Fermented Dairy Ingredients for Bread: Effects on Dough Rheology and Bread Characteristics[1]

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ABSTRACT

Fermented dairy ingredients prepared with *Lactobacillus casei* subsp. *rhamnosus* and containing variable proportions of milk, whey, and whole wheat flour were incorporated in a pan bread formulation and tested according to their effect on dough rheology and bread scoring. In general, according to their pH, fermented dairy ingredients did not change dough water absorption but did reduce peak time, dough mixing stability, and bread specific volume and increased bread firmness after one or seven days. Dough proof time, bread scoring, and mold-free shelf life did not differ from that of standard milk bread. When milk was the main component of the fermented dairy ingredient (no whey or flour), the quality of the bread was about equivalent to that of standard milk bread (dough water absorption, bread specific volume, firmness, scoring). As compared to whole wheat flour, the addition of buckwheat, oats, or wheat flour to the dairy medium before fermentation had the most positive effect on bread volume and flavor among the 11 tested flours.

Variety breads have become very popular in recent years. They are very attractive to consumers looking for products with different appearance and flavor (van Osnabrugge 1988). Sourdough is a good example of high-flavored bread. However, it has a production process that is still quite empirical, long, and difficult to control: a starter is taken from a ripe dough, activated with water and flour, fermented to optimum, and baked. Overall, the fermentation process usually lasts several hours (Stear 1990). Short-time procedures for sourdough have been proposed (Lorenz 1983). For example, Kline (1983) used a freeze-dried culture of *Lactobacillus sanfrancisco* to better control sourdough production. Commercial dry bases are also available to shorten fermentation times, but they sometimes lead to off-flavors (Oura et al 1982). Shenkenberg et al (1972) also described a sourdough process where cottage cheese, whey, and vinegar are added.

Another way to improve the sourdough process is to use a high-flavored dairy ingredient, derived from sweet whey or milk (Gélinas et al 1992). With careful selection of lactic cultures, bread flavor may be enhanced (Gélinas and Lachance 1995); such bread would also benefit from milk nutritional properties and its technological improvements in bread production such as better fermentation tolerance of the dough (Pyler 1988, Doerry 1989). The use of low concentrations of this type of fermented dairy ingredient in the no-time dough process would partly compensate for lack of flavor, a characteristic of bread made from this most accelerated breadmaking process. However fermented dairy ingredients have a negative effect on bread specific volume (Shenkenberg et al 1972, Gélinas and Lachance 1995).

Previously, we focused on the use of selected bacteria and growth media to optimize the flavor of fermented dairy ingredients and bread prepared from it (Gélinas and Lachance 1995). Here, we report on the effect of some ingredients on dough rheology; we searched for optimized ingredients that did not impair bread quality (proof time, loaf volume, scoring, mold-free shelf-life, and firmness).

MATERIALS AND METHODS

Dairy Ingredient Preparation

A volume of 1 L of preferment was prepared with equal mixtures (20% dairy solids) of reconstituted high-heat skimmed milk and sweet whey. The medium was supplemented with 1% (w/v) sodium citrate and inoculated with 2.5% ($\sim 4 \times 10^8$ cells g^{-1} of dairy preparation) of a freeze-dried lactic starter, *Lactobacillus casei* subsp. *rhamnosus* (Institut Rosell, Inc., Montreal, Canada). Variable proportions of whole wheat flour were then added to the dairy preparation (0, 10, or 30 g/100 ml of reconstituted dairy product). Besides whole wheat, other flour types were also evaluated at a concentration of 30% (w/v) in the dairy preparation: arrowroot, barley, buckwheat, corn, millet, oats, rice, rye, soy, and wheat (second patent flour). Fermentation was performed at 38°C for 24 hr and 140 rpm in 500-ml Erlenmeyer flasks containing about 350 ml of dairy preparation. Fermented dairy ingredients were then cooled at 4°C. For the dough rheology tests, ingredients were freeze-dried, then stored in bags at 4°C.

Breadmaking Process

Except where indicated, white pan bread was produced by the no-time dough procedure using: 100% flour (14% moisture), 4% sugar, 3% yeast (30% solids), 3% shortening, 2% salt, 100 ppm ascorbic acid, 60 ppm potassium bromate, 6% fermented dairy ingredient (dry weight), and water (variable). In triplicate, each batch was produced from 2 kg of flour with a Hobart mixer (A-200T), giving nine doughs scaled to 330 g. Doughs were rounded, bench-rested for 10 min, molded, and proofed to constant height (2.5 cm above rim) at 40°C and 100% rh. Bread was baked at 213°C for 20 min; 1 hr after baking, loaf volume was measured by rapeseed displacement. On the following day, breads were scored by an expert in the field for internal and

TABLE I
Scoring Values Used to Evaluate Pan Bread

Quality	Maximum Score
External (30 points)	
Specific volume	10
Crust color	8
Symmetry	3
Evenness of bake	3
Character of crust	3
Break and shred	3
Internal (70 points)	
Grain	15
Taste	15
Crumb color	10
Aroma	10
Keeping quality	10
Texture	10
Total	100

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external characteristics (Table I). Milk bread (6% milk solids, flour basis) was prepared as a reference.

Dough Rheology, pH, and Total Titratable Acidity

Dough water absorption, peak time, and mixing stability were evaluated in triplicate with the farinograph by AACC method 54-21 (AACC 1983). When dairy preferment contained flour, its quantity (50 g) was removed from the amount of flour necessary to perform the test. Table II presents the farinogram parameters according to the type of dairy ingredient. Conditions included: 1) flour only; 2–4) nonfermented dairy ingredients; 5–11) fermented dairy ingredients. All tests were performed at 6% (on a dairy solid/flour basis), except for condition 8 (5.45%, dairy solids) and condition 9 (4.62%, dairy solids) where whole wheat flour was incorporated in the dairy ingredient before fermentation, somewhat reducing the dairy solids proportion. In condition 10, the concentration of the fermented dairy ingredient containing 30% flour (w/v) was corrected to give 6% dairy solids (flour basis). Before performing the farinograms, the flour content of the dairy ingredients already containing flour was considered, except for condition 11.

Dough pH was taken twice (3× repetitions) upon completion of the farinograph test by directly immersing the electrode in the doughs. Total titratable acidity (TTA) and pH of fermented dairy ingredients were determined in duplicate (3× repetitions) on 9 g of dairy ingredient supplemented with 18 g of water. TTA was measured in duplicate with NaOH $N/9$ to pH 8.6, using phenolphtalein (American Public Health Association 1985). For bread samples, a modified procedure was used: 15 g of bread crumb (from the center of the loaf) was shaken for 30 min in 100 ml of water and TTA was measured twice (3× repetitions) by titration to pH 6.6 with NaOH $N/9$ (Sutherland 1989). TTA was expressed as meq. mol lactic acid/g, calculated as: vol NaOH (ml) × Normality (meq. mol. ml^{-1})/ weight of sample (g).

Bread Mold-Free Shelf-Life and Firmness

In triplicate, molding of bread was determined visually on two bread samples, each wrapped in two plastic bags and stored on racks at 21°C until mold appeared. After one and seven days, staling was evaluated on two bread samples with a universal testing machine (Instron model 4201) according to AACC method 74-09 (AACC 1983) with the following specifications: 30 mm sample height (two slices of bread, 15 mm each), 36 mm diameter plunger, 50 N full-scale load and 50 mm/min crosshead speed. Stress and load were reported at 25% of compression, and test ended when compression exceeded 40%. Bread was sliced just before measuring firmness.

Sensory Evaluation

Sensory evaluation was performed to compare bread containing fermented milk-whey (10% flour) with standard bread prepared with nonfermented milk (6%). Breads were prepared the day before the sensory evaluation; crust was removed and pieces of crumb (1 cm^3) were blind-coded. Panel consisted of 43 nontrained judges who received five samples of bread. The two-out-of-five comparison test (Meilgaard et al 1987) was used to identify bread samples and to indicate the nature of differences.

Statistical Methods

Analysis of variance was performed at the 5% significance level; differences between treatment levels were tested by Scheffe F test, except for results presented in Table II, which were analyzed by Fisher Least Significant Difference (LSD) method.

RESULTS AND DISCUSSION

Farinograph Parameters

Fermented milk gave a significantly higher dough water absorption than did nonfermented milk or whey (Table II). The lowest water absorption was obtained when whey (fermented or not) was used; this is in agreement with results obtained in the literature (Barnes et al 1973, Kulp et al 1988). As a consequence, equal mixtures of fermented milk-whey had a slight but significant effect on dough water absorption, compared to flour alone (62.9% and 62.0%). When the amount of flour present into fermented dairy ingredients was considered before performing farinograms, incorporation of high levels of whole wheat flour into the dairy preparation (condition 9 compared to condition 7; 30% flour instead of 0%) did not increase dough water absorption. When flour present in the dairy ingredient was not considered (condition 11 compared to condition 10), fermented dairy ingredients containing flour increased dough water absorption because it brought flour with it, not because they were fermented ingredients. No relationship could be established between the water absorption of the dough and its pH, which varied according to ingredients.

As shown in Table II, the incorporation of nonfermented dairy ingredients into dough gave significantly longer peak times (8.8–9.5 min compared to 6.5 min). Pre-fermentation of dairy ingredients also gave significantly longer peak times, but brought them closer to levels obtained with the flour reference (~8 min compared to 6.5 min). When ingredients contained flour, peak times were similar to those of the reference, which indicates that, in general, dairy ingredients increased peak time, but the latter was reduced according to pH of fermented dairy ingredients. Ingredients containing nonfermented dairy ingredients significantly increased dough mixing stability but pre-fermentation reduced it. Highly acid dairy ingredients, such as those containing 30% flour, significantly reduced dough mixing stability from 10–11 min to 6–7 min. This has already been observed by Barnes et al (1973), who mentioned that adding salt into dough improves the mixing stability of acid doughs.

TABLE II
Dough pH and Farinogram Parameters According to Dairy Ingredient Composition[a]

Ingredient	Dough pH	Absorption (min)	Peak Time (min)	Stability (min)
1. Reference (flour)	5.92 b	62.0 b	6.5 a	10.7 b
2. Milk	6.06 a	63.1 cd	9.5 e	14.7 d
3. Whey	5.94 b	60.1 a	8.8 de	12.7 c
4. Milk-whey	6.00 a	62.1 b	9.5 e	15.5 d
5. Fermented milk	5.52 c	64.3 e	7.8 bc	10.7 b
6. Fermented whey	5.52 c	60.4 a	8.3 cd	11.0 bc
7. Fermented milk-whey (0% flour)	5.51 c	62.9 c	8.2 cd	10.0 b
8. Fermented milk-whey (10% flour; w/v)	5.15 d	62.9 c	8.0 b–d	10.7 b
9. Fermented milk-whey (30% flour; w/v)	4.78 e	63.3 cd	6.7 a	6.2 a
10. Fermented milk-whey[b] (30% flour; w/v)	4.58 f	63.5 d	6.8 a	6.3 a
11. Fermented milk-whey[c] (30% flour; w/v)	4.77 e	69.4 f	7.2 ab	7.0 a
LSD	0.088	0.513	0.932	1.899

[a]All data are means of triplicate measurements, except pH (6). Means in a column followed by the same letter are not different at the 5% significance level (Fisher Least Significant Difference test) (LSD). Except where indicated, all ingredients were tested at 6% (flour basis) and the amount of flour brought by each ingredient was considered before running the farinograph.
[b]Ingredient tested at 15% solids (flour basis).
[c]Ingredient tested at 15% solids (flour basis), except that the amount of flour present in ingredient was not considered before running the farinograph.

Bread pH, TTA, Volume, Mold-Free Shelf-Life, Firmness, and Scoring

The effect of selected fermented dairy ingredients on bread characteristics is presented in Table III. Proof time was not changed by the addition of fermented dairy ingredients (data not shown), but they had a significantly depressing effect on bread specific volume, except for fermented milk (without whey or flour). Replacement of half of the milk by whey lowered bread specific volume, especially when 30% flour was added to the liquid fermentation medium. Bread containing fermented dairy ingredients was not significantly protected against mold contamination: the most acid breads could be kept for 13–14 days instead of about eight days. Incorporation of fermented dairy ingredients usually led to firmer bread after one and seven days; this was a function of bread TTA.

Bread made with fermented dairy ingredients had a score similar to standard (Table IV), whatever the bread TTA, except when 15% was added instead of 6%. Internal characteristics were changed, especially crumb color, aroma, and firmness (data not shown). As determined by the sensory evaluation panel, flavor of breads prepared with fermented dairy ingredients (milk-whey with 10% flour) was judged significantly different than milk breads (6% flour basis); 14 out of 43 judges passed the test ($P < 0.01$ (Meilgaard et al 1987). Flavor was described as slightly enhanced, cheese-like and acid.

The type of flour used in the preparation of the dairy ingredients had an important effect on ingredients as well as on the resulting bread (Table V); this confirms preliminary data presented in Gélinas et al (1992). TTA of ingredients was much affected by flour composition, probably because of differences in the buffering effect and the metabolism of lactic acid bacteria. The type of flour had no effect on dough proof time but, again, bread specific volume was a function of the acidity of the ingredient, except for ingredient with arrowroot that gave low bread volumes even when the TTA was not very high. The taste of the various breads was also very different. However, this time there was no attempt to differentiate all these breads through sensory evaluation involving a large panel. Some of the breads prepared with dairy ingredients containing soya, rice, arrowroot, or millet were rather insipid or had off-flavors. On the basis of bread volume and, possibly taste, dairy preferments prepared from oats and buck-

TABLE III
Effect of Fermented Dairy Ingredient Composition on Bread pH, Total Titratable Acidity (TTA), Volume, Mold-Free Shelf-Life, and Firmness[a]

Ingredient	pH	TTA (10^{-2} meq·mol g^{-1})	Specific Volume ($cm^3 \cdot g^{-1}$)	Mold-Free Shelf-Life (days)	Firmness (N) After 1 day	Firmness (N) After 7 days
Milk	5.96 a	1.0 a	5.04 a	8 a	2.7 a	6.1 a
Fermented milk	4.90 b	3.9 bc	5.08 a	10 ab	2.8 a	7.3 b
Fermented milk-whey	4.91 b	3.6 b	4.73 b	10 ab	3.4 b	8.2 bc
Fermented milk-whey (10% flour)	4.73 c	4.1 cd	4.51 bc	11 ab	3.5 b	9.4 c
Fermented milk-whey (30% flour)	4.62 d	4.5 d	4.24 cd	14 b	4.7 c	12.8 d
Fermented milk-whey (30% flour)[b]	4.51 e	5.7 e	4.08 e	13 ab	4.5 c	13.0 d

[a]All data are means of 6 (pH and TTA), 24 (bread specific volume), 6 (mold-free shelf-life), and 21 measurements (firmness). Means in a column followed by the same letter are not different at the 5% significance level (Scheffe F test). Except where indicated, all ingredients were tested at 6% (flour basis).
[b]Ingredient tested at 15% solids (flour basis).

TABLE IV
Effect of Fermented Dairy Ingredient Composition on Bread Scoring[a]

Ingredient	Bread Scoring: External (max. 30)	Bread Scoring: Internal (max. 70)	Bread Scoring: Total (max. 100)
Milk	24.1 ± 1.0	53.0 ± 1.0	77.1
Fermented milk	21.4 ± 1.5	52.8 ± 3.5	74.2
Fermented milk-whey	22.1 ± 2.6	49.6 ± 3.7	71.7
Fermented milk-whey (10% flour)	22.9 ± 1.8	50.6 ± 1.0	73.5
Fermented milk-whey (30% flour)	24.1 ± 0.7	48.5 ± 3.3	72.6
Fermented milk-whey (30% flour)[b]	22.8 ± 0.8	43.9 ± 2.9	66.7

[a]All data are means (± standard deviation) of six measurements from three repetitions. Except where indicated, all ingredients were tested at 6% (flour basis).
[b]Ingredient tested at 15% solids (flour basis).

TABLE V
Effect of Flour Type (30%, w/v) on Some Characteristics of Fermented Dairy Ingredient and Bread[a]

Flour Type in Ingredient	Dairy Ingredient pH	Dairy Ingredient TTA (× 10^{-2} meq·mol g^{-1})	Bread[b] pH	Bread[b] TTA (× 10^{-2} meq·mol g^{-1})	Specific Volume ($cm^3 \cdot g^{-1}$)
Soya	4.16 cd	38.3 a	4.59 ab	6.4 a	3.90 a
Buckwheat	4.07 bc	30.5 b	4.67 bc	5.3 ab	4.37 c
Barley	3.97 ab	29.7 bc	4.56 a	5.5 ab	4.07 ab
Rye	3.94 a	29.6 bc	4.54 a	5.7 ab	4.08 ab
Wheat (whole)	3.91 a	28.4 cd	4.69 bc	4.6 a–d	4.04 ab
Wheat	3.92 a	27.2 d	4.74 c	4.2 b–d	4.21 bc
Rice	4.27 de	24.9 e	4.78 c	4.7 a–d	4.40 c
Oats	4.38 ef	24.6 e	4.78 c	5.0 a–c	4.36 c
Corn	4.20 d	24.5 e	4.75 c	4.8 a–c	4.06 ab
Millet	4.97 g	15.8 f	5.30 e	3.0 d	4.99 d
Arrowroot	4.49 f	14.7 f	4.99 d	3.4 cd	4.35 c

[a]All data are means of four replicates. Means in a column followed by the same letter are not significantly different at the 5% significance level (Scheffe F test).
[b]Recipe: flour, 100; sugar, 4; yeast (30% solids), 3.75; shortening, 3; salt, 1.75; fermented dairy ingredient, 10 (dry weight); SSL, 0.25; water, variable, ascorbic acid, 100 ppm; potassium bromate, 60 ppm. Bread was baked at 213°C for 15 min. Fermented dairy ingredients were prepared with equal concentrations of milk and whey (20% dairy solids).

wheat were considered as good choices, but ingredients prepared with whole wheat flour also gave bread with a most pronounced flavor, without off-flavor.

CONCLUSION

In general, fermentation of dairy ingredients with *L. casei* subsp. *rhamnosus* before incorporation into dough reduced its peak time and mixing stability. Dough water absorption was increased only when fermented dairy ingredients contained flour. Breads prepared with dairy pre-ferments had lower specific volumes, and they were much firmer, except when milk was the main component of the fermented dairy ingredient (no whey or flour), in which case a high-quality bread was produced. When higher TTA was needed, the incorporation of buckwheat, oats, or wheat flour in the dairy preparation (before its fermentation) gave acceptable bread volumes and most pleasant flavors.

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