Polysorbate 60: Effects in Bread[1]

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ABSTRACT

Polysorbate 60 (polyoxyethylene (20) sorbitan monostearate) has been studied as an antistaling agent and dough conditioner in yeast-raised baked goods. It is shown to be an effective dough-conditioning agent at levels as low as 0.2% based on flour weight. It is further shown that optimum antistaling and dough conditioning effects can be obtained by utilizing mono- and diglycerides in conjunction with polysorbate 60. The chemical and physical characteristics of polysorbate 60 are reviewed. Data are presented on its effect in basic starch slurries and doughs as well as in finished baked goods.

Polysorbate 60, the common name for polyoxyethylene (20) sorbitan monostearate, is the reaction product of ethylene oxide and the sorbitan ester of stearic acid. It is very hydrophilic, but does contain a lipophilic moiety and is therefore surface active. At 25°C. it is a viscous, yellow liquid which, because of its hydrophilic character, is readily soluble in water.

This paper reports our findings on the effects of polysorbate 60 in bread, used alone or in combination with glycerol monostearate, and offers some explanation of these effects, as inferred from the results of both standard and specially developed cereal chemistry techniques.

MATERIALS AND METHODS

Bakings

Standard white bread sponge-dough formulation and procedure were used. Doughs were proofed to template height. All bakings were replicated four times and averaged; loaf volumes were determined by rapeseed displacement. Crumb firmness data were obtained from 3- and 6-day-old bread compressed with an Instron Universal Tester adapted for this purpose. To determine the relative firmness between batches, an index was computed by dividing the mean compression value for each test batch by a comparable value for a blank control. The lower this index, the softer the crumb.

Commercial polysorbate 60 was evaluated in the following baking series: a) at levels ranging from 0.05 to 0.5% (flour basis); b) at 0.2% in combination with 0.05 to 0.45% glycerol monostearate (GMS); and c) combined with GMS in a 60:40 GMS:polysorbate 60 ratio, the combination evaluated at 0.1 to 0.5%. The GMS consisted of about 56% alpha-monoglyceride and 67% total monoglyceride; its iodine value was 30.3. Additives were incorporated at the dough stage.

Farinograph Studies

AACC Method 54-21A (1) was used. Constant absorption was maintained to permit evaluation of the effect of additives on curves. Materials examined were: 3% unemulsified lard (commercial, food grade), 0.5% GMS, 0.2% polysorbate 60, and

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0.5% GMS:polysorbate 60 (60:40). These levels are normal for the respective materials in bread.

Extensigraph Studies

AACC Method 54-10 (1) was used, except that a 2-min. mixing followed the 5-min. rest. This change permitted a study of the conditioning effect of additives on underdeveloped dough. Six replicates of each test were averaged. Polysorbate 60 (0.2%) was compared with 0.5% commercial calcium stearoyl-2 lactylate (CSL) and a control. These levels were chosen because they appeared optimum for the respective test materials.

Extensigraph "proportional numbers," obtained by dividing resistance to extension (measured in Brabender Units (B.U.) at 5-cm. extension) by total extension (in cm.), were used as one means of evaluating extensigrams. For undermixed doughs, proportional numbers increase as dough development increases.

Visco/amylo/graph Studies

AACC Method 22-10 (1) was used. The heating procedure used by Gray and Schoch (2) was followed: heat from 30° to 95°C., hold for 1 hr., cool to 50°C., and hold for 1 hr. Heating and cooling rates were 1.5°C. per min. Slurry pH was 5.5. These materials were tested: 0.2% polysorbate 60, 0.25% commercial polyoxyethylene (8) stearate (POES), 0.5% GMS, and 0.5% GMS:polysorbate 60 (60:40).

Microscopic Studies

Flour defatted with five hexane extractions was used to make a 1% aqueous slurry (by wt.). GMS, POES, and polysorbate 60 were used at a level of 7% (defatted flour basis), and were added to the defatted flour by washing with hexane in which the additive had been dissolved. The slurry was heated and mildly agitated. Samples were taken at 2°C. intervals as the temperature passed through the gelatinization range of wheat starch (60° to 74°C.). The samples were then stained with dilute KI_3 and examined microscopically.

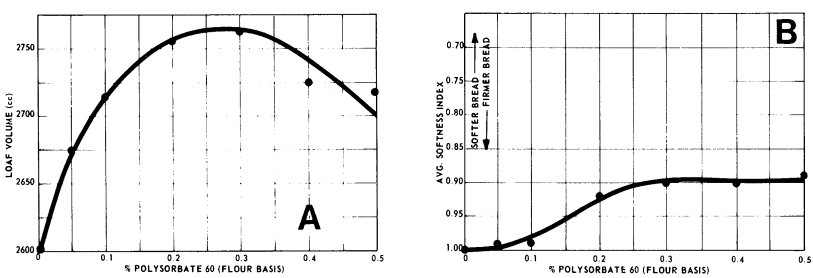

Fig. 1. Effect of polysorbate 60 on (A) loaf volume and (B) av. softness index.

RESULTS AND DISCUSSION

Bakings

Loaf volume increased by 155 cc. up to a polysorbate 60 concentration of 0.2%; it decreased above 0.3% (Fig. 1, A). The effect of varying amounts of polysorbate 60 on crumb firmness is shown in Fig. 1, B. Only at 0.15% and above was the crumb significantly less firm than the control. Since little additional softness was obtained by increasing the level above 0.2%, both volume and softness data revealed the optimum polysorbate 60 level to be about 0.2%.

Although polysorbate 60 does soften crumb, it is not as effective a softener as other materials, such as GMS. A typical comparison would be:

Level	*Average Softness Index* *Polysorbate 60*	*GMS*
0.25%	0.91	0.88
0.50%	0.89	0.83

GMS effectively softens crumb but does not significantly increase loaf volume. Polysorbate 60 was found to have the opposite effect. Subsequent bakings, therefore, examined their combined effect.

The optimum GMS:polysorbate 60 ratio was determined by maintaining the latter at 0.2% while varying the former from 0.05 to 0.45%. As expected, GMS improved loaf volume only slightly (Fig. 2, A), but significantly reduced loaf firmness (Fig. 2, B). As the GMS level increased, crumb firmness decreased, but above 0.3% relatively little additional benefit was derived. Thus, optimum functionality was obtained with about 0.3% GMS, yielding a GMS:polysorbate 60 ratio of 60:40.

This ratio was then evaluated at varying levels to determine its optimum level. Loaf volume data indicate this to be 0.3 to 0.4% (Fig. 3, A); firmness data show it to be 0.4 to 0.5% (Fig. 3, B). A level of 0.4% of the 60:40 ratio was therefore considered optimum for increasing loaf volume and decreasing crumb firmness. This

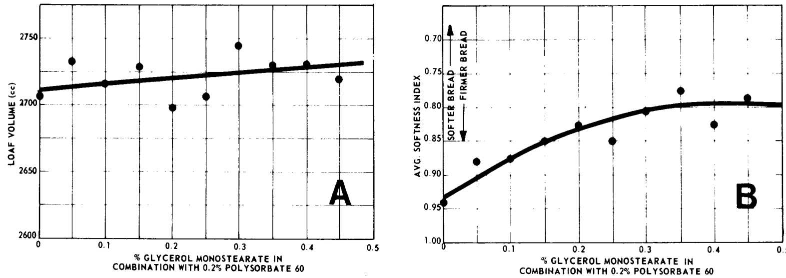

Fig. 2. Effect on (A) loaf volume and (B) av. softness index of GMS in combination with 0.2% polysorbate 60.

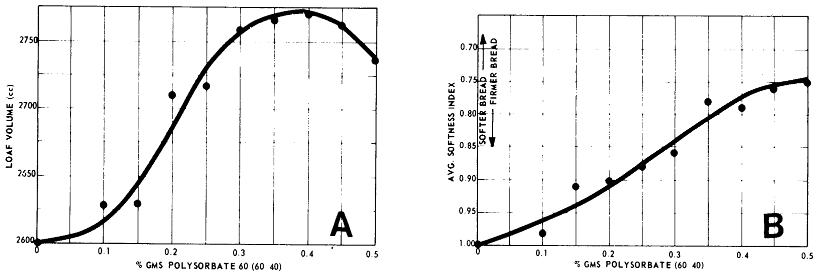

Fig. 3. Effect of GMS:polysorbate 60 (60:40) on (A) loaf volume and (B) av. softness index.

level yields a crumb firmness at 5 days comparable to that of control bread at 3 days (Fig. 4).

These baking studies reveal that polysorbate 60 significantly increased loaf volume, but give no indication of the mechanism through which it functioned. One possible explanation is that it mellowed, or conditioned, dough, permitting greater ovenspring and increased volume. Alternatively, it could have acted simply as a lubricant, producing greater oven expansion. In this respect, it might have lubricated by itself or have acted upon lard, through surface tension reduction, to increase the lubricating ability of lard. To examine these theories, farinograph and extensigraph tests were conducted.

Farinograph Studies

These tests were designed to determine whether or not polysorbate 60 functioned by lubricating gluten strands. The test results refute this hypothesis (Table I). The lubricating effect of lard is shown by the downward shift it induced in the farinogram, revealing that it reduced the force that the dough exerted on the farinograph mixing blades. GMS had the same effect. At 30°C., GMS (as used in this study) has a plastic consistency and cannot perform its primary function of complexing the linear starch fraction. Thus, its only effect on the dough was increased lubrication.

Two-tenths percent polysorbate 60, however, functioned differently: the center of its curve at peak exceeded 500 B.U., indicating that its effect was counter to that of lubrication. This difference cannot be explained in physical terms, because

TABLE I. FARINOGRAPH TEST RESULTS

Treatment	Center of Curve at Peak B.U.	Change from Control B.U.
None (control)	500	...
3% Lard	465	−35
0.5% GMS	475	−25
0.2% Polysorbate 60	520	+20
0.2% Polysorbate 60 + 0.66 g. additional water	518	+18
0.5% GMS:polysorbate 60 (60:40)	515	+15

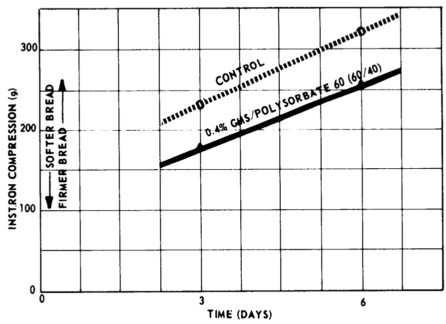

Fig. 4. Crumb firmness vs. age.

polysorbate 60 is liquid at 30°C. and would be expected to lubricate if its structure were not altered chemically. Chemical interaction with dough, then, is a logical conclusion.

These results also reveal that polysorbate 60 imparted a dry consistency to dough, an effect similar to that noted by Knightly (3) with POES. Since both materials are hydrophilic, we hypothesized that they functioned by binding water molecules and depriving flour of moisture, thus creating the dry dough consistency. To examine this possibility, the amount of water bound by polysorbate 60 was calculated by the findings of Boehmke and Heusch (4) and Kushner and Hubbard (5), who concluded that one oxyethylene group reaches maximum hydration with about four water molecules. This calculation revealed that polysorbate 60 bound about 0.66 g. of water during the farinograph test. If this is the primary mechanism

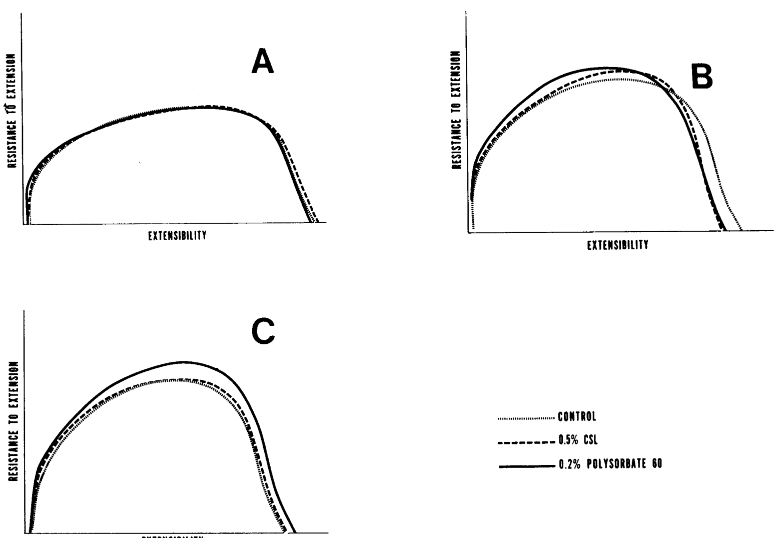

Fig. 5. Extensigrams at (A) 45 min., (B) 90 min., and (C) 135 min.

through which polysorbate 60 functioned, the incorporation of 0.66 g. additional water should move the farinogram peak very close to the 500 B.U. line. As Table I reveals, however, this did not occur, indicating that polysorbate 60 altered dough by means other than simple binding with water.

The final farinogram of the series shows the effect of a 60:40 GMS:polysorbate 60 blend. Comparison of this farinogram with those of the individual components of the blend revealed that polysorbate 60 decidedly controlled the dough character, though it was present at a lower level than GMS.

Extensigraph Studies

These tests examined the ability of polysorbate 60 to condition, or strengthen, underdeveloped dough. Figure 5, A compares the extensigram effects of polysorbate 60, CSL, and a control after 45 min. (CSL was chosen because of its wide commercial use as a dough conditioner.) The doughs were slack, as characterized by low resistance to extension and high extensibility. Neither additive affected curve shape at this point.

After 90 min., however, both polysorbate 60 and CSL reduced extensibility (Fig. 5, B). Resistance to extension, measured at 5-cm. extension, was increased more by polysorbate 60 than by CSL.

At 135 min. (Fig. 5, C), the polysorbate 60 effect was most noticeable. The control curve had good shape but lacked surface area because the dough was undermixed initially. The polysorbate 60 curve had basically the same shape but was much more full and covered more surface area, revealing that this dough was better developed. CSL also improved dough, but to a lesser extent. Plotting proportional number vs. time further illustrates the conditioning effect of polysorbate 60 (Fig. 6).

Visco/amylo/graph Studies

These tests were conducted to further examine the polysorbate 60 interaction with flour concluded above. We found that polysorbate 60 increased both hot and cold paste viscosities, thereby exerting a significant effect on the system (Fig. 7), and confirming polysorbate 60 and flour interaction. This phenomenon is at least partly explained by the results of the microscopic studies that follow, which revealed that polysorbate 60 formed insoluble complexes with the linear starch

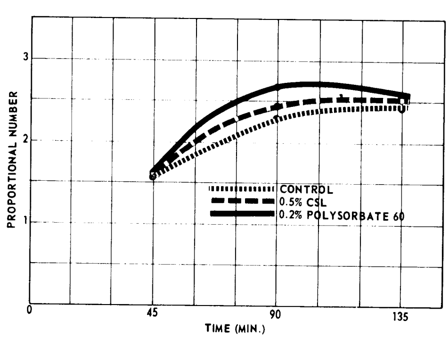

Fig. 6. Extensigram proportional number vs. time.

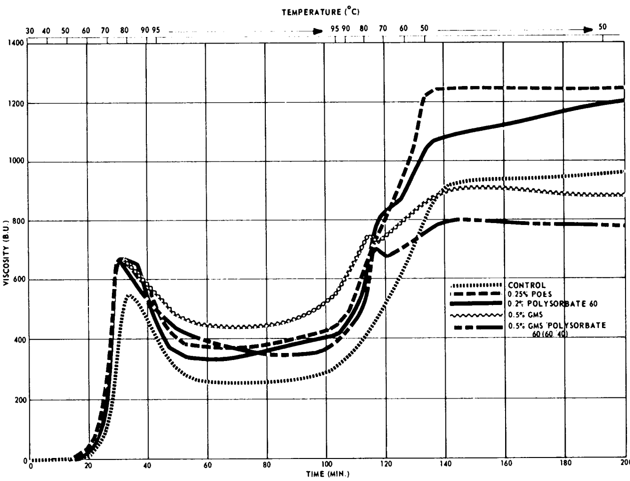

Fig. 7. Visco/amylo/graph curves.

fraction (amylose). Other workers (6,7,8) have shown that similar materials, such as GMS and POES, also complex amylose, and have theorized that this is the mechanism through which they soften bread crumb.

Those familiar with the studies of Schoch and French (9), Osman et al. (6), Gray and Schoch (2), Leach et al. (10), and others on the effect of fatty materials on starch gelatinization will recognize that the curves presented here differ in two respects from others reported in the literature. The fatty materials tested neither increased gelatinization temperature nor decreased maximum hot paste viscosity.

We believe there are two reasons for our deviations. 1) Most of the literature is concerned with starch other than wheat. As a consequence, most general conclusions have been drawn from nonwheat starch studies. With respect to the effect of fatty adjuncts on maximum hot paste viscosity, we believe that wheat starch may differ from most starches. Our data certainly indicate this, and others have obtained similar results. For example, Tenney et al. (11) found that sodium stearoyl-2 lactylate raises maximum hot paste viscosity of wheat starch even though it reduces that of rice, tapioca, and potato starches. 2) We have worked with a flour rather than a starch system, and this may explain both deviations noted. As Osman (12) has noted, the "effects of fatty acids on starch pastes appear to differ from one system to another."

Microscopic Studies

Figure 8, A is a photomicrograph of iodine-stained wheat starch granules and their surrounding aqueous medium. The gray areas near the border of the medium resulted from amylose-iodine complexing. (Complexes are formed throughout the medium, but their color is most easily seen at the border where it is more concentrated. As the medium evaporates, its borders recede to create this effect.)

Figures 8, B and 8, C show the effect of the known starch-complexing materials, GMS and POES, respectively. No soluble amylose is noted (i.e., there is no gray

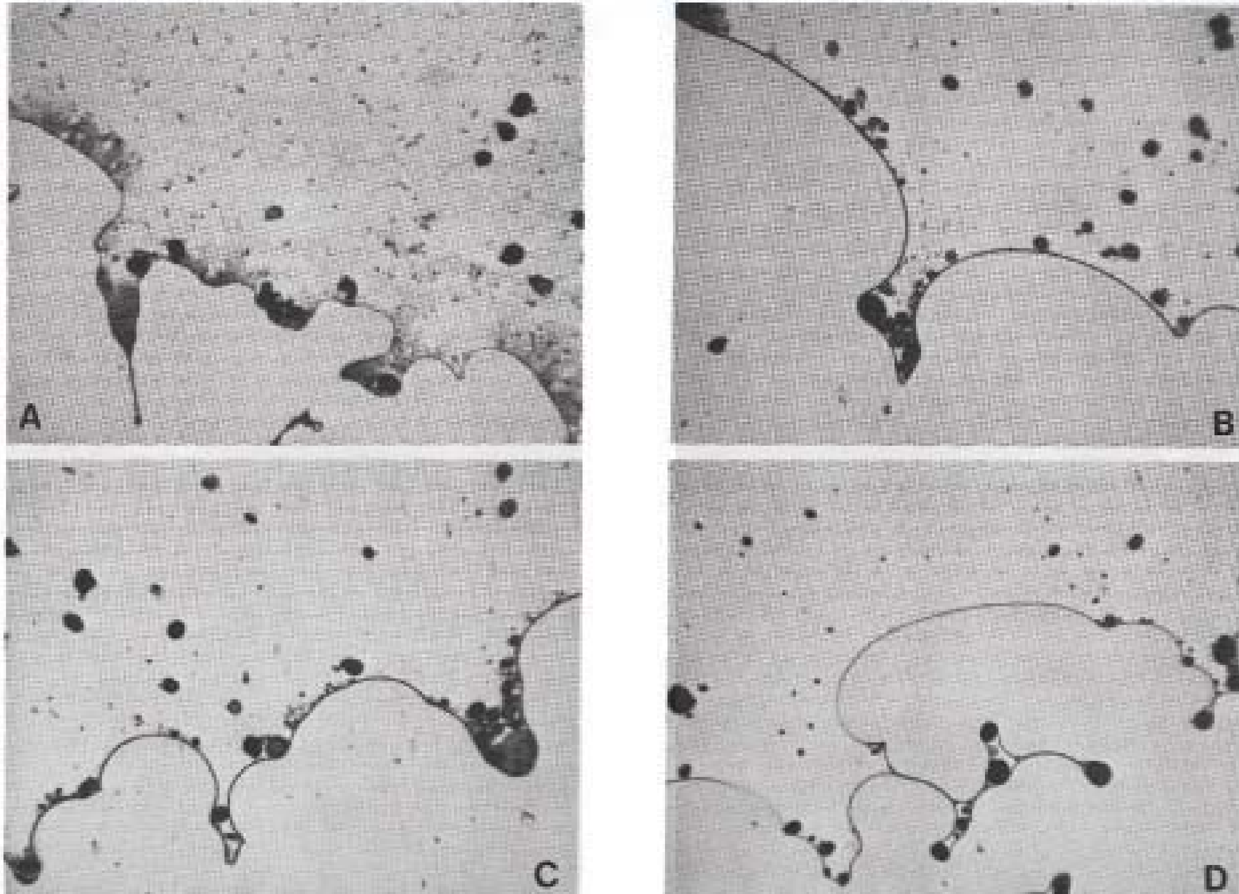

Fig. 8. Photomicrographs (75X) of slurries containing (A) no additive, (B) GMS, (C) POES, and (D) polysorbate 60.

material near the borders) because the amylose was rendered insoluble through complexing, and therefore was unavailable to interact with iodine.

Figure 8, D shows the effect of polysorbate 60. No gray color is present in the aqueous medium (other than the granules themselves), indicating that part of the effect of polysorbate 60 in bread was related to its complexing of amylose.

SUMMARY

Bakings revealed, and extensigrams confirmed, that polysorbate 60 conditioned dough. Optimum effects on crumb firmness and loaf volume were obtained with 0.4% of a 60:40 GMS:polysorbate 60 combination. Farinograms indicated that polysorbate 60 effects were related to its chemical interaction with flour. Amylograms showed a significant polysorbate 60 effect on starch, and microscopic studies revealed interaction with the linear starch fraction. Additional work is required, however, to explain the complete polysorbate 60 mechanism of action.

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