Low-Lactose Bread[1]

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ABSTRACT

Satisfactory low-lactose white panned bread made from a dough that contains 6% sugar (flour basis) can be produced from milk that has been treated with lactase. For preparation of such bread by a straight-dough procedure, however, two requirements must be met: malt with or without sucrose must be added to the dough to supplement the amount of lactose-derived glucose, and the lactase-treated milk, like regular milk, must be heat treated.

Lactose, a disaccharide, is the major carbohydrate in milk. Digestion of lactose requires the presence of the enzyme lactase (β-D-galactoside galactohydrolase, 3.2.1.23) in the small intestine. Lactase cleaves the disaccharide into equimolar amounts of glucose and galactose, which enter the bloodstream and are metabolized in the liver. In individuals lacking the enzyme, lactose moves on to the large intestine where it is fermented by bacteria, producing acids and carbon dioxide. Individuals deficient in lactase in the small intestine are lactose intolerant, and symptoms of the intolerance can include a bloated feeling, flatulence, belching, abdominal cramps, and diarrhea.

Estimates by Bayless and Rosenweig (1966), Chung et al (1973), Cook and Kajubi (1966), and Cuatrecasas et al (1965) of the number of lactose intolerant people vary. From various studies, Kretchmer (1972) concluded that many more groups all over the world are intolerant than tolerant and that real tolerance occurs only in northern Europeans and in the members of two pastoral tribes in Africa.

Milk is commonly used in bread making in many countries and is a good source of proteins, vitamins, and minerals. In the United States, it is readily available as nonfat milk solids and dry whey. Because milk solids contain more than 50% and whey more than 70% lactose, the properties of lactose often determine their use in food. Lactose is used as a carrier for flavors, in pharmaceuticals for tablets, and in baked goods for flavor, texture, appearance, shelf life, and toasting qualities (Ash 1976; Holmes and Lopez 1977; Nickerson 1978a, b). Lactose has some limitations, including low solubility and rate of solution and, of course, indigestibility in certain individuals.

Use of lactase-hydrolyzed milk for bread making could enable lactose-intolerant individuals to eat the bread; moreover, the milk would still be nutritionally balanced and would provide some glucose for yeast fermentation.

Pomeranz et al (1962) added bacterial and fungal lactases to bread doughs containing several sources of lactose. They found that the hydrolysis of lactose did not supply adequate amounts of fermentable sugars. Bacterial, yeast, and fungal lactases have been added to milk during processing (Guy 1974, Rand and Linklater 1973, Sorensen and Crisan 1974). Milk solids in which lactose is nearly completely hydrolyzed are now commercially available.

Hydrolyzed lactose therefore might be used in bread production as a source of fermentable sugars and to produce low-lactose bread for lactose-intolerant people. Some questions relating to the use of lactase-treated milk solids for bread making are:

1) What is the contribution to fermentation and bread quality (loaf volume, crumb grain, and overall quality) of a mixture of glucose and galactose?
2) What is the contribution to fermentation and bread quality of lactase-hydrolyzed milk solids?
3) Can acceptable bread be produced with milk solids in which lactose is nearly completely hydrolyzed (ie, do the milk proteins remain functional in bread making)?
4) If the answer to 3) is "yes" and the answer to 2) is "minimal," can the insufficiency of sugars be remedied by the use of malt or additional fermentable sugar?

MATERIALS AND METHODS

A composite flour (RBS-75) of many hard red winter wheats harvested throughout the U.S. Great Plains region was used. It contained 12.4% protein (N × 5.7, 14% moisture basis) and had good loaf-volume potential and medium mixing and oxidation requirements.

The eight samples of milk solids used in this study are described in Table I. A commercial nonfat dry milk (NFDM) regularly used in our laboratory in baking studies was a laboratory control. Samples M_1, M_2, and M_3 were controls for samples M_4 and M_5, all prepared by Eugene Guy of the Eastern Regional Research Center, U.S. Department of Agriculture, Philadelphia, PA. One of the remaining commercial samples was supplid by Alan E. Kligerman of SugarLo Company, Atlantic City, NJ; the other by Robert J. Kolf of Precision Foods Company, Minneapolis, MN. Four samples had been treated at high temperature and three at low temperature. One sample was presumed to have been treated at high temperature. The need for, and conditions of, high-temperature treatment of milk used in bread production have been well documented (Ponte 1971).

Glucose, galactose, and lactose were reagent grade from Fisher Scientific Co. Sucrose was granular or powdered.

For comparison, experimental milk solids, sucrose, glucose, galactose, and lactose were pulverized and added as dry powders to the flour. When breads were made under optimum conditions,

TABLE I
Description[a] of Samples of Milk Solids in this Study

Description	Hydrolyzed Lactose	Heat Treatment	Type	Source
Nonfat dry milk	None	High-temperature	Nonfat	Commercial
M_1	None	Low-temperature	Nonfat	Experimental
M_2	93%	Low-temperature	Nonfat	Experimental
M_3	None	High-temperature	Nonfat	Experimental
M_4	89%	High-temperature[b]	Nonfat	Experimental
M_5	>88%	High-temperature[c]	Nonfat	Experimental
M_6	>99%	Unknown[d]	Full-fat	Commercial
M_7	96%	Low-temperature	Nonfat	Commercial

[a]Data from commercial or laboratory sources.
[b]Heat-treated only before lactose hydrolysis.
[c]Heat-treated before and after lactose hydrolysis.
[d]Presumably, high temperature.

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Mention of specific instruments or trade names is made for identifaction purposes only and does not imply any endorsement by the U.S. government.

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however, sucrose was added as a solution.

We used a straight-dough baking procedure in which mixing time, water absorption, and oxidant (5 ppm potassium bromate and 50 ppm ascorbic acid) were optimized. Baking formula for laboratory contol was: 100 g of flour (14% moisture), 6 g of sucrose, 1.5 g of salt, ~3.5 g of yeast (depending on gassing power), 4 g of NFDM, 0.25 g of malted barley (54 dextrinizing units, used as an extract), and 3 g of shortening. In test formulas, sucrose was replaced by 0–10 g of glucose, 0–10 g of a 1:1 mixture of glucose and galactose, 0–10 g of galactose, or 0–9 g of lactose. The loaves of glucose-galactose bread were baked with and without NFDM. In formulas with varying levels of sucrose, NFDM was sometimes replaced by experimentally or commercially prepared milk solids (Table I), with and without malt. Additional details of the baking method are given by Finney (1945) and Finney and Barmore (1943; 1945a,b). The standard deviation for the average of duplicate loaf volumes was 20 cc. All data were averages of two or more determinations.

Moisture and protein were determined by AACC approved methods 44-15A and 46-11. α-Amylase activity (dextrinizing units) was determined according to the methods of the American Society of Brewing Chemists Methods of Analysis (1958). Gassing power was determined by the method of Shogren et al (1977). Crumb compressibility was measured with a Bloom gelometer both 1 hr and 3 days after baking. The weight required to depress a 25-mm diameter plunger 4 mm into the bread crumb after the crust had been removed is reported as crumb compressibility. Loaves were stored in plastic bags at room temperature. Crumb and crust (top) color were determined with a Hunterlab color meter. To standardize the instrument, we used Hunterlab Tile Standard 025-931 ($L = 83.1$; $a_L + 4.0$; $b_L + 26.2$). To simplify bread color comparisons, we calculated total color differences (ΔE) between control (with NFDM) and experimental loaves according to:

$$(\Delta E) = \sqrt{(\Delta L^2) + (\Delta a^2) + (\Delta b^2)}$$

RESULTS AND DISCUSSION

The effect on loaf volume of various levels of a 1:1 mixture of glucose and galactose with and without 4 g of NFDM, and various levels of glucose without NFDM are shown in Fig. 1 for loaves without malt or sucrose.

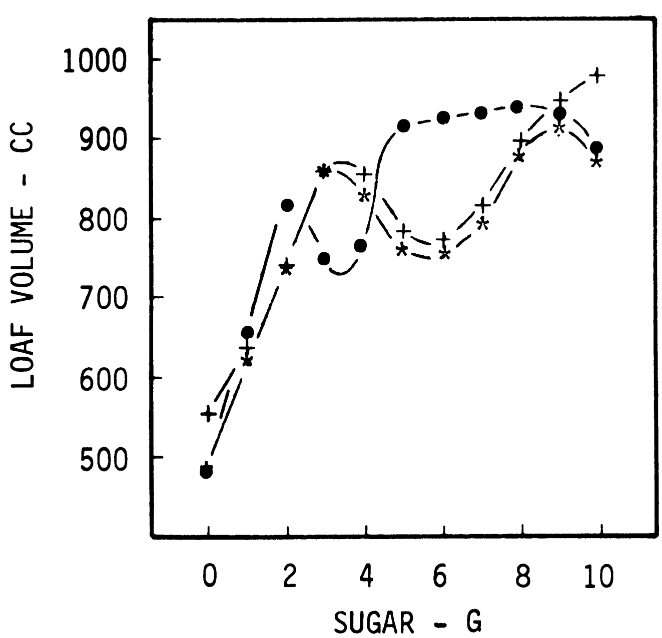

Fig. 1. Loaf volume of bread from 100 g of flour baked with (•) 0–10 g of glucose without nonfat dry milk (NFDM), or (*) 0–10 g of a 1:1 mixture of glucose and galactose without NFDM, or (+) 0–10 g of a 1:1 mixture of glucose and galactose with 4 g of NFDM; all without malt or sucrose.

Loaf volume of bread without NFDM peaked twice—with about 2 and 8 g of glucose—and was minimum with about 3.5 g of glucose. Such a loaf-volume response to various levels of sugar was reported earlier (Finney et al 1972, Pomeranz et al 1964). A similar curve resulted with the mixture of glucose and galactose without NFDM, except that the dip occurred with about 6 g of total sugar (3 g of glucose). Of loaves containing more than 3 g of the sugar mixture, loaf-volume response was slightly higher when NFDM was also present.

Adding 4 g of NFDM in which the lactose was completely hydrolyzed added about 2 g of a mixture of glucose and galactose. From Fig. 1, the contribution to loaf volume of 2 g of hydrolyzed lactose can be estimated. For instance, at the 2-g level of added sugar mixture (glucose and galactose), loaf volume increased to about 740 cc from 481 cc—the volume of bread with neither sugar nor NFDM.

In the absence of NFDM or other added sugars, loaf volume only increased to 510 cc with 6 g of lactose and to 680 cc with 8 g of galactose (not shown in Fig. 1). In gassing power tests both lactose and galactose inhibited yeast fermentation of naturally occurring sugars (data not shown). In doughs containing no added sugars, fermentation was brisk through the first punch (69 min) and second punch (additional 34 min) but thereafter fell to practically zero, ie, naturally occurring sugars were spent before panning. Consequently, loaf volume was 481 cc. When 8 g of galactose was added, the rate of fermentation was initially slowed so that after panning (120 min), some natural sugars remained to support limited fermentation during proofing. Hence, loaf volume was 680 cc. Lactose had an intermediate effect on fermentation and loaf volume was 510 cc. Glucose and fructose repress maltose uptake and fermentation by *Saccharomyces cerevisiae* (Lovgren and Hautera 1977). It would be interesting to know whether lactose and galactose exhibit a repressive effect.

Data in Fig. 1 suggested that bread with only 1 g of glucose from 4 g of lactase-hydrolyzed milk solids would not be satisfactory. Loaf volumes of bread baked with commercial, heat-treated milk solids (4 g) and no malt increased as sucrose was increased from 4 to 6 g and then remained essentially constant as sucrose was increased to 8 g (Table II). With each of the four milk samples, 6 g of sucrose was required for optimum loaf volume. When the sucrose level was 6 g, three of the four lactase-hydrolyzed milk samples produced bread that was comparable in loaf volume to the bread containing commercial NFDM. Both nonfat and full-fat samples were satisfactory. Loaf volume for M_7 was low because of low-heat treatment.

Characteristics of bread differing in milk source (Table I) are compared in Table III. The loaves were baked under optimized conditions, which included 0.25 g of malt. Loaves with high-temperature-treated milk solids (NFDM, M_3, M_4, M_5, and M_6) were satisfactory, but those with low-temperature-treated milk solids (M_1, M_2, and M_7) were not.

Lactase treatment, per se, did not affect loaf volume of either the low-temperature-treated samples (compare M_1 with M_2) or the high-temperature-treated samples (compare M_3 with M_4 and M_5). Lactase treatment of the experimental samples M_2, M_4, and M_5, but not the commercial samples, imparted a definite creamy tan color to the crumb grain. Color-difference values reflected the visual assessment.

Mixing times differed little, as did all crumb-compressibility

TABLE II
Loaf Volume (cc) of Bread Baked with 4 g of Milk Solids Without Malt and Various Levels of Sucrose

Sample of Milk Solids[a]	Sucrose Added (g/100 g flour) 4	5	6	7	8
Nonfat dry milk	875	920	968	1,000	984
M_4	880	910	950	948	958
M_5	858	910	948	953	943
M_6	868	923	964	960	968
M_7	800	858	878	870	885

[a]For description, see Table I.

values except one. The low compression value determined on day 3 for M_6 may have been associated with its fat content.

Loaves of bread were baked with 4 g of NFDM, M_4, or M_1 and different sucrose-malt combinations (Table IV). The loaves with 1.0 g of malt but no sucrose are compared with the loaves with neither sucrose nor malt in Fig. 2. The combination of 6 g of sucrose and 0.25 g of malt was optimum for the sugar dough formulation, but 1.0 g malt alone was optimum for no-sugar doughs.

Our study showed that lactase-hydrolyzed milk can be used in the production of low-lactose bread for lactose-intolerant people, but the amount of glucose derived from the lactose must be supplemented by adequate amounts of fermentable sugars from other sources. The study also showed that lactase-hydrolyzed dry milk must be heat treated for use in bread production so that the milk proteins are functional. Loaf volumes averaged 1,013 cc for high and 925 cc for low heat-treated milks.

TABLE III
Characteristics of Loaves Baked with Sucrose (6 g), Optimum Malt (0.25%), and One of Eight Sources of Milk Solids (4 g)

Milk Source	Loaf Volume (cc)	Mixing Time (min)	Crumb[a]		ΔE[b]		Crumb Compressibility	
			Grain	Color	Interior	Exterior	1-hr (g)	3-day (g)
Nonfat dry milk	1,028	5	S	CW	...	...	75	225
M_1	934	4-5/8	Q	C	0.22	0.17	72	223
M_2	927	4-1/2	Q	CT	2.90	0.66	72	211
M_3	1,026	5	S	CW	0.14	0.22	76	210
M_4	990	4-1/2	S	CT	2.58	0.69	75	214
M_5	1,010	4-5/8	S	CT	2.63	0.88	64	211
M_6	1,010	4-1/2	S	C	1.28	0.35	65	192
M_7	916	4-3/8	Q-S	C	0.45	0.81	71	229

[a] Visually evaluated: S = satisfactory, Q = questionable, CW = creamy white, C = creamy, and CT = creamy tan.
[b] $E = \sqrt{(\Delta L^2) + (\Delta a^2) + (\Delta b^2)}$ = total Hunterlab color differences between control and experimental loaves.

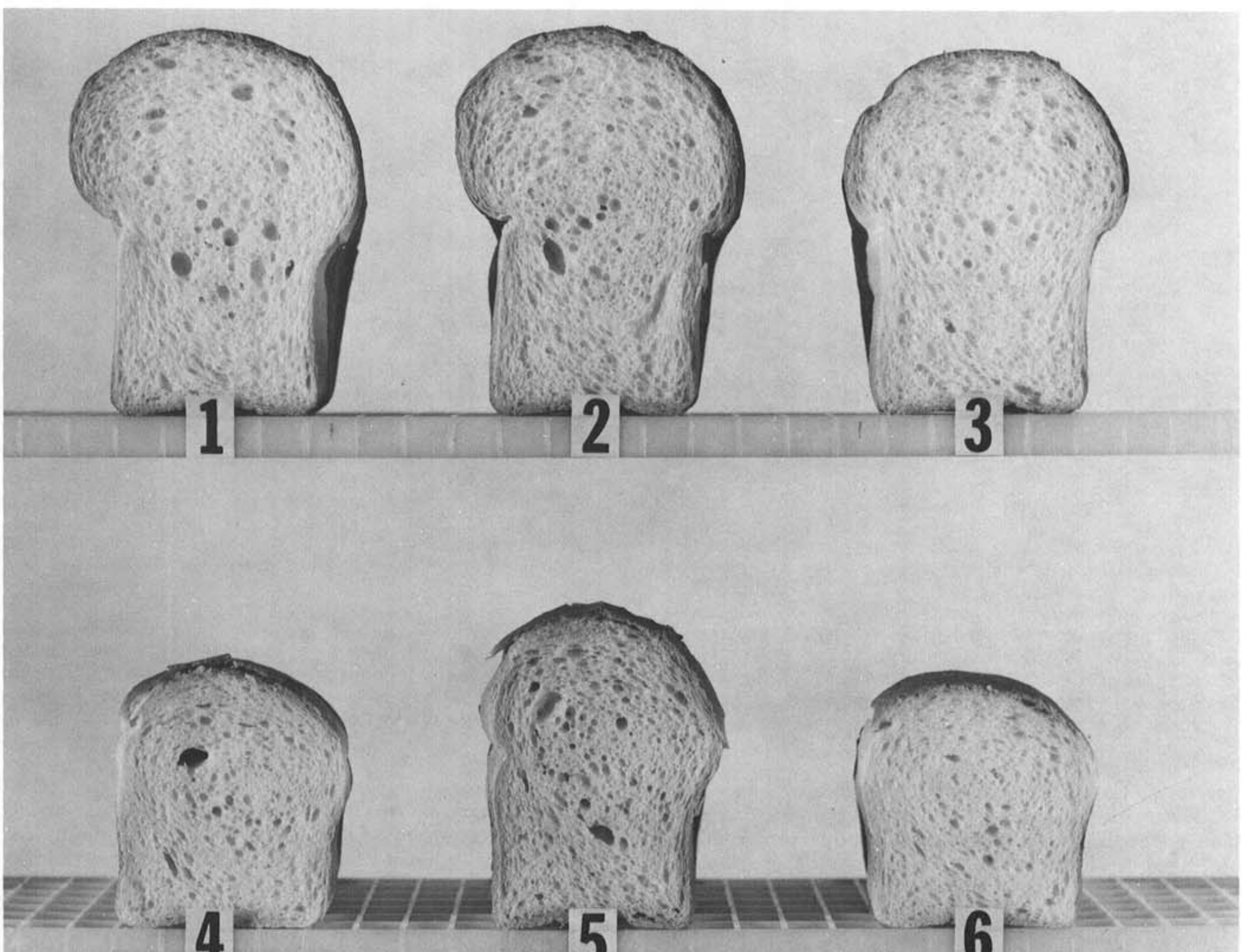

Fig. 2. Bread loaves baked with nonfat dry milk (**1** and **4**) M_4, (**2** and **5**) or M_1 (**3** and **6**) according to a no-sucrose formulation containing either 1.0 g of malt (**1–3**) or no malt (**4–6**).

TABLE IV
Loaf Volumes of Bread Baked with 4 g of Nonfat Dry Milk (NFDM), M_4, or M_1 and Sucrose and Malt

Sucrose (g)	Malt (g)	Loaf Volumes (cc)		
		NFDM	M_4	M_1
6	0	968	950	868
6	0.25	1,028	990	934
0	1.0	1,000	1,000	920
0	0	563	715	518

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