# Effect of Surfactants and Baking Procedure on Total Water-Solubles and Soluble Starch in Bread Crumb[1]

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## ABSTRACT

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Conventional and continuous mix baking procedures were used to investigate the effect of five commercial surfactants on total water-solubles and soluble starch in bread crumb. The amount of soluble material extracted from the conventionally made bread was less than the amount from the continuous-mix baked bread. The amount of extractable soluble material decreased on aging; the decrease was greatest during the first 12 hr and smaller thereafter. The decrease in total solubles in the presence or absence of surfactant was not as great for the continuous-mix baked breads, which could be a result not only of the type of processing but also of difference in formulation. Extracts of bread crumbs containing surfactants and made by either baking procedure contained less amylose than did the control bread crumb, whether measured in the total soluble material or in the soluble starch. The data indicated that amylose and the surfactant formed a complex that varied among surfactants. Amylose content decreased as the bread aged; the decrease was greatest during the first 24 hr of storage. Estimated as a percent of the total extractable water solubles, the values for amylose in the soluble starch were lower for the continuous-mix than for the conventionally baked bread. Such results would be expected, because the amount of solubles in the continuous-mix bread crumb is greater. With the continuous-mix baking procedure, both the total soluble starch and the amylopectin content changed less as the bread aged than they did with the conventional baking procedure.

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Surfactants are most widely used by U.S. bakeries to retard firming in bread. Their function as crumb softening agents is closely related to their interaction with starch, particularly the linear amylose fraction of starch.

The ability of many surfactants to form complexes with amylose has been reported by numerous investigators, including Mikus et al (1946), Lord (1950), Strandine et al (1951), Bourne et al (1960), Osman et al (1961), Schoch (1965), Krog and Jensen (1970), Lagendijk and Pennings (1970), and Lonkhuysen and Blankestijn (1974). The concensus has been that the formation of such complexes with amylose in bread causes the bread-softening action of these compounds and their ability to retard bread staling.

Knightly (1948) and Krog (1971) suggested that surfactants might slow the rate of bread firming by forming a complex with the amylopectin fraction within the starch granule. De Stefanis et al (1977) showed that a crumb softener formed a complex with both the amylose and the amylopectin fraction of starch in bread.

Surfactants of different chemical structures differ widely in their effect on crumb firmness (Ofelt et al 1958). Schoch and French (1947) reported that free fatty acids depress both the amount and the iodine affinity of soluble starch leached from starch pastes.

Kim and D'Appolonia (1977) found that the amount of amylopectin in bread crumb decreases as bread ages. Although the amount of amylose in soluble starch from fresh bread is small, it sharply decreases during the first day of storage. Thereafter, the change in amylose is minor, and the amylopectin alone controls the retrogradation process.

The amount of soluble starch extractable from bread crumb is known to decrease as the bread is aged. This study, therefore, was undertaken to examine the effect of different commercially available surfactants on the total water-solubles and the soluble starch extracted from bread crumb after different periods of storage. Although results could not be directly compared because of differences in formulation, the conventional straight dough and the continuous-mix methods of bread production were examined.

## MATERIALS AND METHODS

### Flour Samples

Untreated and unbleached flour was from Waldron, a hard red spring wheat, milled on a pilot mill (Shuey and Gilles 1967). The flour had a protein content of 14.3% (14% mb), a Farinograph absorption of 63.8% (14% mb), a dough development time of 10 min, a stability value of 13 min, and a mechanical tolerance index of 20BU.

### Bread Samples

*Straight Dough Procedure.* A 3-hr fermentation, 55-min proof period at 30°C, and 25-min bake at 230°C were used. After fermentation, the dough was divided into 500-g portions and baked in 1-lb bread pans. The baking formula, based on flour weight, was as follows: 3,000 g of flour (14% mb), 5% sugar, 2% salt, 3% yeast, 0.5% surfactant, and 62.8% water.

*Continuous-Mix Baking Procedure.* The procedure of D'Appolonia et al (1971) was used with a Wallace and Tiernan laboratory model continuous baking unit (Baker Process Co., Belleville, NJ). The baking formula, based on flour weight, was as follows: 5,000 g of flour (14% mb), 8% sugar, 2.25% salt, 2% non fat dry milk, 0.5% yeast food, 2.75% yeast, 3.25% shortening, 67.8% water, 0.5% surfactant, 60 ppm potassium bromate, and 12 ppm potassium iodate. The surfactant was incorporated at the broth stage. The bread was baked for 20 min at 430° F.

For both baking procedures, the bread was removed from the oven and allowed to cool for 2 hr, except for samples collected before the 2-hr storage. These were sliced and stored in plastic bags at 30°C and a relative humidity of 85–90%.

The crust was removed from the sliced bread at different times after baking and the crumb frozen immediately and then freeze-dried. Crumb samples were collected at 10 min and at 1, 2, 5, 12, 24, 48, 72, and 96 hr after removal of the bread from the oven. The freeze-dried crumb was ground on a Wiley mill to pass through a 60-mesh sieve.

### Surfactants

Five commercially available monoglyceride and diglyceride types of surfactant were incorporated at the 0.5% level.

*Panatex.* Panatex is a hydrate of hard distilled monoglycerides manufactured to produce a uniform plastic dispersion containing at least 22.5% $\alpha$-monoglyceride (the active material). The surfactant was obtained from ITT Paniplus (Olathe, KS 66061).

*Dimodan P.* This is a powdered distilled monoglyceride in the free flowing form, made from refined hydrogenated lard consisting of 90% minimum monoester. Dimodan P was obtained from Grindsted Products, Inc. (Overland Park, KS 66212).

*Amidan B-250.* This powdered distilled monoglyceride is composed of distilled monoglyceride (82%) made from edible, refined hydrogenated fat and a mixture of food ingredients (18%) such as soya proteins and soya flour. The distilled monoglyceride

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had the following specification: monoester 90% minimum, free fatty acid 1.5% maximum, free glycerol 1% maximum, and an iodine value of 3. Amidan B-250 was also obtained from Grindsted Products, Inc.

*Tandem-8.* Tandem-8 is a creamy white plastic solid at 77°F consisting of approximately 37% total monoglycerides (alpha and beta forms) with 31% minimum of the alpha form. It was obtained from ICI United States Inc., Specialty Chemicals Division, Wilmington, DE 19897.

*Tally 100.* This is a light hard white type of emulsifier consisting of 32% monoglycerides and diglycerides with a monoglyceride content of 24–28%. Tally 100 was obtained from SCM Durkee Foods (Cleveland, OH 44115).

### Isolation of Total Water-Solubles

The water-soluble material was extracted from the freeze-dried bread crumb (5 g) with 30 ml of distilled water by agitating the mixture on a wrist-action shaker for 20 min. The slurry was centrifuged (2,000 × *g* for 5 min) and the supernatant filtered. The procedure was repeated twice on the residue, and the combined supernatants were frozen and freeze-dried.

### Isolation and Determination of Soluble Starch

Schoch and French's procedure (1947) was used with modifications to isolate and determine the soluble starch content in the total water-solubles extracted from the bread crumb before freeze-drying. Three volumes of methanol were added to the total water-solubles, and the mixture was heated on a steam bath for 1 hr and left overnight at 4°C. The flocculated soluble starch was collected by centrifugation (16,300 × *g* for 20 min), dispersed in 25 ml of distilled water, and freeze-dried. To remove traces of fatty material that could interfere with the estimation of iodine affinity, the soluble starch was Soxhlet-extracted for 16 hr with methanol.

### Determination of Amylose and Amylopectin Content in Soluble Starch

The amylose content in the soluble starch was determined according to the procedure of Williams et al (1970). A 20-mg sample was weighed into a 50-ml beaker, exactly 10 ml of 0.5*N* KOH solution was added, and the starch was completely dispersed. The dispersed sample was transferred to a 100-ml volumetric flask and adjusted to volume with distilled water. An aliquot of the test starch solution (10 ml) was pipetted into a 50-ml volumetric flask, and 5 ml of 0.1*N* HCl was added, followed by 0.5 ml of iodine reagent. The volume was diluted to 50 ml, and the absorbance of the blue color was measured at 625 nm after 5 min. A standard curve for amylose was prepared by the same procedure, using the amylose isolated from the control flour. The amylopectin content in the soluble starch was obtained by subtracting the amount of amylose from the total amount of soluble starch.

## RESULTS AND DISCUSSION

### Effect on Total Extractable Water-Solubles and their Amylose Content

The effects of five different commercial surfactants on the total amount of water-solubles extracted from bread crumb at different storage times, using the conventional straight dough and the continuous baking procedures, are shown in Table I.

The amount of soluble material extracted decreased as the storage time increased for the control and the surfactant-containing bread crumbs made by the straight dough procedure. The decrease in soluble material was greatest during the first 12 hr of storage; thereafter the bread crumbs containing surfactants showed smaller decreases in extractable soluble material. With the continuously baked bread, only a slight reduction in extractable soluble material occurred in the presence or absence of surfactants as the bread aged. The results with the conventionally made bread agree with the findings of Kim and D'Appolonia (1977). The higher amount of water-soluble material extracted from bread crumb made by the continuous baking procedure could be due to the difference in baking formula as well as to the elimination of the bulk fermentation stage used in conventional baking. The data in Table I might indicate that surfactants form a complex with some

TABLE I
Effect of Surfactants and Baking Procedure on Total Water-Solubles from Bread Crumb

| | Straight Dough Procedure | | | | | | Continuous Baking Procedure | |
|---|---|---|---|---|---|---|---|---|
| Storage Time (hr) | Control (%) | Panatex (%) | Amidan B-250 (%) | Dimodan P (%) | Tandem 8 (%) | Tally 100 (%) | Control (%) | Panatex (%) |
| 0.16 | 9.66 | 8.56 | 8.84 | 8.03 | 8.62 | 8.39 | 14.87 | 14.69 |
| 1 | 9.22 | 8.60 | 8.49 | 8.00 | 8.41 | 8.24 | 14.81 | 14.46 |
| 2 | 9.13 | 8.45 | 8.04 | 8.17 | 8.28 | 7.74 | 14.74 | 14.29 |
| 5 | 7.68 | 7.99 | 7.53 | 7.50 | 7.23 | 7.32 | 14.71 | 14.28 |
| 12 | 7.58 | 7.60 | 7.04 | 6.72 | 7.13 | 7.13 | 14.55 | 14.27 |
| 24 | 6.86 | 7.12 | 6.96 | 6.58 | 7.10 | 7.10 | 14.40 | 14.11 |
| 48 | 6.85 | 7.08 | 6.90 | 6.35 | 7.07 | 7.07 | 14.21 | 14.10 |
| 72 | 6.78 | 7.03 | 6.79 | 6.19 | 6.83 | 6.83 | 14.20 | 14.03 |
| 96 | 6.70 | 6.78 | 6.52 | 6.23 | 6.51 | 6.51 | 14.02 | 13.95 |

TABLE II
Effect of Surfactants and Baking Procedure on Amylose Content in Water-Solubles of Bread Crumb

| | Straight Dough Procedure | | | | | | Continuous Baking Procedure | |
|---|---|---|---|---|---|---|---|---|
| Storage Time (hr) | Control (%) | Panatex (%) | Amidan B-250 (%) | Dimodan P (%) | Tandem 8 (%) | Tally 100 (%) | Control (%) | Panatex (%) |
| 0.16 | 10.45 | 7.95 | 3.29 | 8.71 | 6.26 | 7.17 | 3.89 | 1.98 |
| 1 | 8.45 | 6.37 | 3.05 | 6.01 | 4.75 | 4.93 | 2.84 | 1.67 |
| 2 | 5.21 | 4.74 | 3.01 | 3.77 | 2.85 | 2.50 | 1.87 | 1.23 |
| 5 | 4.99 | 3.79 | 1.99 | 3.25 | 2.71 | 2.15 | 1.79 | 0.98 |
| 12 | 4.95 | 3.26 | 1.93 | 2.52 | 2.46 | 1.88 | 1.54 | 0.83 |
| 24 | 3.91 | 3.16 | 1.87 | 2.09 | 2.25 | 1.85 | 1.34 | 0.82 |
| 48 | 3.27 | 2.79 | 1.87 | 2.00 | 2.21 | 1.62 | 1.97 | 0.79 |
| 72 | 3.22 | 2.63 | 1.84 | 1.96 | 2.21 | 1.30 | 0.91 | 0.79 |
| 96 | 2.82 | 2.65 | 1.65 | 1.86 | 2.04 | 1.05 | 0.80 | 0.67 |

of the water-soluble components (carbohydrate, nitrogenous compounds, and glycoproteins). Data in Table II, which gives the amount of amylose estimated as a percent of the total water-solubles extracted from the bread crumb, might also imply formation of a complex. Krog (1977) reported that surface-active lipids may be bound to proteins by hydrophobic interactions, hydrogen bonding, or ionic reactions. De Stefanis et al (1977) found that surfactants were firmly bound by the gluten proteins during dough mixing and that in bread, surfactants such as sodium stearoyl-2-lactylate and succinylated monoglyceride were strongly bound to the starch. They reported that these surfactants occupied different binding sites during dough mixing.

Table II indicates that the amount of amylose decreased as the bread aged, with the greatest decrease occurring during the first 24 hr of storage. In all cases, the bread containing surfactants had lower amylose values than did the control bread, which might indicate that a complex was formed between the amylose and the surfactant. Based on the results in Table II, we speculate that the composition of the surfactant is important in the possible formation of a complex.

With the continuous baking procedure, the amylose also decreased as the bread aged (Table II). For this type of baking procedure, only one surfactant was studied. Again, we speculate that a complex was formed between the amylose and the surfactant. Values for amylose content estimated as a percent of the water-soluble material were clearly lower for the continuously baked bread than for the conventional bread. Such results might be due either to the higher amount of water-solubles extracted from the continuously baked bread or to the difference in processing and formulation for the continuous baking procedure.

**Effect on Extraction of Soluble Starch, Amylose, and Amylopectin**

Tables III and IV show the amount of total soluble starch, amylose, and amylopectin extracted after different storage times from bread crumb made by the conventional straight dough and continuous baking procedures. The amount of soluble starch, amylose, and amylopectin decreased as the bread aged; the decrease was most apparent in bread made by the straight dough method.

The amount of amylose, although small in comparison to the amount of amylopectin in the soluble starch, decreased sharply during the first 24 hr of storage, after which it decreased less. The data support the results obtained by Kim and D'Appolonia (1977), who indicated that the crystallization of starch gels is characterized by the retrogradation of both amylose and amylopectin over the first day of storage, after which amylopectin alone controls the retrogradation process. Tables III and IV indicate that different surfactants produce different results on the content of total soluble

TABLE III

Effect of Surfactants on the Soluble Starch, Amylose, and Amylopectin Extracted from Bread Crumb (Straight Dough Method)

| Surfactant Composition of Soluble Starch | Storage Times (hr) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0.16 | 1 | 2 | 5 | 12 | 24 | 48 | 72 | 96 |
| Control | | | | | | | | | |
| Soluble starch, % | 2.06 | 1.76 | 1.36 | 1.28 | 1.23 | 1.11 | 1.09 | 0.86 | 0.81 |
| Amylose, % | 0.93 | 0.64 | 0.49 | 0.41 | 0.40 | 0.31 | 0.27 | 0.22 | 0.19 |
| Amylopectin, % | 1.13 | 1.12 | 0.87 | 0.86 | 0.83 | 0.80 | 0.82 | 0.64 | 0.62 |
| Panatex | | | | | | | | | |
| Soluble starch, % | 1.69 | 1.32 | 1.09 | 1.07 | 1.06 | 0.88 | 0.86 | 0.63 | 0.60 |
| Amylose, % | 0.58 | 0.41 | 0.40 | 0.32 | 0.32 | 0.24 | 0.23 | 0.22 | 0.19 |
| Amylopectin, % | 1.11 | 0.91 | 0.69 | 0.75 | 0.74 | 0.64 | 0.63 | 0.41 | 0.41 |
| Amidan-B 250 | | | | | | | | | |
| Soluble starch, % | 1.45 | 1.28 | 1.08 | 0.98 | 0.96 | 0.95 | 0.95 | 0.94 | 0.92 |
| Amylose, % | 0.28 | 0.21 | 0.21 | 0.19 | 0.16 | 0.16 | 0.13 | 0.12 | 0.11 |
| Amylopectin, % | 1.17 | 1.07 | 0.87 | 0.79 | 0.80 | 0.79 | 0.82 | 0.82 | 0.81 |
| Dimodan P | | | | | | | | | |
| Soluble starch, % | 1.83 | 1.54 | 1.15 | 0.91 | 0.90 | 0.86 | 0.78 | 0.67 | 0.61 |
| Amylose, % | 0.67 | 0.39 | 0.38 | 0.24 | 0.21 | 0.17 | 0.14 | 0.12 | 0.12 |
| Amylopectin, % | 1.16 | 1.15 | 0.77 | 0.67 | 0.69 | 0.69 | 0.64 | 0.55 | 0.49 |
| Tandem 8 | | | | | | | | | |
| Soluble starch, % | 1.68 | 1.38 | 1.16 | 1.11 | 1.03 | 0.93 | 0.49 | 0.46 | 0.42 |
| Amylose, % | 0.63 | 0.40 | 0.23 | 0.22 | 0.19 | 0.16 | 0.16 | 0.14 | 0.14 |
| Amylopectin, % | 1.05 | 0.98 | 0.93 | 0.89 | 0.84 | 0.77 | 0.33 | 0.32 | 0.28 |
| Tally 100 | | | | | | | | | |
| Soluble starch, % | 2.03 | 1.66 | 0.94 | 0.89 | 0.86 | 0.76 | 0.74 | 0.40 | 0.29 |
| Amylose, % | 0.52 | 0.36 | 0.21 | 0.18 | 0.14 | 0.13 | 0.10 | 0.08 | 0.06 |
| Amylopectin, % | 1.51 | 1.30 | 0.73 | 0.71 | 0.72 | 0.63 | 0.64 | 0.32 | 0.23 |

TABLE IV

Effect of Surfactants on the Soluble Starch, Amylose, and Amylopectin Extracted from Bread Crumb (Continuous Baking Method)

| Storage Time (hr) | Control | | | Panatex | | |
|---|---|---|---|---|---|---|
| | Soluble Starch (%) | Composition of Soluble Starch | | Soluble Starch (%) | Composition of Soluble Starch | |
| | | Amylose (%) | Amylopectin (%) | | Amylose (%) | Amylopectin (%) |
| 0.16 | 1.84 | 0.63 | 1.21 | 1.62 | 0.39 | 1.23 |
| 1 | 1.66 | 0.38 | 1.28 | 1.56 | 0.26 | 1.30 |
| 2 | 1.45 | 0.34 | 1.11 | 1.54 | 0.27 | 1.27 |
| 5 | 1.42 | 0.24 | 1.18 | 1.47 | 0.20 | 1.27 |
| 12 | 1.39 | 0.20 | 1.19 | 1.34 | 0.15 | 1.19 |
| 24 | 1.40 | 0.17 | 1.23 | 1.31 | 0.15 | 1.16 |
| 48 | 1.39 | 0.15 | 1.24 | 1.31 | 0.13 | 1.18 |
| 72 | 1.31 | 0.14 | 1.17 | 1.17 | 0.15 | 1.02 |
| 96 | 1.31 | 0.15 | 1.16 | 1.02 | 0.12 | 0.90 |

starch and amylose in bread crumb. Compositional differences among various commercial surfactants apparently are responsible for differences in the bread crumb. Klein (1971) and Lagendijk and Pennings (1970) found that the complexing ability of saturated fatty acids increased with increasing carbon chain length up to C-16.

Values for amylose in the extracts of bread crumb obtained with the continuous baking procedure (Table IV) were generally lower than those obtained with the straight dough method, especially during the first 24 hr of storage. These results support the data given in Table II. The decrease over time in the total soluble starch and the amylopectin in the crumb from the continuously baked bread was not as great as that from the straight dough baking procedure.

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