesh extrusion-processed soy flour mixtures. Why this one sample of soy flour stood out from the others cannot be explained. Results of the heating-holding-cooling cycle on suspension viscosity may relate to the possible changes that can be made to offset weakening ability of oilseed flours in doughs. In the presence of an ample amount of water for gelatinization of starch, dough-baking performance of oilseed

TABLE IV. AMYLOGRAPH-STABILITY OF OILSEED FLOUR SUSPENSIONS (25% LEVEL OF REPLACEMENT OF WHEAT FLOUR)

		Peak		Viscosity		
Oilseed Flour	Initial Swelling Temperature °C.	Temperature °C.	Viscosity B.U.	1 hr. at 95°C. B.U.	Cooled to 50°C. B.U.	1 hr. Holding at 50°C. B.U.
Cottonseed, glanded	59	76	355	100	340	415
Cottonseed, glandless	59	72	370	75	250	270
Peanut, raw, SURDD	59	73	375	85	440	650
Peanut, raw, commercial	58	73	425	90	420	650
Peanut, roasted	59	72	390	55	290	450
Safflower seed	60	73	405	220	730	905
Soy (full-fat)						
Village process						
100-mesh	60	71	390	50	200	290
80-mesh	62	71	330	45	170	270
Extrusion process						
100-mesh	60	71	375	40	185	325
80-mesh	60	71	420	60	325	640
Wheat, control	57	68	740	35	270	380

flours can be simulated. Higher temperatures for initial swelling or for peak viscosity may be reflected in bread-baking performance. Modifications in baking technique may also improve bread volume. Variations in viscosity during prolonged heating can reflect enzyme activity and starch properties of the various oilseeds in combination with wheat flour.

Microscopic examination of unstained doughs revealed variation in distribution of starch granules. High concentration of starch granules in straight dough, as shown in Fig. 3, can prevent maximum gelatinization owing to limited water availability. In contrast, Fig. 4 shows a better distribution of starch granules in soft

Fig. 3. Birefringent starch granules in straight doughs (polarized light, 250X).

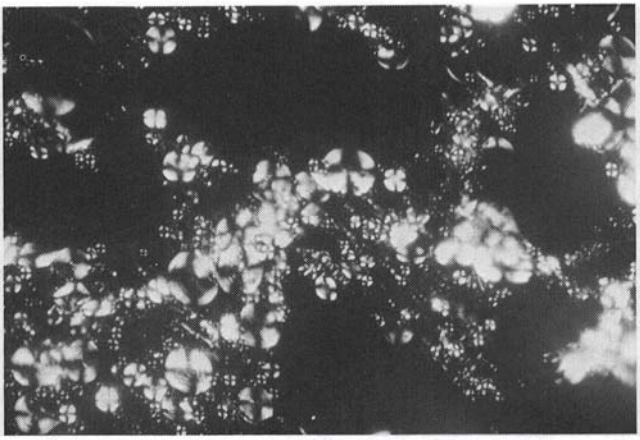


Fig. 4. Birefringent starch granules in soft doughs (polarized light, 250X).

doughs which can allow maximum gelatinization and swelling. Greater availability of water for gelatinization of the starch granules in soft doughs may account for the increased volume of these breads. In Fig. 5, the structural distribution of carbohydrate and protein components can be seen in straight doughs made with soy and wheat flour. The dense network of dark-stained carbohydrate and light-stained protein structure is obvious. In Fig. 6, the discontinuous network of soy-wheat mixtures when used in soft doughs can be observed. The temperatures at which these structural networks form the texture of bread can be recorded. The formation of the textural network can also be observed.

On the basis of this research, some principles can be established for the use of oilseed flours in combination with wheat flour.

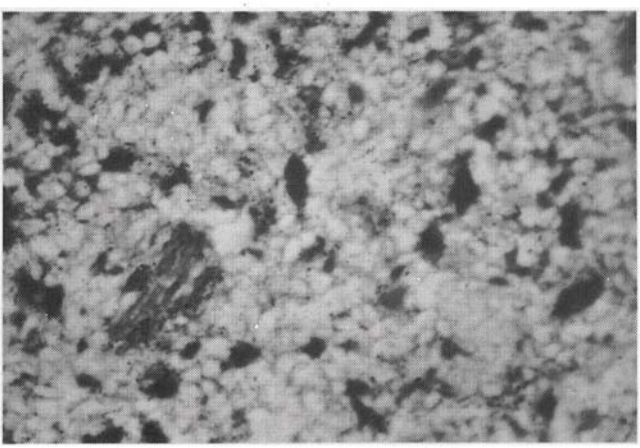


Fig. 5. Distribution of carbohydrate (dark-staining) and protein (light-staining) components in straight doughs made with soy and wheat flours. Note tight network.

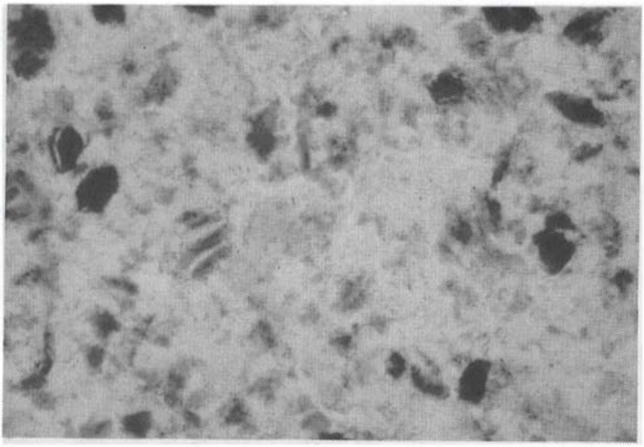


Fig. 6. Distribution of carbohydrate (dark-staining) and protein (light-staining) components in soft doughs made with soy and wheat flours. Note discontinuous network.

Uniform blending of oilseed flour with wheat flour is essential for minimum mixing time and uniform quality of doughs.

More liquid in doughs than called for in the farinograph test prevents stretching and tearing of gluten strands and provides more water for gelatinization of starch granules in the doughs during baking.

Heat-treatment in processing may drastically affect dough-making properties of oilseed flours; e.g., the roasting of peanuts before preparation of the flours dramatically improves the breadmaking quality of peanut flour.

In replacing wheat flour with oilseed flour at high levels (25% or more), changes must be made in one or more of the following: decreasing time or speed of mixing; decreasing consistency of doughs; decreasing fermentation and proofing times; and increasing levels of ingredients such as yeast or fat.

Research needs to be conducted to determine the maximum amount of the various oilseed flours that can be used to meet consumer acceptance standards. New consistency standards for the farinograph and extensigraph are needed. Information on the kinds and amounts of carbohydrate in oilseed flours should be obtained and related to performance of oilseed flours at various levels. Particular attention should be given to the amino acid balance of the different oilseed flours. Ways to improve the protein quality as well as protein content of oilseed breads should be investigated.

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