Bread Staling Studies. I. Effect of Surfactants on Moisture Migration from Crumb to Crust and Firmness Values of Bread Crumb[1]

W. PISESOOKBUNTERNG and B. L. D'APPOLONIA,[2] Department of Cereal Chemistry and Technology, North Dakota State University, Fargo, ND 58105

ABSTRACT

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The effect of surfactants on moisture migration from the crumb to the crust of bread and firmness values of bread crumb were investigated. In bread containing surfactant, moisture migration from the crumb to the crust was greater than in the control bread. The level of surfactant commonly used in breadmaking, 0.5%, did not lower surface tension of water in bread crumb, and thus could not assist in moisture retention within the crumb. The adsorption of surfactant onto the starch surface, as well as the complex formation between starch and surfactant, prevented starch from taking up water released from gluten during bread aging. Consequently, this water released from the gluten would be available to migrate from the crumb to the crust of the bread. Surfactant did not appreciably affect firmness of fresh bread crumb, but did slow the firming rate of bread crumb during bread storage. The lower firmness values of bread as the bread aged suggested that sodium stearoyl lactylate had the strongest binding ability with starch among the surfactants studied.

For more than 30 years, surfactants or emulsifiers have been used to improve the quality of baked products (Birnbaum 1977). Surfactants that function as bread softeners by complexing with starch and interacting with gluten are referred to as dough conditioners and are commonly used in bread-type products.

Birnbaum (1955) concluded that surfactants reduce the effective concentration of moisture in the starch phase and increase the moisture retention of the gluten, tying up moisture in the bread crumb. Surfactants would thus assist in moisture retention during the baking and aging of bread and give greater initial crumb softness (Coppock and Cookson 1954, Coppock et al 1958).

Although several studies on the role of surfactants in retarding bread firmness have been published, the mode of their action in improving the shelf life of bread has been controversial. One hypothesis has been that surfactants form a complex with amylose, resulting in softer crumb in the fresh bread but without influencing the firming rate (Schoch 1965). Other workers have shown that surfactants have little or no effect on initial bread crumb firmness but do affect the firming rate during storage (Favor and Johnston 1947, Ofelt et al 1958, Skovholt and Dowdle 1950). Published data also have shown that surfactants can form a complex with amylopectin (Knightly 1948).

We investigated the effect of surfactants on moisture migration from the crumb to the crust in bread and studied the effect on firmness values of the bread crumb.

MATERIALS AND METHODS

Flour Sample

We used a high-protein commercial flour containing 13.7% protein and 0.43% ash, with a farinograph absorption of 65.1%, expressed on a 14.0% moisture basis.

Baking Additives

Sodium stearoyl-2-lactylate (Emplex) was obtained from Patco Products Division, C. J. Patterson Co., Kansas City, MO. Tandem 8, a soft plastic form of 40% polysorbate 60 and 60% mono- and diglycerides, and Atmul 500, a soft plastic form of mono- and diglycerides were obtained from ICI Americas, Wilmington, DE.

Bread-Baking Procedure

Bread was prepared from the following formula (flour weight): 1,500 g flour, 5% sugar, 2% salt, 3% compressed yeast, 3% shortening, and 63% water.

A 2-hr fermentation at 86° F and 80% relative humidity (rh) with a single punch after 55 min was used. After fermentation, the dough was scaled into 500-g pieces and allowed to rest for 20 min before molding into pans. The panned loaves were proofed for 55 min and baked for 25 min at 400° F. The breads investigated were: control, control + SSL, control + Tandem 8, and control + Atmul 500. The level of each surfactant used in the bread formula was 0.5% (flour weight). Bread was cooled at room temperature for 2 hr before it was sliced. The storage temperatures studied were 2 and 30° C.

Moisture Migration

So that moisture migration from the crumb to the crust could be measured, five loaves of bread were baked from 1,500 g of flour, cooled for 2 hr, and sliced. The crust of one loaf was removed, and crumb moisture of the slice in the center of the loaf was measured.

Two of the loaves, with their crusts intact, were wrapped in polyethylene bags and stored under suitable temperatures. One of these loaves was removed from storage after one day and decrusted. Crumb moisture of the center bread slice was measured after the decrusted loaf was left at room temperature for 45 min. The other loaf remained in storage for four days, then was removed, decrusted, and left at room temperature for 45 min. Crumb moisture of the center bread slice was then measured.

The remaining two loaves were decrusted before they were wrapped in polyethylene bags and stored under the same conditions as the two loaves whose crusts had been left intact. One loaf was removed from storage after one day and allowed to sit at room temperature for 45 min. Crumb moisture of the bread slice in the center of the loaf was then measured. The other decrusted loaf was removed from storage after four days. Crumb moisture of the center slice was measured after the loaf was allowed to sit at room temperature for 45 min.

Crumb moisture on all loaves was determined according to AACC standard procedure 44-18 (AACC 1962).

Firmness Values

Firmness values of bread slices from five loaves were measured with the aid of an Instron Universal Testing Instrument (Instron Corporation, Canton, MA). Three slices from each loaf—the center slice and the slices on either side of the center—were used for all measurements. The bread slices were compressed 0.5 cm with a specially designed Plexiglas™ tooth described by Walsh (1971). Three measurements were made on each of the three slices of bread, and the results were averaged. The experiment was repeated three times, and average firmness values are based on 27 observations.

Five loaves of bread were baked from 1,500 g of flour, cooled 2 hr, and sliced, with the crusts left intact. Firmness of one loaf was measured immediately. The other four loaves were wrapped in

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[2] Graduate research assistant and professor, respectively. Present address of W. Pisesookbunterng: United Flour Mill Co., Ltd., 51 Poochaosmingprai Rd., Samutprakarn, Thailand.

polyethylene bags, and two of these were stored at 2° C. One was removed from storage after one day and left to sit at room temperature for 45 min. With the crusts still intact, firmness was measured. The other loaf stored at 2° C was removed after four days, and firmness measurements were made after the loaf sat at room temperature for 45 min.

The two remaining loaves were stored at 30° C. One loaf was removed after one day, and firmness was measured after the loaf had sat 45 min at room temperature. After four days of storage the other loaf was removed, and its firmness was measured after it had remained at room temperature for 45 min.

RESULTS AND DISCUSSION

Moisture Migration

The results of moisture migration from the crumb to the crust are shown in Table I. Each bread sample with and without surfactant and stored with crust intact showed a definite decrease in crumb moisture after one and four days of storage at 2 and 30° C, respectively. Confirming the results of Bechtel et al (1953), the crumb moisture of bread stored without crust at 2 and 30° C remained essentially constant. For this reason, the crumb moisture values of bread samples stored without crust at 2 hr after baking and after one and four days of storage were averaged, and this value was used to determine moisture migration from the crumb to the crust of the bread at a given temperature. So that moisture migration could be determined, the crumb moisture of bread stored with crust was subtracted from this average value. In bread stored at 30° C, greater moisture migration occurred from the crumb to the crust than in bread stored at 2° C.

Interestingly, after storage for one and four days at 2 and 30° C, bread with surfactant had greater moisture migration from the crumb to the crust than the control bread. Since bread is very seldom wrapped in an airtight container, moisture migration from the crumb to the crust may occur. This moisture is finally lost in the space between the wrapping material and the surface of the bread. Salas and Labuza (1968) found that when fruits and vegetables are treated with a high concentration of surfactant, the surface tension of water in the pores of the fruit or vegetable is reduced, resulting in reduced drying rate or reduced moisture migration and greater moisture retention in the food. At a concentration of surfactant below 1%, however, the moisture content of the treated food differed little from that of the control. The study by Schott (1967) showed that the surface tension of the liquid is not lowered until the amount of surfactant adsorbed on the material is sufficiently high, as it may be at 1%. This suggests that the concentration of surfactant should exceed 1% in order that the surface tension of the water will be lowered and the higher moisture content of the material maintained. The maximum effective level of most surfactants used in breadmaking is 0.5% (flour weight).[3] This level of surfactant may not cause a decrease in the surface tension of water in the bread crumb, so the bread crumb containing surfactant would not assist in retaining moisture, compared to the control.

Bechtel and Meisner (1954) indicated that the moisture that migrated from the crumb to the crust during bread storage came largely from the gluten. Studies by Alsberg and Griffing (1927) and Bachrach and Briggs (1947) regarding the increased gluten hardening during storage due to the moisture shift from the gluten to the starch are pertinent to the present investigation. The above investigators suggested that water associated with gluten may be transferred to the starch or the crust during bread storage. In bread containing surfactant, the adsorption of surfactant onto the starch surface might not allow the starch granules to take up water released by gluten to the same extent as the control bread. As previously noted, a level of 0.5% of surfactant may not be high enough to reduce the surface tension of the water in bread crumb. Consequently, water released by gluten in bread containing a surfactant during storage would be available for migration from the crumb to the crust.

Although the greater moisture migration from the crumb to the crust of bread containing surfactant may tend to promote crust staling, crumb staling in such bread has been found lowered in a number of studies (Favor and Johnston 1947, Ofelt et al 1958, Skovholt and Dowdle 1950). Crust staling is generally less objectionable than crumb staling (Newbold 1976).

Firmness Values of Bread Crumb

Firmness values of bread crumb with and without surfactant are

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TABLE I
Crumb Moisture of Bread Stored With and Without Crust and Moisture Migration from Crumb to Crust[a]

		Storage Temperature					
		2°C			30°C		
Bread	Storage Time[b] (Days)	Without Crust (%)	With Crust (%)	Moisture[c] Migration (%)	Without Crust (%)	With Crust (%)	Moisture[c] Migration (%)
Control	0	45.42	···	···	45.28	···	···
	1	45.16	44.83	0.34	44.95	43.56	1.62
	4	44.94	43.73	1.44	45.31	40.70	4.48
		45.17[d]			45.18[d]		
With sodium stearoyl lactylate	0	45.36	···	···	45.36	···	···
	1	45.06	44.64	0.47	44.81	42.85	2.32
	4	44.92	42.84	2.27	45.34	39.84	5.33
		45.11[d]			45.17[d]		
With Tandem 8	0	45.31	···	···	45.33	···	···
	1	45.01	44.46	0.61	45.02	43.54	1.69
	4	44.90	42.73	2.34	45.22	38.66	6.57
		45.07[d]			45.19[d]		
With Atmul 500	0	45.28	···	···	45.22	···	···
	1	44.96	44.66	0.41	44.82	43.54	1.69
	4	44.98	43.12	1.95	45.65	38.66	6.57
		45.07[d]			45.23[d]		

[a]Values are an average of three determinations.
[b]Bread moisture values at zero-day storage represent samples taken 2 hr after baking.
[c]Values reported are percentage points of change between moisture content of bread stored with crust intact and of bread stored without crust.
[d]Average of the three moisture values of bread without crust at zero, one, and four days of storage.

TABLE II
Effect of Surfactants on Firmness Values of Bread Crumb

Bread	Storage[a] Time (Days)	Values[b] at	
		2°C	30°C
Control	0	53	53
	1	234	102
	4	314	234
With sodium stearoyl lactylate	0	61	61
	1	171	89
	4	239	134
With Tandem 8	0	60	60
	1	212	102
	4	277	150
With Atmul 500	0	56	56
	1	221	100
	4	284	171

[a]Zero day storage represents bread 2 hr after removal from oven.
[b]Values expressed as g·cm and averaged from three determinations, each with three readings made on each of the bread slices.

given in Table II. The added surfactants did not appear to affect initial crumb firmness as shown by the firmness values for bread with and without surfactant measured 2 hr after baking. As storage time increased, firmness values of each bread with and without surfactant stored at 2 and 30°C increased because crumb rigidity increased. The firmness values of each bread containing surfactant stored at 2 and 30°C for one and four days were less than the control bread stored at the same temperatures. The results indicate that surfactants retard firming during bread storage rather than produce an initially softer crumb in the freshly baked bread. These results support those of earlier studies by Favor and Johnston (1947), Skovholt and Dowdle (1950), and Ofelt et al (1958). They conflict, however, with those of Schoch (1965), who found that surfactants gave a softer bread crumb in fresh bread but did not influence the firming rate.

Crumb firmness values or bread containing SSL after one and four days of storage were the lowest of all samples. An anionic surfactant such as SSL or polysorbate 60, present in Tandem 8, binds with protein during dough mixing and fermentation (Krog 1977) and thus strengthens dough. After three days of storage, the increased crumb harshness caused by the moisture loss from the gluten was of major importance in the staling process (Bechtel and Meisner 1954). The increased rigidity in gluten gels was also found to be less than that in flour and starch gels within one or two days after preparation, but the rigidity in gluten gels became evident after that time (Cluskey et al 1959). Consequently, the dough-strengthening effect resulting from incorporation of SSL and polysorbate 60 might affect the denaturation or configurational modifications of gluten in bread crumb, particularly those occurring after four days of storage. The increase in protein denaturation and possibly a configurational modification in the protein, in addition to starch retrogradation, are also involved in the firming process of the bread (Willhoft 1971a, 1971b).

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