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RESEARCH NOTE

Influence of Substituting Water with Ultrafiltered Milk Permeate on Dough Properties and Baking Quality of White Pan Bread

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Milk permeate is a by-product of cheese making produced by means of ultrafiltration of milk. The ultrafiltration process has produced a new opportunity in recent years for the dairy industry to fractionate milk into a protein concentrate and lactose-rich permeate[1]. Milk permeate consists of 5% total solids, 90% of which is lactose[2]. Fermentation is an effective process for developing new dairy ingredients[3]. Main[4] described four types of fermented dairy products as food ingredients, one of them being cultured whey. Permeate forms about 65–80% of the total milk used for manufacturing Fetta and Cheddar cheeses[5]. The functional properties of hydrolyzed whey permeate syrups as a substitute for sucrose in bread formulation has been studied by Ogunrinola *et al.*[6] Their results indicated little significant difference in the yeast fermentation rate, proof time, and bread quality among doughs formulated with sucrose. The dairy industry has been developed recently in Saudi Arabia. The process of ultrafiltering milk for cheese production has been incorporated into many dairy plants which has resulted in large quantities of permeate being produced. At the same time, water supply represents a major cost factor for the food industry in Saudi Arabia, therefore, reducing the water consumption is of great importance for the food industry. Unlike whey, milk permeate has no caseins or β-lactoglobulin. Many studies have been made on the effect of whey and whey permeate, but not milk permeate, on functional properties of doughs and breads. Therefore, the use of milk permeate as bakery additives is of interest due to the limited amount of research in this area. The objectives of this study were to examine the possibility of replacing water in white pan bread formulation with milk permeate, and to find the best combination of water and fermented or unfermented permeate in relation to their effects on the mixing properties of bread doughs, the pasting properties of starch, and on the eating and keeping qualities of bread.

Milk permeate was prepared by running fresh cows milk through a sanitary commercial ultrafiltration system operated at 50 °C with a pressure of 3 bar at the National Agricultural Development Corporation dairy plant (Harad, Saudi Arabia). The resulting permeate has 5·6% total solids, 4·9% lactose, 0·45% ash, 0·20% protein and 0·0% fat. The permeate was pasteurised at 72 °C for 15 s.

Freeze-dried lactic culture Thermophilic lactic culture type yoghurt CH-1 (Chr. Hanse's Laboratorium, Denmark) was used. The culture was inoculated in sterilised skim milk and incubated at 40 °C, then reactivated by three successive subcultures in sterilised skim milk medium. The

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pasteurised permeate was inoculated with the activated culture at a level of 1% and incubated at 37 °C for 24 h. Water was replaced at levels of 25, 50, 75 and 100% with fermented and unfermented permeate and used for bread preparation. Farinograph tests were made according to AACC methods[7] 54-21. Owing to low flour *alpha*-amylase activity in the experimental wheat, a modified Amylograph procedure according to AACC methods[7] 22-10 was performed using a 55 g sample. Because the flour showed a high peak viscosity over 1000 BU, a 200 g weight was added to prevent readings from going off-scale.

A bread formula[8] was chosen for this experiment. A commercial local bread making hard flour with extraction of about 73% (Grain Silos & Flour Mills Organization, Saudi Arabia), with protein content of 11·5%, was used in this experiment. Dry ingredients (flour 100%, sugar 3%, salt 1·5%, shortening 1% and instant active dry yeast 2%) were mixed at low speed for 1 min using a Hobart mixer Model A-120 (The Hobart Manufacturing Company, Troy, Ohio U.S.A.). Permeate-water mixture was added (based on the Farinograph optimum absorption) and mixed for 2 min at low speed. The mixing speed was then changed to medium for 2 min, and then at high speed for 1 min. The dough was divided into pieces of 175 g, rounded by hand, and allowed to relax for 20 min in a fermentation cabinet at 30 °C and 90% relative humidity (rh). The doughs were moulded with a SH-E-L Pat Bend molder (National Mfg, Lincoln, NE, U.S.A.). Doughs were panned and proofed for 55 min at 30 °C and 90% rh. The proofed pieces were baked at 220 °C for 20 min. Loaf weights and volumes were measured by rapeseed displacement immediately after baking. Breads were evaluated according to Pyler[9]. A penetration test for the measurement of crumb firmness of breads was performed using a penetrometer (Stanhope-Seta Setamatic Penetrometer, Surrey, U.K.) with a cone weight of 102·3 g. The distance travelled was measured in millimetres at 0, 3 and 6 days of storage at room temperature. A multiple comparison statistical procedure using Fisher's least significant difference (LSD) procedure using PC-SAS (SAS software version 6.11, SAS Institute, Cary, NC, U.S.A.) was used to determine the significance of the differences among various experimental treatments.

Unfermented and fermented permeate increased the Farinograph water absorption (Table I). Doughs with 100% of unfermented or 25% of fermented permeate had significantly higher water absorptions than other treatments. This was reminiscent of the results reported by Erdogdu *et al.*[10], who observed that dairy ingredients including whey powder increased water absorption. The Farinograph peak time was significantly increased at 50 and 75% of unfermented permeate. However, the Farinograph peak time was significantly decreased by fermented permeate. This could be due to the lower lactose content of fermented permeate, and the increased hydrogen ion concentration, which affects the solubility of salts[11]. The substitution of water with unfermented permeate up to 100% and fermented permeate up to 50% increased the Farinograph stability time. This was associated with a significant increase in dough mixing tolerance. The increase in the mixing tolerance could be explained on the basis that permeate did not contain either caseins or β-lactoglobulin. Volpe and Zabik[12] postulated that interaction between κ-casein and β-lactoglobulin with dough proteins caused the mixing tolerance to be reduced. The Farinograph arrival time showed a wide range of variation among all treatments. The substitution of water with 50–100% of unfermented permeate and 50–75% of fermented permeate significantly reduced the arrival time. Both fermented and unfermented permeate significantly prolonged the Farinograph departure time. This was more marked at 50% of unfermented permeate.

Substituting water with fermented or unfermented permeate significantly increased the gelatinisation temperature compared with the control (100% water) as determined using the Amylograph (Table I). Except for 100% substitution of fermented permeate, both fermented and unfermented mixtures caused the maximum viscosity to be significantly increased. The values for maximum viscosity were higher for fermented compared with the unfermented permeate. The high increase in maximum viscosity when fermented permeate was used could be due to the increase in the hydrogen ion concentration. Moreover, the calcium and phosphate present in the permeate may both cause association or dissociation of dough components[13], which might influence the starch pasting properties.

The highest loaf volume was obtained with 50% of unfermented and fermented permeates (Table I). Our results indicate that permeate at 50% substitution is most effective in increasing the loaf volume. This could be due to lactose and lactic

Table I Effect of substituting water with milk permeate on Farinograph dough mixing properties, Amylograph pasting properties and breadmaking quality

	Water	Unfermented permeate				Fermented permeate			
	100%	25%	50%	75%	100%	25%	50%	75%	100%
Farinograph properties:									
Absorption(%)	65^{bc}	66·4^{ab}	66·2^{ab}	66^{abc}	67^{a}	67·5^{a}	64·4^{c}	65^{be}	65·2^{d}
Peak time (min)	10^{bc}	11·5^{b}	15·5^{a}	16^{a}	10^{bc}	10^{bc}	8^{ed}	7^{e}	9^{cd}
Stability (min)	15^{d}	17·5^{c}	23^{a}	18·5^{bc}	19·5^{b}	7^{f}	19·5^{b}	17·5^{c}	13^{e}
Mixing tolerance index (BU)	20^{e}	35^{b}	30^{c}	30^{c}	40^{a}	40^{a}	40^{a}	20^{e}	25^{d}
Arrival time (min)	2^{c}	1·5^{d}	1·5^{d}	1·5^{d}	2^{c}	5·5^{a}	1·5^{d}	1·5^{d}	5^{b}
Departure time (min)	17^{d}	19^{c}	24·5^{a}	21^{b}	21·5^{b}	12·5^{e}	21^{b}	19^{c}	18^{cd}
Amylograph properties:									
Gelatinisation temperature	39^{c}	43·5^{b}	42^{bc}	43·5^{b}	46·5^{a}	42^{bc}	43·5^{b}	42^{bc}	43·5^{b}
Maximum viscosity (BU)	560^{f}	590^{e}	650^{d}	660^{d}	520^{g}	690^{c}	860^{b}	870^{ab}	880^{a}
Temperature of maximum viscosity (°C)	72·8^{a}	72·8^{a}	72^{a}	72^{a}	71·3^{a}	71·3^{a}	72^{a}	72^{a}	72^{a}
Breadmaking performance:									
Loaf volume	680de	670^{e}	775^{a}	670^{e}	677de	690^{cd}	715^{b}	692^{cd}	700^{cb}
Bread score:									
Volume (15)	13·2^{e}	13^{e}	15^{a}	13^{e}	13^{e}	13·4^{cd}	13·8^{b}	13·4^{cb}	13·6^{bc}
Crust colour (5)	4·2^{ab}	4·3^{ab}	3·8^{b}	3·7^{b}	3·7^{b}	4·8^{a}	5^{a}	4·43^{ab}	4·3^{ab}
Symmetry (5)	4·2^{ab}	3·7^{b}	4·7^{a}	3·8^{ab}	4·2^{ab}	4·7^{a}	4·3^{ab}	4·3^{ab}	4·3^{ab}
Bake uniformity (5)	4·7^{a}	4·3^{a}	4·3^{a}	4·2^{a}	4·2^{a}	5^{a}	5^{a}	4·2^{a}	4·5^{a}
Texture (15)	13·5^{b}	13·8^{ab}	14·3^{ab}	13·8^{ab}	14·3^{ab}	14·2^{ab}	15^{a}	14·3^{ab}	15^{a}
Crumb colour (10)	9^{bcd}	8·7^{cd}	9·3^{abcd}	8·5^{d}	8·5^{d}	9·5^{abc}	10^{a}	9·5^{abc}	9·7^{ab}
Grain (10)	8·3^{b}	9·7^{a}	8·7^{ab}	9·7^{a}	8·5^{ab}	8·7^{ab}	8·8^{ab}	9·2^{ab}	9·2^{ab}
Aroma (15)	12·7^{b}	13·7^{ab}	13·5^{ab}	13·5^{ab}	13^{b}	14·5^{a}	14·5^{a}	14·5^{a}	14·3^{a}
Taste (20)	16·3^{b}	18^{a}	18^{a}	18^{a}	17·7^{ab}	18^{a}	18·7^{a}	19^{a}	18·3^{a}
Total (100)	86·1^{b}	89·2^{ab}	91·6^{ab}	88·2^{b}	87·1^{b}	92·8^{ab}	95·1^{a}	92·83^{ab}	93·2^{ab}
Bread firming [Penetration (mm)]:									
0 days	26·1^{bcd}	24·4^{d}	28·1^{ab}	24·3^{d}	27·4^{bc}	25·3^{cd}	27·6^{abc}	24·5^{d}	30^{a}
3 days	19·6^{c}	19·5^{c}	20·4^{ab}	18·9^{c}	20^{abc}	21·3^{a}	20^{abc}	20^{abc}	21^{a}
6 days	18·2^{bc}	18·3^{bc}	20·2^{a}	17·1^{c}	18·8^{abc}	19·1^{ab}	17·3^{bc}	18^{bc}	19·5^{ab}

Within each row, means with the same letter are not significantly different.

acid fermentation which may stimulate the gas formation during dough proofing.

Substitution of water with 50% of unfermented and fermented permeates significantly increased the score for loaf volume compared with the rest of the treatments and the control (Table I). Crust colour was significantly improved at 50% of fermented permeate. However, the unfermented permeate did not significantly improve the crust colour. This may have been due to the high lactose levels producing a dark brown crust colour due to increased Maillard reaction products at high substitution. The highest score for symmetry was noticed at 50 and 25% for unfermented and fermented permeates, respectively. There were no significant differences among all treatments in their effect on the uniformity of bake. Substitution of water with fermented or unfermented permeate significantly improved the crumb texture and colour and this was more remarkable for fermented permeate. This may be due to the lower lactose content in the fermented permeate. Bread grain, aroma and taste were improved as a result of permeate substitution, but the fermented permeate was more effective in this respect. A significant improvement in softness was observed with 50 and 100% substitution with unfermented and fermented permeates, respectively (Table I). The effects of using modified permeate as a bakery additive by means such as high heat treatment, drying and hydrolyzing the lactose using enzymes need to be studied. Furthermore, investigating the substitution of sugar with milk permeate in breadmaking is highly recommended.

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