DEVELOPMENT OF A YEAST-LEAVENED RICE-BREAD FORMULA[1]

K. D. NISHITA, R. L. ROBERTS, and M. M. BEAN, Western Regional Research Laboratory, Agricultural Research Service, U.S. Department of Agriculture, Berkeley, CA 94710; and B. M. KENNEDY, Department of Nutritional Sciences, University of California, Berkeley 94720

Cereal Chemistry 53(5): 626-635

ABSTRACT

Development of a rice-flour bread formulation was undertaken to provide a product for those allergic to wheat (coeliac disease), and for patients on low-protein and low-sodium diets. Certain hydroxypropylmethylcelluloses were the only useful gum-type additives capable of providing doughs with the viscosity necessary to trap fermentation gases, and with the "water-release" effect necessary for starch gelatinization during baking to develop a rigid, yet porous cell structure and good loaf volume. Plastic fats and surfactants, which normally improve wheat bread, had the opposite effect in rice breads. Refined vegetable oils produced satisfactory volumes, grain, and texture. Initial taste panel evaluations showed that less than half the judges liked the bread. However, when it was identified as rice bread, more than half (19 out of 31) of the taste panel members gave a score of 5 or higher on a hedonic scale of 9.

The need for nongluten, low-sodium, or low-protein breads could be partially met if some means could be found to use rice flour in yeast-leavened breads. Rice

[1]Work done in partial fulfillment for an M.S. degree from the University of California, Berkeley, 1973, by K. D. Nishita.

Reference to a company or product name does not imply approval or recommendation of the product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

has properties, such as the absence of gluten, low levels of sodium, protein, fat, and fiber, and a high amount of easily digested carbohydrates, which are desirable for certain special diets. Patients with wheat or gluten allergies, hypertension, nephritis, or digestive difficulties could benefit if good-quality rice bread were made available, especially since it would provide another choice in their diets. A literature search failed to locate any formulas for yeast-leavened rice breads, although recipes for rice breads using chemical leavening agents can be found (1–3). Commercially prepared frozen rice breads, as well as a rice-bread mix, can be obtained from some food outlets. However, none of these products resemble typical wheat breads in the grain and texture characteristics preferred by most people.

The problems associated with rice-bread formulation are due mainly to the absence of gluten; thus, they are similar to those encountered in starch bread formulation. It has been demonstrated that bread-like products could be made with certain pure starches if a gum, such as locust bean (4), or a surfactant, such as glyceryl monostearate (GMS) (5,6), were used. By adapting the basic concepts developed in these studies, several investigators have prepared special dietary breads from starches. For example, McGreer (7) designed a gluten-free product from wheat and potato starches for coeliac patients. Smith (8,9) and Sorensen (10) used wheat starch in breads for uremic and phenylketonuric patients. Christiansen *et al.* (11) developed a protein-fortified wheat- or corn-starch bread, containing xanthan gum, that they claim resembled regular bread. A formula for a low-protein wheat-starch bread was reported by Steele *et al.* (12), and other formulas containing higher levels of protein were described by Kulp *et al.* (13). In all of these formulations, some form of gluten substitute, such as carboxymethylcellulose (CMC), guar gum, methylcellulose, or xanthan gum, was used. Smith's (8,9) formula also included GMS.

Breads have been made from nongluten flours, such as sorghum or barley flours (14), or composite flours consisting of starchy tubers, expressed oilseeds, and nonwheat cereals (15,16). Ingredients for products containing 100% starch, nongluten, or composite flours must be mixed as a batter and poured directly into the baking pan instead of developed into a dough which is kneaded and molded. The volume and crumb texture of such baked products more closely resemble those of muffins or corn bread than those of yeasted breads.

In spite of these difficulties, if bread-type products can be made with starches and composite flours, none of which contain gluten, it should also be possible to convert rice flour into a bread. Such a conversion would benefit certain patients, described earlier, and would provide another use for rice. This paper describes the development of a yeast-leavened rice-bread formula by modifying a typical wheat-bread formula. Rice flour was substituted for all of the wheat flour.

MATERIALS AND METHODS

Materials

Heron Brand rice flour (100 lb), milled from a blend of short- and medium-grain rice, was obtained from the C. E. Grosjean Rice Milling Co., San Francisco, Calif., and stored in airtight containers at −10° F until needed. The proximate composition of the flour is shown in Table I.

The gums studied included hydroxypropylmethylcellulose obtained from

Dow Chemical Co.,[2] Midland, Mich.; locust bean and guar from Stein-Hall; sodium carboxymethylcellulose from Hercules, Inc.; carrageenan from Kraftco, Inc.; and xanthan gum from Kelco Co. Baker's compressed yeast was obtained fresh from a local commercial source. Dough conditioners tested at 0.50% (of flour) included sodium stearoyl-2-lactylate (SSL) and calcium stearoyl-2-lactylate (CSL) from C. J. Patterson Co., succinylated monoglycerides (SMG) from Eastman Chemical Products, Inc., ethoxylated monoglycerides (EMG) from Ashland Chemical Co., and mono- and diglycerides from SCM Corp.

Methods

Particle size of the rice flour (Table I) was determined by shaking 200 g flour through 100-, 140-, and 200-mesh (U.S. Standard Sieve Series) screens on a Ro-Tap Testing Sieve Shaker for 10 min. Pasting temperature was determined by the method of Halick and Kelly (17). This defines the temperature at which a concentrated slurry (100 g rice flour to 400 ml water) shows an initial viscosity increase when heated in an amylograph.

Variables tested during development of the optimum formula included types and levels of methylcellulose and other gums, variations in absorption, and substitution of solid shortenings and dough conditioners for all or part of the oil.

[2]The methylcellulose compounds used in this study are now identified by the manufacturer as Methocel E4M Premium, F4M Premium, and K4M Premium for 60, 65, and 90HG 4000, respectively; and K15M Premium for 90HG 15,000.

TABLE I
Composition and Properties of Rice Flour

		Sieve Classification	
	%	Mesh size	%
Moisture	13.0	+100	56
Protein (N × 5.95)	5.3	−100, +140	12
Crude fat	1.27	−140, +200	20
Crude fiber	0.71	−200	12
Ash	1.38	...	...
Pasting temperature	57°	...	...

TABLE II
Optimum Rice-Bread Formula

	%
Rice flour (14% mb)	100
Baker's compressed yeast	3.0
Salt	2.0
Sucrose	7.5
Oil, refined vegetable[a]	6.0
Methylcellulose "HG"[b]	3.0
Water	75.0

[a]Wesson oil.
[b]Methocel 90HG 4000.

Gums were added to the flour as dry powder or hydrated with part of the absorption water. Powdered dough conditioners were mixed with the dry flour; plastic types (added on an equal solids basis) and shortenings were added at the mixer or melted with oil and the mixture cooled before using. Each variable was tested two or more times.

The optimum formula is shown in Table II. It was modified from a wheat-starch bread formulation developed by Bradley (18). Flour and methylcellulose were blended and added to a 3-qt Hobart C-100 mixer bowl, containing yeast, water, sugar, and salt. Oil was added and all the ingredients were mixed with the paddle attachment, first by hand, to wet the ingredients, then at speed 2 for 2 min. Bowl and paddle were scraped, followed by additional mixing at speed 2 for 3 min. Constant weight of dough (165 g) was scaled into a well-greased, small loaf pan (Wearever aluminum No. 5431), and fermented 2 hr at 86° F and 87% relative humidity. Bread was baked at 365° F for 35 min, removed from the pan, and cooled on a rack for at least 1 hr. Loaf volume was measured by the rapeseed displacement method, and final weight was determined at this time. Specific volume was calculated as loaf volume/baked weight. Most test batches were based on 100 g rice flour. Multiples, up to 400 g, were used for some variables, including breads for taste panel evaluations. Quality of the bread was judged by its volume and by subjective appraisal of its grain, texture, and overall appearance. Acceptability was determined by three taste panels composed of laboratory personnel. Two panels of 28 and 29 different members were asked to rate the unidentified bread sample, and the third panel of 31 members was told, before the judging, that the bread was rice bread. Breads for the taste panels were wrapped in plastic bags and stored overnight at room temperature. Before serving, crusts were removed and each loaf was sliced into samples, approximately 2-1/4 in. × 1 in. × 1/2 in. To prevent drying, the samples were

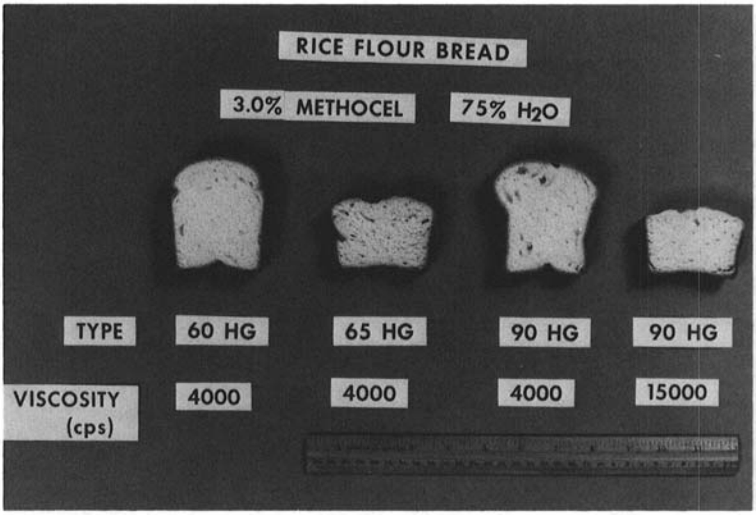

Fig. 1. Effect of Methocel types on rice bread.

covered with plastic material until served. They were rated on a hedonic scale ranging from 9 (like extremely) to 1 (dislike extremely).

RESULTS

The optimum rice-bread formula, shown in Table II, differed from a wheat-bread formula in several ways: 1) by inclusion of methylcellulose (Methocel "HG" series); 2) by use of oil rather than shortening; and 3) by increased water absorption. The resulting rice-flour "doughs" were quite thick and pasty on mixing, and could not be sheeted and molded as are wheat-bread doughs. Instead, they had to be pressed into baking pans with a spatula.

Of the gums, the methylcelluloses showed the most promise for improving gas retention in rice-bread dough. Effectiveness of four types, each at the 3.0% level, is demonstrated in Fig. 1. Both 60HG 4000 and 90HG 4000 produced breads with fine crumb characteristics and volumes between 660 and 680 ml, giving specific volumes ranging from 5.0 to 5.3 ml/g; whereas 65HG 4000 and 90HG 15000 showed lower volumes (357 and 322 ml, respectively) rather coarse, dense texture, and specific volumes of less than 3 ml/g. When the two best methylcelluloses were tested in increments from 0 to 7.0% of the flour, 3.0% appeared to be the optimum for both; hence, either 60HG 4000 or 90HG 4000 could have been chosen for further experiments. However, 90HG 4000 was selected on the basis that it seemed to produce slightly better volumes. Results with four levels of 90HG 4000 are shown in Fig. 2. Bread baked without methylcellulose had almost the same volume as the original dough placed in the pan, indicating no gas retention during proofing. Specific volume increased from 1.5 ml/g (200 ml) without methylcellulose to 5.3 ml/g (680 ml) with 3.0% 90HG 4000, and decreased with each subsequent level (4.1 and 2.3 ml/g, respectively). Oven spring, *i.e.*, increase in volume during early stages of baking, was obtained

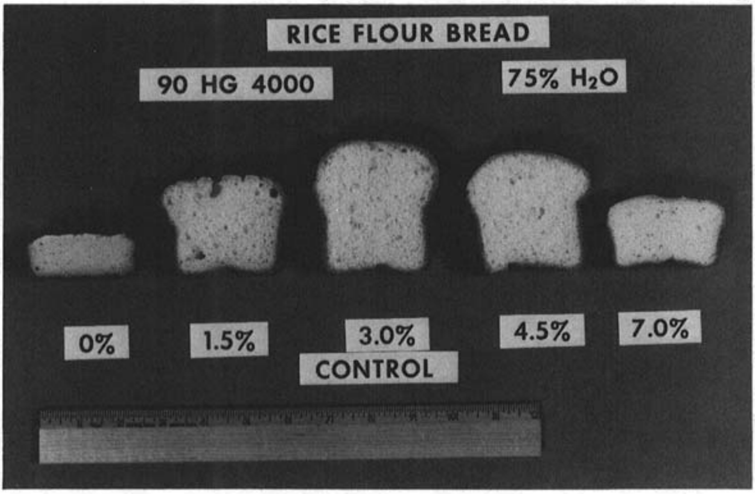

Fig. 2. Effect of Methocel levels on rice bread.

only in loaves containing 3.0 and 4.5% 90HG 4000. The rice bread with 3% 90HG 4000 had fairly good grain, a very white crumb, and the flavor, although bland, was satisfactory when fresh. The bread staled fairly quickly but could be improved by toasting.

The amount of water used in the formula was critical, as demonstrated in Fig. 3. Insufficient water made a very stiff dough which did not rise much during proofing. The volume of the bread was low and the loaf compact. Each additional increment of water made the dough slightly softer and increased proof height as well as bread volume. Excessive water caused overexpansion during baking. The resulting large-volumed loaves contained big holes, which became progressively enlarged and more numerous as the amount of water was increased from 75 to 85% and higher. In spite of holes, the crumb appearance, *i.e.*, grain, of the loaf made with 85% water was best—the cell walls were finer than either the loaf with 65% or the loaf with 75% absorption. However, texture was soft and somewhat gummy and crust walls were weak from overexpansion. The optimum water level appeared to be 75%. The specific volumes increased from about 2.0 ml/g at 65% absorption to 6.5 at 85%.

Breads baked with several gums added at levels to give the same viscosity (4000 cP) are shown in Fig. 4. Batter consistencies varied slightly among the gums. Except for 90HG 4000, none was able to retain gases during fermentation and baking; thus, they produced loaves with very low volumes and compact, gummy texture. Similar unsatisfactory results were obtained when these gums, as well as tragacanth, arabic, and alginates, were added at the 3% level. Whether the gums were added as dry powders or hydrates made no difference, as all made poor breads.

The refined vegetable oils tested (safflower, rice, coconut, and cottonseed-soy blend) all produced breads of nearly comparable quality, with specific volumes

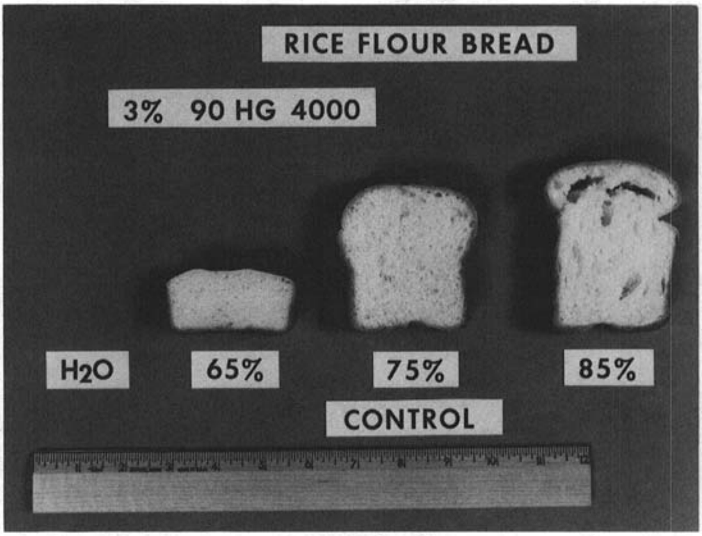

Fig. 3. Effect of water levels on rice bread.

ranging from 4.4 for coconut to 5.0 for cottonseed-soy. Effects of solid fat and typical dough conditioners are shown in Fig. 5. Both lard and hydrogenated vegetable shortening depressed volumes somewhat and negatively affected grain and texture. More adverse effects were noted with hydrogenated shortening than with lard, and more when the hydrogenated vegetable shortening contained emulsifiers.

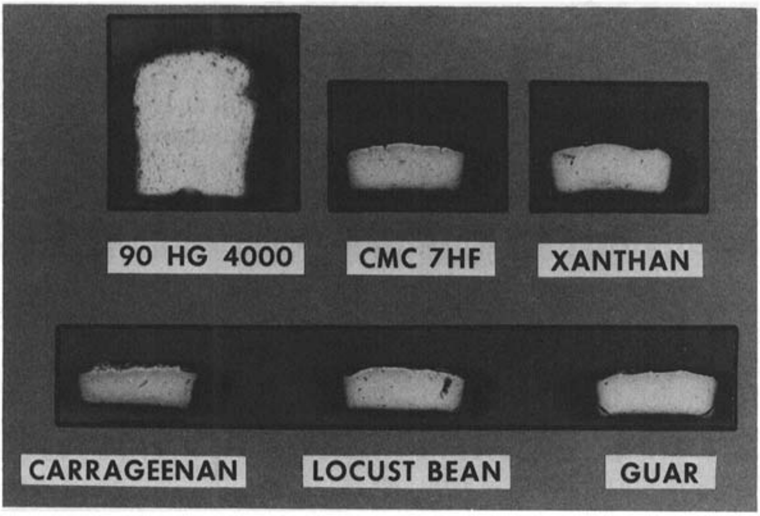

Fig. 4. Effect of gums on rice bread.

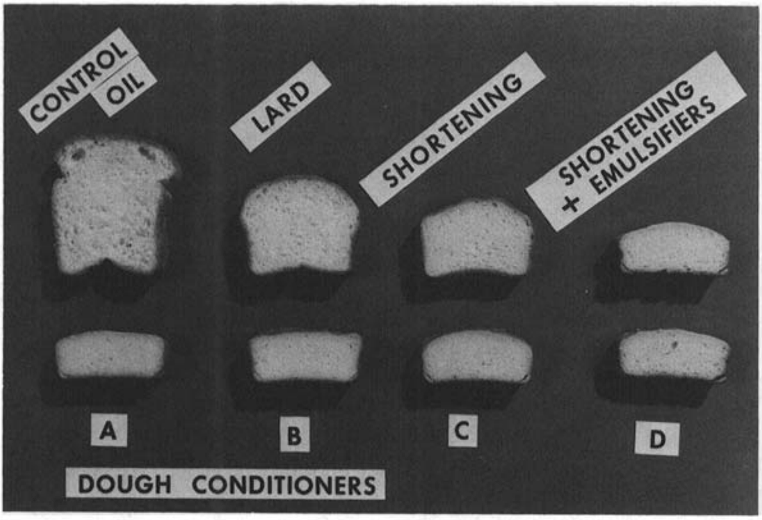

Fig. 5. Effect of fats and dough conditioners on rice bread. A = SSL; B = CSL; C = SMG; and D = EMG.

Dough conditioners, known to improve wheat breads, had the opposite effect on rice-flour breads. All gave depressed loaf volume when added either with or without oil to the formula. Typical results are shown in Fig. 5 for SSL, CSL, SMG, and EMG. Similarly poor breads were obtained with mono- and diglycerides.

Taste panel appraisals by 57 judges, not told that they were tasting rice bread, produced a mean rating of 4.2 (dislike slightly) on the hedonic scale. However, when the bread was identified as rice bread, the mean rating of 31 judges was higher, 5.1 (neither like nor dislike).

DISCUSSION

Substitution of 100% rice flour in a typical wheat-bread formula yielded a thick mass resembling clay more than a gluten-containing dough. It was not capable of being stretched into thin elastic films; hence, it could not trap the gases produced during fermentation. Adjustment of water or the addition of shortening and dough conditioners did not improve doughmaking properties. An additive was needed to provide gas-retaining and water-absorbing characteristics usually supplied by wheat gluten. Certain hydroxypropylmethylcellulose-type compounds appeared to provide these properties. According to Windover (19), they hold water at room temperature and release it during heating. The availability of water during baking allows the starch to gelatinize. This effect parallels that of hydrated gluten in wheat bread, whereby water is released during heat denaturation and made available for gelatinization (20).

By contrast, the other gums tested allowed starch gelatinization during heating but did not provide the necessary gas-retention properties during fermentation. Other workers have reported successful use of various gums in producing wheat-starch breads (7,8–11,13). We have confirmed these results using xanthan gum in wheat-starch bread. The lack of success with xanthan in rice-flour breads is not understood.

The most effective methylcellulose (3% 90HG 4000) resulted in a loaf with a specific volume of about 5.0 ml/g, as compared with about 1.2–1.4 ml/g for the other hydrocolloids tested, and about 1.5 when no gum was used. For comparison, the specific volume of commercial American-style bread is about 6.0, European-style bread, about 4.0 (21), and composite flour breads, 3.0 or lower (15,16).

Methylcellulose products may be used in foods for which there is no Standard of Identity under Title 21, Section 121.1021, of the Code of Federal Regulations (CFR) (22); they have also been approved for use by the Codex Committee on Food Additives of the Joint FAO/WHO Food Standards Programme (23).

Dough conditioners or surfactants are often used to improve the volume, texture, and handling quality of wheat breads baked without fat (24). They are used quite effectively, also, in high-protein breads (25,26) containing proteins from soy flour, fish protein concentrate, nonfat dry milk, cottonseed flour, or other sources, and are believed to form complexes with gluten to strengthen dough structure. In contrast, all the dough conditioners tested were found to depress rice-bread loaf volume. Our results were contrary to those reported by Jongh (5,6) for wheat-starch bread. He effectively used a commercial mono- and diglyceride preparation to improve the stability of a wheat-starch bread formulation without methylcellulose or other gums. Rice breads baked without methylcellulose, but with the various dough conditioners, were poor; *i.e.*, similar to A, B, C, and D in Fig. 5. Kulp *et al.* (13) have also noted that SSL did not improve their starch-xanthan bread. The reasons for the lack of functionality of the dough conditioners are not obvious. It is possible that these dough conditioners interfere with functionality of the methylcellulose or of the starch granules, or are dependent upon the level or nature of the protein in the flour. Some have been shown to complex with a specific wheat protein (27).

Finally, the rice starch granules may contribute to the limited ability of rice flour to yield bread. The granules are the smallest of the common starches (4–8 μ) (28) and the gelatinization properties are quite different from wheat starch. Varietal differences significantly influence gelatinization temperature, amylose content, and gel properties of rice. These may be important in determining rice-bread texture.[3] How these properties affect bread crumb is not known, but deserves further study.

The acceptability of the rice bread appeared to be influenced by conscious or subconscious comparison with wheat bread. When identified as rice bread, the scores improved. A person with wheat allergy has a limited choice of baked products, and may not be as critical as one without an allergy when judging bread quality characteristics.

For patients on sodium-free diets, a salt-free rice bread can be prepared simply by omitting salt from the formula and reducing final proof time slightly.

Since this bread has a relatively short shelf-life, it is best when prepared daily at the point of use, such as in a hospital or at home. A dry mix containing most of the ingredients would offer the most convenience. Such a product is under consideration, with special attention given to rice-flour properties.

[3]Personal communication by M. M. Bean with Mrs. Alicia Perdon, International Rice Research Institute, Los Banos, Laguna, Philippines, August 1975.

Literature Cited

1. BOWMAN, F. Wheat-gluten-egg and milk-free recipes for use at high altitudes and sea level. Colorado Agr. Exp. Sta. Bull. No. 544S (1970).
2. BOWMAN, F., DILSAVOR, W., and LORENZ, K. Rationale for baking wheat-, gluten-, egg-, and milk-free products. Baker's Dig. 47(2): 15 (1973).
3. SLEISENGER, M. H., RYNBERGEN, H. J., PERT, J. H., and ALMY, T. P. A wheat-, rye-, and oat-free diet. J. Amer. Diet. Ass. 33: 1137 (1957).
4. ROTSCH, A. Chemische und backtechnische Untersuchungen an künstlichen Teigen. Brot Gebaeck 8: 129 (1954).
5. JONGH, G. The formation of dough and bread structures. I. The ability of starch to form structure, and the improving effect of glyceryl monostearate. Cereal Chem. 38: 140 (1961).
6. JONGH, G., SLIM, T., and GREVE, H. Bread without gluten. Baker's Dig. 42(3): 24 (1968).
7. McGREER, R. H. A gluten-free wheat product made with cellulose gum. J. Amer. Diet. Ass. 51(6): 534 (1967).
8. SMITH, E. B. Gluten-free breads for patients with uremia. J. Amer. Diet. Ass. 59: 572 (1971).
9. SMITH, E. B. Development of recipes for low-protein, gluten-free bread. J. Amer. Diet. Ass. 65: 50 (1974).
10. SORENSEN, M. K. A yeast-leavened, low-protein, low-electrolyte bread. J. Amer. Diet. Ass. 56: 521 (1970).
11. CHRISTIANSEN, D. D., GARDNER, H. W., WARNER, K., BOUNDY, B. K., and INGLETT, G. E. Xanthan gum in protein-fortified starch bread. Food Technol. 28: 23 (1974).
12. STEELE, B. F., HJORTLAND, M. C., and BLOCK, W. D. A yeast-leavened, low-protein bread

for research diets. J. Amer. Diet. Ass. 47: 405 (1965).
13. KULP, K., HEPBURN, F. N., and LEHMANN, T. A. Preparation of bread without gluten. Baker's Dig. 48(3): 34 (1974).
14. HART, M. R., GRAHAM, R. P., GEE, M., and MORGAN, A. I., Jr. Bread from sorghum and barley flours. J. Food Sci. 35: 661 (1970).
15. KIM, J. C., and de RUITER, D. Bread from non-wheat flours. Food Technol. 22: 867 (1968).
16. KIM, J. C., and de RUITER, D. Bakery products with non-wheat flours. Baker's Dig. 43(3): 58 (1969).
17. HALICK, J. V., and KELLY, V. J. Gelatinization and pasting characteristics of rice varieties as related to cooking behavior. Cereal Chem. 36: 91 (1959).
18. BRADLEY, M. A. S. Development of a low protein bread. M.S. Thesis. Univ. of Iowa (1972).
19. WINDOVER, F. E. Alkyl and hydroxyalkylcellulose derivatives. In: Water-soluble resins, ed. by R. L. Davidson and M. Sittig. Reinhold: New York (1962).
20. BUSHUK, W. Distribution of water in dough and bread. Baker's Dig. 40(5): 38 (1966).
21. POMERANZ, Y. Bread without bread. Baker's Dig. 43(1): 22 (1969).
22. CODE OF FEDERAL REGULATION. Title 21, Chap. I. U.S. Government Printing Office: Washington, D.C. (1973).
23. JOINT FAO/WHO EXPERT COMMITTEE ON FOOD ADDITIVES. Toxicological evaluation of some food additives including anticaking agents, antimicrobials, antioxidants, emulsifiers, and thickening agents. WHO Food Additives Series No. 5. World Health Organization: Geneva (1974).
24. TSEN, C. C., and HOOVER, W. J. The shortening-sparing effect of sodium stearoyl-2 lactylate and calcium stearoyl-2 lactylate in bread baking. Baker's Dig. 45(3): 38 (1971).
25. TSEN, C. C., HOOVER, W. J., and PHILLIPS, D. High-protein breads. Use of sodium stearoyl-2 lactylate and calcium stearoyl-2 lactylate in their production. Baker's Dig. 45(2): 20 (1971).
26. TSEN, C. C., and TANG, R. T. K-State process for making high protein breads. I. Soy flour bread. Baker's Dig. 45(5): 26 (1971).
27. FULLINGTON, J. G. A protein from wheat flour that binds calcium and stearoyl-2 lactylate ions. Cereal Chem. 51: 250 (1974).
28. SCHOCH, T. J. Properties and uses of rice starch. In: Starch: Chemistry and technology, ed. by R. L. Whistler and E. F. Paschall, Chap. IIIa, Vol. II. Academic Press: New York (1967).

[Received June 4, 1975. Accepted October 20, 1975]