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Effect of shortening and surfactants on selected chemical/physicochemical parameters and sensory quality of Arabic bread

Imad Toufeili,* Sossy Shadarevian, Adnan M. A. Miski & Iman Hani

Department of Food Technology and Nutrition, FAFS, American University of Beirut, Beirut, Lebanon

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Shortening (0·5 or 1·0% on flour-mass basis), distilled monoglycerides (MG), sodium stearoyl-2-lactylate (SSL), diacetyl tartaric acid esters of monoglycerides (DATEM) or L-ascorbyl-6-palmitate (AP) at the 0·25 or 0·50% level, and shortening/surfactant combinations were added to Arabic bread and the effects on water-binding capacity (WBC), amylose content of soluble starch and sensory properties evaluated. WBC and percentage amylose of soluble starch were not affected by shortening and decreased in the presence of surfactants. The sensory quality of breads was not affected by shortening. At the 0·25% level, the first-day quality was not affected by MG and improved in the presence of SSL, DATEM or AP. High levels (0·5%) of surfactant adversely affected the breads' first-day quality. Addition of shortening to surfactant-containing formulations negatively affected the first-day quality of the product. Surfactants, alone or in combination with shortening, had deleterious effects on the keeping quality of Arabic bread.

INTRODUCTION

Flat breads are the main dietary staple of many populations in the Third World. Apart from crisp breads, these breads have a notably poor shelf-life (Faridi, 1988). The positive contribution of shortening and surfactants to pan bread characteristics, including an established reduction in the staling rate, has led different workers to harness their functionality in an endeavour to prolong the shelf-life of flat breads. To this end, a significant reduction in the staling rate of Iranian Barbari bread and Indian Chapati has been achieved upon incorporation of shortening, monoglycerides (MG) and sodium stearoyl-2-lactylate (SSL) into the bake mix (Maleki *et al.*, 1981; Swaranjeet *et al.*, 1982; Sidhu *et al.*, 1989). Likewise, the keeping quality of the pocket-type flat Arabic bread has been reported to benefit from the inclusion of shortening and SSL in the formula (Qarooni *et al.*, 1989).

Evidence indicates that surfactants retard staling via complexing with amylose, thus reducing its leaching from the granule, minimising granule swelling and possibly through reducing the rate of retrogradation of amylopectin within the partially swollen starch granules (Schuster & Adams, 1984; Stauffer, 1990). The improving effects of shortening (i.e. increased loaf volume, better grain characteristics and retention of freshness) have been linked to its modulation of protein-native polar lipid interactions in dough systems (Pomeranz, 1988).

Apart from shortening and SSL, the effects of MG, diacetyl tartaric acid esters of monoglycerides (DATEM) and L-ascorbyl-6-palmitate (AP) on quality parameters of Arabic bread have not, as yet, been evaluated. Furthermore, in contrast to the numerous studies on pan bread, no information exists as to the effects of shortening and surfactants on the biochemical/physicochemical characteristics of Arabic bread. In the present work, the effects of shortening, AP, DATEM, MG and SSL on sensory quality, composition of soluble starch and water-binding capacity (WBC) are evaluated in an attempt to clarify their functionality in the pocket-type flat Arabic bread.

MATERIALS AND METHODS

Materials

A commercial baker's flour (moisture, 14·65%; protein (N × 5·7), 10·3%; fat, 0·43%; ash, 0·62%; falling number, 400 s; farinograph absorption, 58·0%; resistance to extension (135 min pull) 650 extensograph units; extensibility, 120·0 mm; AACC, 1983) was used in the

*Address for correspondence: FTN/FAFS, AUB/Lebanon, c/o AUB Office, 850 Third Avenue, 18th Floor, New York, NY 10022, USA.

preparation of bread samples. Powdered preparations of distilled MG (AMIDAN SDM-T), SSL (ARTODAN SP55) and DATEM (PANODAN 150) were obtained from Grindsted products (Brabrand, Denmark). AP was obtained from Hoffmann-La Roche (Nutley, NJ, USA). Active dry yeast (Fermipan, Gist Brocades Co., Delft, the Netherlands), a hydrogenated vegetable oils shortening free of emulsifiers (Creamtex, Durkee Industrial Food, SCM Corp., Cleveland, OH, USA), table sugar and salt were procured from the local market.

Preparation of bread samples

Doughs contained flour (1000 g), sugar (30 g), salt (15 g), yeast (10 g) and variable amounts of water to optimum dough consistency; the 850 Brabender units (BU) line was the reference value used for optimum consistency. When added, the surfactants were sifted with the flour to ensure a uniform distribution throughout the dough. Doughs were prepared and baked at 500°C for 30 s as described by Maleki and Daghir (1967). After baking, the loaves were allowed to cool at room temperature (*c.* 10 min) and then stored in sealed polyethylene bags to prevent moisture loss.

Chemical/physicochemical analyses

Bread moisture was determined by the AACC two-stage procedure (AACC, 1983). For the determination of WBC and amylose content, 0·1-h-old loaves were freeze-dried (Stokes 902-18, Penwalt Corporation, Philadelphia, PA, USA) to 2–3 g/100 g moisture content and ground in a coffee grinder (Moulinex 241, France) to pass through 300-μm perforations. Ground samples were stored at –20°C in air-tight containers until analysed. WBC was measured by the alkaline-water-retention-capacity test as reported by Yamazaki *et al.* (1968) and without adjusting to 14% moisture. The WBC is reported as the weight gain per 100 g dry solids. Soluble starch was isolated and defatted as described by Morad and D'Appolonia (1980) and its amylose content determined colorimetrically (Morrison & Laignelet, 1983). Amylose content is reported as percent soluble starch. Analyses were carried out in duplicate on two replicate bakes.

Sensory evaluation

Bread samples were judged for their quality on two consecutive days. Two hours after baking, loaves (three-digit codes) from three different treatments were randomised and evaluated by five highly trained assessors for their cracks, crumb colour, grain, rollability, tearing quality and chewiness. On the second day, loaves from the same treatments were judged for their keeping quality on the basis of their rollability and tearing quality after 36 h of baking. The samples were rated on a four-interval scale anchored with the following descriptors: very poor, poor, satisfactory, good and excellent. The aforementioned quality parameters have been defined previously (Williams *et al.*, 1988; Quail *et al.*, 1990) and are shown, along with their maximum scores, in Table 1. Assessments were carried out in triplicate in partitioned booths equipped with white light.

Table 1. Maximum scores of Arabic bread quality attributes

	Attribute	Maximum score
First day	Cracks	5
	Crumb colour	5
	Grain	5
	Rollability	10
	Tearing quality	10
	Chewiness	10
Second day	Rollability	10
	Tearing quality	10
Total score		65

Experimental design and statistical analysis

Each surfactant was used at three levels (0, 0·25% and 0·5%) in a 2 × 3 factorial design with shortening levels of 0, 0·5 and 1% on flour-mass basis. For each surfactant, data were subjected to a factorial analysis of variance to determine differences between the treatments. Differences between the untreated control and individual treatment levels were ascertained by Dunnett's test. Treatment levels are defined as the responses from the individual surfactant type for each surfactant/shortening amounts (0/0, 0·25/0, 0·50/0, 0/0·50, 0·25/0·50. 0·50/0·50, 0/1, 0·25/1 and 0·5/1). The reproducibility of determinations was estimated by analysis of variance of a nested classification of the data. The factorial, one-way and nested-design analyses of variance were carried out as outlined by Gacula and Singh (1984) and Caulcutt and Boddy (1983) using the MSTAT (1989) programs FCOVAR, AOV and CORREG, respectively.

RESULTS AND DISCUSSION

The WBC, amylose content of soluble starch, first-day score, second-day score, total score and moisture content of breads are shown in Table 2. Factorial analysis of variance (data not shown) indicated that, apart from a non-significant effect of DATEM on WBC, the surfactants significantly affected the WBC and percentage amylose of soluble starch of bread. The statistical significance of the surfactant was, in general, mainly due to linear rather than quadratic effects. Shortening levels did not significantly affect the WBC or the amylose content of soluble starch of the samples. The sensory properties of bread were significantly affected by the shortening and surfactant levels. The first-day, second-day and total scores were affected more by changes in the surfactant levels rather than shortening levels. The statistical significance of both factors, as well as their interactions, was due to linear and

Table 2. Effect of shortening and surfactants on Arabic bread

Additive[a]	Water-binding capacity[b] (g H_2O bound/ 100 g dry solids)	Amylose[b] (% soluble starch)	First-day score[c]	Second-day score[c]	Total score[c]	Moisture content[b] (%)
0/0 (control)	326	17·4	37·5	17·9	55·4	23·4
0/0·5	315[d]	15·8[d]	37·6[d]	16·5	54·1[d]	23·9[d]
0/1·0	312[d]	15·3[d]	39·2[d]	17·1[d]	56·3[d]	23·1[d]
MG						
0·25/0	299	5·52	36·4[d]	16·7[d]	53·1[d]	23·4[d]
0·50/0	239	ND[e]	28·3	10·1	38·4	23·4[d]
0·25/0·50	303	4·44	32·3	10·4	42·7	22·8[d]
0·50/0·50	231	ND	22·7	9·1	31·8	23·6[d]
0·25/1·0	304	3·90	32·7	13·1	45·8	23·6[d]
0·50/1·0	225	ND[e]	25·5	12·9	38·4	23·6[d]
SSL						
0·25/0	311[d]	9·30	40·8	14·7	55·5[d]	25·0[d]
0·50/0	290	6·59	28·4	8·5	36·9	26·6
0·25/0·50	310	8·74	37·2[d]	11·5	48·7	25·8
0·50/0·50	294	5·92	29·3	6·7	36·0	24·2[d]
0·25/1·0	307	8·45	39·0[d]	10·4	49·4	24·7[d]
0·50/1·0	287	5·46	22·4	5·5	27·9	24·2[d]
AP						
0·25/0	294	10·6	41·4	14·4	55·8[d]	26·1
0·50/0	277	8·03	29·4	7·1	36·5	26·5
0·25/0·50	292	9·81	40·4	14·8	55·2[d]	27·4
0·50/0·50	228	8·17	29·3	6·0	35·3	25·9
0·25/1·0	289	9·54	39·4[d]	13·1	52·5	25·7
0·50/1·0	263	7·66	26·3	5·1	31·4	27·5
DATEM						
0·25/0	313[d]	13·2	41·1	9·0	50·1	24·7[d]
0·50/0	304	12·5	28·8	5·9	34·7	26·1
0·25/0·50	314[d]	12·3	40·8	8·5	49·3	26·5
0·50/0·50	305	11·4	23·4	4·7	28·1	26·9
0·25/1·0	298	13·3	28·3	6·9	35·2	26·5
0·50/1·0	301	10·8	15·2	3·5	18·7	26·3
SEM[f]	2·27	0·33	0·26	0·15	0·33	0·43
LSD[g] (α = 0·05)	4·45	0·85	1·30	0·88	1·72	2·66

[a]First and second numbers indicate percent surfactant and shortening, respectively (on flour-mass basis); (MG, monoglycerides; SSL, sodium stearoyl-2-lactylate; AP, L-ascorbyl- 6-palmitate; DATEM, diacetyl tartaric acid esters of monoglycerides).
[b]Average of duplicate determinations on two replicate bakes.
[c]Average of three determinations. For details of this scoring system refer to Table 1; maximum first-day, second-day and total scores are 45, 20, 65, respectively.
[d]Values do not differ significantly ($P < 0{\cdot}05$) from the control by Dunnett's test.
[e]Not detected.
[f]Standard error of the mean.
[g]Least significant difference.

quadratic effects, with the linear effects contributing more as judged by their larger mean squares. When compared by Dunnett's test, it was evident that both physicochemical and subjective measurements of the experimental breads are significantly altered as compared to the control.

Effect on water binding capacity and amylose content of soluble starch

The WBC and the percentage amylose of soluble starch of the samples were affected by the type and amount of surfactant incorporated into the bake mix. The parameters were affected most by MG and least by DATEM, with AP and SSL exhibiting intermediate effects.

The WBC of bread is largely determined by the extent of starch gelatinisation during baking. The delay in starch swelling, and the concomitant decrease in the degree of gelatinisation in the presence of surfactants, have been linked to their adherence onto the surface of the starch granule and the formation of insoluble films which hinder the transport of water into the system (Eliasson, 1985). The efficacy of MG in curtailing starch gelatinisation in starch–water systems has been highlighted by several workers (Ghiasi *et al.*, 1982*a*; Riisom *et al.*, 1984) and a significant reduction in the WBC of pan bread has been noted upon inclusion of MG in the formula (Martin *et al.*, 1991). The relatively marginal effects of SSL on the WBC observed in the present study could be attributed to the loss of the structure-supporting effects of the surfactant on starch granules, at the high baking temperature. Starch swelling was shown not to be affected by SSL when suspensions were heated at temperatures above 85°C (Ghiasi *et al.*, 1982*a*; Eliasson, 1985). Furthermore, the gelatinisation characteristics of starch were not altered by SSL, at the concentrations employed in baking, in starch–gluten model systems (Eliasson, 1983). AP seemed to possess a stabilising effect on the starch granules, *vis-à-vis* swelling, as evidenced by the marked reduction in the WBC of the AP-containing samples as compared to the control. Moreover, the pattern of change in the WBC of the AP-containing breads was, in general, similar to that of samples prepared in the presence of MG, albeit of a lesser magnitude. Accepting the thesis that the crumb-softening effects of surfactants are mediated via interactions with the starch fraction of the dough, the present findings are in line with the reported similarities in functionality of AP and MG in pup loaves (Koch *et al.*, 1987). DATEM showed minimal effects on the WBC of breads with no significant differences from the control being detected at the 0·25% level (on flour-mass basis) of the surfactant in the absence and/or the presence of 0·5% shortening in the formula. The functionality of DATEM, presumably its antifirming effects in pan bread, has been attributed to its modification of the cell wall thickness and elasticity of the crumb rather than its interaction with the starch fraction of the dough (Krog *et al.*, 1989). The WBC of the bread samples was not affected significantly by the presence of up to 1% shortening in the formula. This finding is in accord with previous studies which showed no differences in the WBC of shortening-free and 2%-shortening-containing pita breads over 72 h of storage (Faridi & Rubenthaler, 1984).

All surfactant-containing samples had lower proportions of amylose in their soluble starch fraction, as compared to the control. This reduction is presumably due to the formation of amylose–surfactant complexes and has been reported by different workers in pan bread systems (Ghiasi *et al.*, 1979; Morad & D'Appolonia, 1980). In the present study, MG reduced the amylose content of soluble starch most, with no free amylose being detected at the 0·5% level of the surfactant. Differential scanning calorimetry of MG-supplemented pan bread has indicated that all free amylose is complexed by the surfactant when used at the 1% level on flour basis (Joensson, 1989). These differences could be attributed to variations in the bread formulations and/or the possible formation of a high proportion of MG-lamellar mesophases, considered as being the most efficient in promoting amylose–surfactant interactions (Krog, 1981), at the high-temperature/short-time baking procedures employed in the production of Arabic bread. Incorporation of SSL into the bake mix resulted in a pronounced reduction of amylose in the soluble starch fraction, as compared to the control. The reduction in the amylose content by SSL observed in the present study, despite its inefficacy in hindering the leaching of amylose from the swollen starch granules as implicated by the WBC data, could be attributed to the reformation of SSL–amylose complexes in the intergranular spaces of the breads upon cooling (Ghiasi *et al.*, 1982*b*). AP exhibited a noted affinity towards amylose as judged by the predominance of amylopectin in the starch leached from the AP-containing breads. The amylose-complexing ability of acyl esters of L-ascorbic acid has been invoked by Hoseney *et al.* (1976) to explain differences in their crumb-softening effects in pan bread. Among the surfactants studied in the present work, DATEM showed the least effects on the composition of soluble starch, a further evidence of its relatively weak interaction with the starch fraction in dough systems. Incorporation of shortening into the bake mix had no significant effect on the composition of the soluble starch fraction in Arabic bread.

Effect on sensory quality

Apart from DATEM, inclusion of the surfactants at the 0·25% level in the bake mix had no significant effect on the overall quality of the shortening-free samples. The first-day and the second-day scores were not affected by MG. The significant improvement in the first day quality observed in the presence of the other surfactants was largely due to an improvement in the tearing quality, chewiness and/or crumb colour of breads. More specifically, the AP-containing and DATEM-containing samples needed, desirably, slightly less force to affect tearing and had a more tender, *al dente* chew as compared to the control; the improving effect of SSL was associated with a superior tearing quality and more notably with an increased whiteness in the crumb colour. The deterioration in the keeping quality, as judged by the significantly lower second-day scores, was due to the reduction in the ability of the samples to resist stress (rollability) and shear (tearing quality), with the effects being most pronounced in the case of DATEM.

Despite the improvement in crumb colour, the overall quality of bread was adversely affected by the presence of 0·5% of the surfactants in the shortening-free formulations. Irrespective of the surfactant added, the loaves tore apart with very little resistance and had an excessively short bite when judged 2 h after baking. Furthermore, apart from the DATEM-containing loaves which showed similar grain properties to the control, the crumb acquired a woolly appearance marked by thick-walled non-uniform cells. Moreover, apart from the MG treatment where the integrity of the layers was not affected, the bottom layers of the loaves exhibited, at this level of surfactant addition, a large crack across the entire surface in addition to the numerous small cracks at the edges. The breads' rollability on the first day was not, generally, affected by this treatment. The deterioration in the indicated quality attributes is associated with a general 'weakening', presumably mediated through surfactant–gluten interactions, in the dough structure. Although the exact mechanism is largely unknown, the modification in the properties of gluten upon binding to polar lipids/surfactants is universally recognised and has great technological advantages in pan bread production (Greene, 1975; Knightly, 1988; Carr *et al.*, 1992). In the present work, incorporation of 0·5% surfactant into the bake mix seemed to impart a highly plastic nature to the gluten network, as evidenced by the reduced tolerance of the dough to the pressure of the rapidly expanding gases during baking. The extensive cracking of the loaf layers, coupled with the markedly reduced ability of the loaf to resist shearing forces, applied during manual tearing and mastication, are consistent with this hypothesis. After overnight storage, the loaves lost their elasticity as shown by their inability to resist shearing forces, and cracked extensively upon application of stress during rolling. Similar effects on Arabic bread quality were noted by Qarooni *et al.* (1989) upon incorporation of 0·5% SSL into the bake mix.

Apart from the AP treatment, where the overall quality was not significantly affected, addition of 0·5% shortening to the 0·25%-surfactant-containing formulations led to a deterioration in the quality of the breads. While negatively affected in the MG and SSL formulations, the breads' first-day quality was tolerant to the addition of 0·5% shortening to the doughs containing AP and DATEM. In general, the breads were more tender, as compared to their shortening-free counterparts, with the deterioration in quality being most apparent in the tearing quality and/or chewiness. The second-day scores were unaffected (AP, DATEM) and reduced (MG, SSL) by the presence of 0·5% shortening in the formula. However, while the first-day quality varied in its response, the keeping quality of the breads baked from the 0·25%-surfactant/0·50%-shortening combinations was decidedly inferior to the control. In a related study, Qarooni *et al.* (1989) noted a slight improvement in the keeping quality of Arabic bread prepared with 0·25% SSL in the absence or presence of 0·5% shortening in the formula. The negative effects of the aforementioned treatments on the keeping quality of Arabic bread observed in the present study could be attributed to the inherent subjectivity of the judging procedure and the differences in the scoring systems used to assess quality. Moreover, it is noteworthy that, in contrast to the deleterious effects of relatively low concentrations (50–70 ppm) of ascorbic acid on Arabic bread quality (Qarooni *et al.*, 1989), the quality of the product was not affected significantly by the presence of 0·25% AP in shortening-free and 0·5%-shortening-containing formulations. Incorporation of 1% shortening to the 0·25%-surfactant-containing formulations significantly reduced the total scores of the breads. The deterioration was, again, associated with an excessive tenderness in the loaves. Apart from DATEM, where a noted deterioration was observed, the breads' first-day quality was not affected by increased levels of shortening in the dough. In contrast to the other treatments, the keeping quality of the MG-supplemented loaves benefited from increased levels of shortening in the bake mix.

Addition of shortening to the 0·5%-surfactant-containing formulations imparted excessive softness to the doughs. Upon baking, the doughs yielded over-tender loaves with thick layers which tore with relatively no resistance, cracked to varying degrees upon rolling and had an excessively short bite akin to that of pan bread, as judged by the first-day assessments. After overnight storage, the breads generally staled at a faster rate than their shortening-free counterparts. The negative effects of shortening on bread quality were most apparent at the high (1%) level of addition. In effect, the shortening seemed to amplify the aforementioned deleterious effects of high levels (0·5%) of surfactants on bread quality.

The overall quality of bread was not affected significantly by the incorporation of shortening into the formula. This is in line with earlier findings which indicated no change in the quality of pita bread baked from low extraction rate flours upon the addition of 1% shortening to the bake mix (Faridi & Rubenthaler, 1984).

CONCLUSIONS

Similar to pan bread systems, the water-binding capacity and the amylose content of the soluble starch fraction of Arabic bread are reduced by the presence of food-grade surfactants in the formula. Increased whiteness of the crumb is the most tangible positive effect of surfactants on Arabic bread quality. However, the keeping quality of the product does not benefit from the inclusion of shortening, surfactants and/or shortening/surfactant combinations in the bake mix. The overall quality of Arabic bread was tolerant to the presence of 0·25% of L-ascorbyl palmitate in the formula. In addition, at this level of incorporation, the surfactant seemed to enhance the 'bready' flavour of the product. These observations, coupled with the marginal effects of the high-temperature/short-time baking procedure on vitamin C activity of L-ascorbyl palmitate, point to the potential usefulness of the surfactant in the fortification programmes of pocket-type flat breads.

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