Model Studies of Cake Baking. III. Effects of Silicone on Foam Stability of Cake Batter

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ABSTRACT

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Batter expansion, starch gelatinization, protein coagulation, and cake crumb structure from cake batters containing 0.5–10 ppm of silicone were observed during actual and model baking. Silicone in batters tended to cause poor batter expansion, small cake volume, a gummy layer, bottom rise, coarse grain, and a ringlike pattern on the cake. Starch gelatinization and protein coagulation were not affected by silicone dosage. These phenomena were interpreted as indications of a lack of foam stability of cake batter during baking.

Cakes consist of four main ingredients—wheat flour, sugar, egg, and fat. Many studies have attempted to clarify the relationship between cake structure and these four ingredients. Cake can be defined as a gaseous emulsion system. During baking the gas-liquid emulsion of cake batter is converted to the gas-solid emulsion of cake crumb (Mizukoshi et al 1980). High-quality cakes have large volume, uniform and fine grain, symmetrical contour, tender texture, and good mouthfeel and flavor. All of these properties are affected by the foam structure of the cake system. Thus, it is necessary to investigate the role of gas—the fifth ingredient of cakes—in a cake system.

Although research interest in chemical and physical changes during baking has increased in recent years, limited attempts have been made to explain the development of foam structure during baking. Handleman et al (1961) described the relationship among bubble size in cake batter, bubble growth during baking, and final cake structure from the standpoint of bubble mechanics. Ellinger and Shappeck (1963) explained the importance of determining the optimum specific gravity for producing cakes of the desired quality. Bell et al (1975) and Shepherd and Yoell (1976) reported bubble size distribution during heating of cake batter. Miller et al (1967) and, more recently, Kissell et al (1979), Kissell and Yamazaki (1979), and Clements and Donelson (1982a,b) measured thermal expansion of cake batter during baking to show the effect of chlorination on the free lipids of cake flour. Ramstad (1958) and Kissell and Donelson (1968) reported the effects of silicone contamination on cake quality.

Observations on starch gelatinization and swelling, protein coagulation and batter expansion, and the role they play on structural development of cake batter, especially cake volume, have also been made (Mizukoshi et al 1979, 1980). The objective of this study is to elucidate the importance of foam structure in cake batter during baking on final cake structure. Silicone, a typical defoaming agent, was added to a cake system to create various degrees of foam stability in cake batter.

MATERIALS AND METHODS

The unchlorinated cake flour (Violet, 7.18% protein, 0.33% ash, 14% moisture), was milled by Nisshin Flour Mill Co., Ltd. The 30% silicone (dimethylpolysiloxane) oil-in-water emulsion was obtained from Shin-Etsu Chemical Industry. Other cake ingredients, cake formulation, preparation of cake batter, model baking method, and measurement of light transmission were reported previously (Mizukoshi et al 1979, 1980). The silicone emulsion was dispersed into the water used to prepare the cake batter. The silicone concentration cited is the amount of actual silicone, not the silicone emulsion, added to cake flour. Six concentrations of silicone, ranging from 0 to 10 ppm, were used. The density of each batter was 0.50 g/cm^3. Sponge cake batter (500 g) was weighed into 18-cm round pans and baked in an electric oven at 170°C for 40 min. Cake height was monitored during baking by the method of Clements and Donelson (1981). Cake volume was determined by rapeseed displacement. Cake batter (4.05 g) was weighed into a 20-ml graduated cylinder, which was placed in the water bath on the model baking equipment for viscosity measurements. Changes in batter volume, temperature, and light transmission during baking were continuously monitored. All actual and model baking data are the means of duplicate measurements.

RESULTS AND DISCUSSION

The expansion of batters containing 0, 0.5, 1, 2, 5, and 10 ppm silicone was affected during the first 15 min of baking. Continuous baking caused drastic changes in batter expansion (Fig. 1). At only 0.5 ppm silicone, batter expansion was restricted significantly. Batter expansion gradually decreased with increasing concentrations of silicone. Silicone reduced not only batter expansion but also the baking time of batter expanded to the maximum. Large bubbles appeared and ruptured on the surface of cake batters containing silicone, and this may account for the reduced batter expansion. Silicone may have enhanced the escape of gas bubbles from the batters.

Final cake volumes after cooling were plotted against silicone levels (Fig. 2). As the silicone concentration increased, cake volume decreased. Compared to cakes containing no silicone, cakes

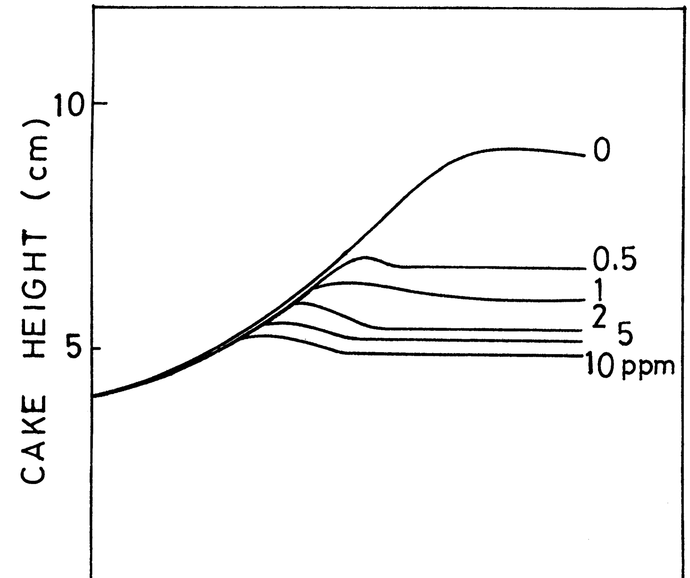

Fig. 1. Expansion of cake batters containing 0–10 ppm silicone (dimethylpolysiloxane) during oven baking.

containing silicone levels of 0.5, 1, 2, 5, and 10 ppm had volumes reduced 15, 18, 21, 33, and 45%, respectively.

Surface (Fig. 3) and cross-section (Fig. 4) photographs show the effects of silicone on cake appearance. Data on cake quality (cake volume, surface ring, gummy layer, bottom rise, and coarse grain) are summarized in Table I. Cake batter without silicone had the greatest expansion and the largest cake volume. This control cake had no surface ring, gummy layer, bottom rise, or coarse grain. Only 0.5 ppm of silicone changed the surface appearance and internal structure, causing a coarse grain and a distinguishable surface ring pattern that had a caramelized structure and color. Further addition of silicone (1 and 2 ppm) accelerated the formation of coarse grain, a surface ring, a gummy layer that was easily recognized by its yellow-greenish color, and a dense, gumlike, tough layer without sponge structure that usually formed at the bottom of the cakes. At silicone levels of 5 and 10 ppm, the most striking effects were observed; a caramelized color dominated the outer edge of the surface; a dense gummy layer formed at the bottom; the cake bottom raised upward; and coarse grain appeared between the cake surface and the gummy layer.

To further ascertain the effects of silicone on batter expansion, model baking studies were conducted on cake batters. Batter expansion as a function of temperature in the model baking system is shown in Fig. 5. The control batter (without silicone) had almost the same expansion curve as the ideal expansion curve calculated from the equation proposed by Mizukoshi et al (1980). As

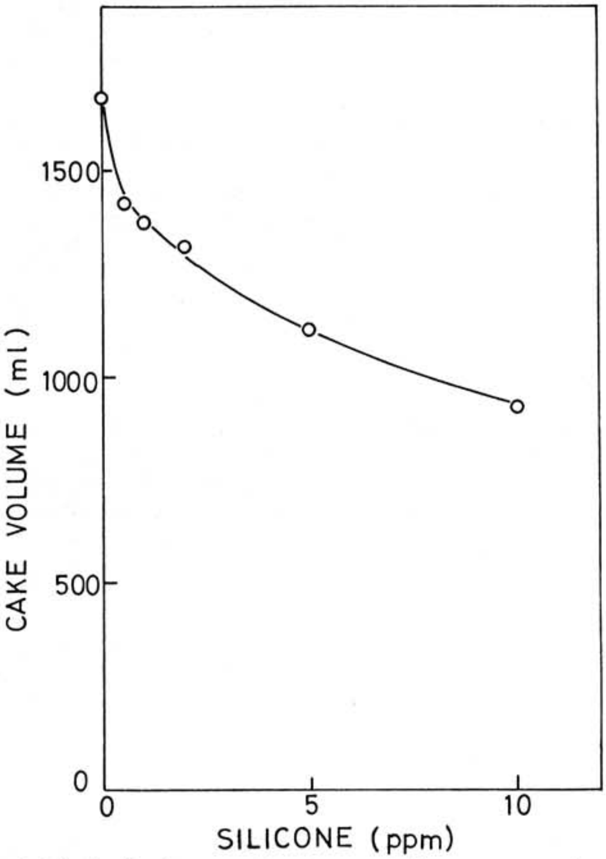

Fig. 2. Relationship between cake volume and silicone concentration.

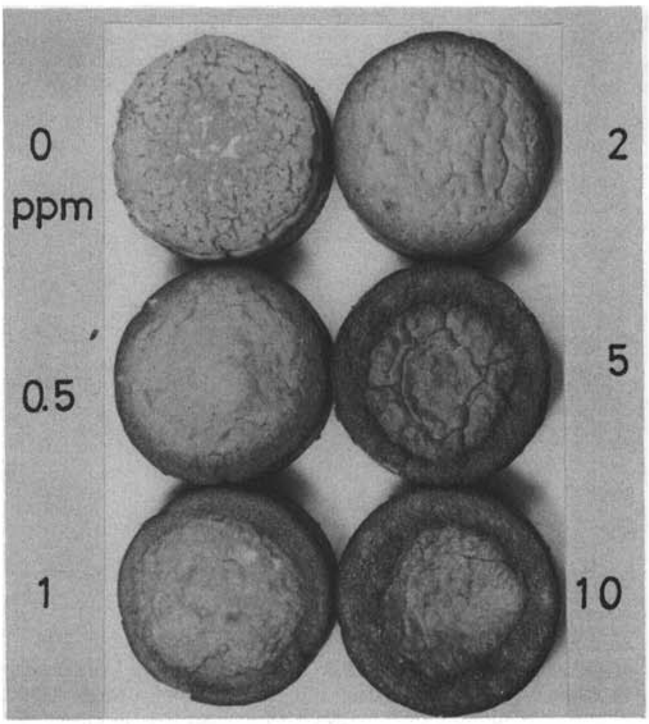

Fig. 3. Surfaces of cakes made from batters containing 0–10 ppm silicone.

TABLE I
Quality of Cakes Made from Batters Containing 0–10 ppm Silicone

Silicone Concentration[a] (ppm)	Cake Volume (ml)	Surface Ring[b]	Gummy Layer[b]	Bottom Rise[b]	Coarse Grain[b]
0	1,676	−	−	−	−
0.5	1,422	+	±	−	+
1	1,372	+	+	−	+
2	1,320	+	+	−	+
5	1,118	++	++	++	++
10	927	++	+++	++	++

[a] Dimethylpolysiloxane, as ppm (flour weight basis).
[b] Symbols represent: −, not present; ±, barely present; +, present; ++, clearly present; and +++, prominently present.

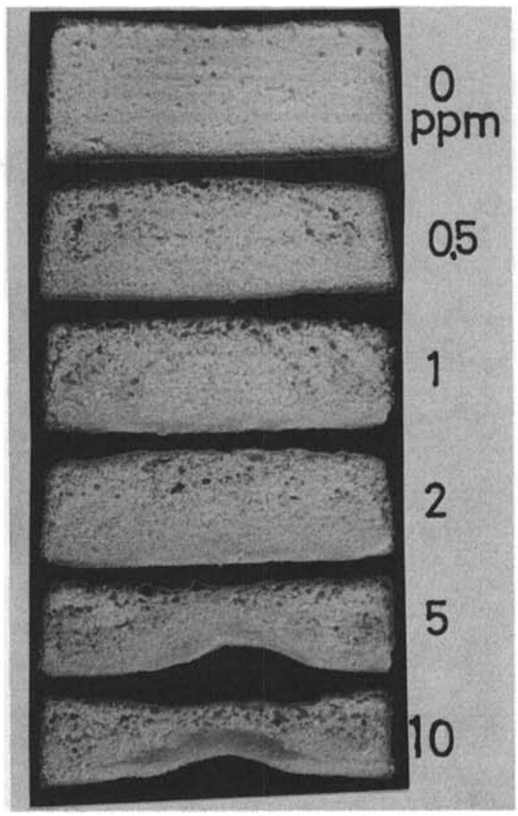

Fig. 4. Cross sections of cakes made from batters containing 0–10 ppm silicone.

expected, the model baking data also showed the reduction of batter expansion that resulted from the addition of silicone. In the model system, silicone also reduced the temperature at which maximum batter expansion occurred. This temperature is defined as the temperature at which batter expansion ceases (t_4). Continued baking above t_4 caused the sudden decrease in batter volume. At 0.5 ppm, silicone reduced the final batter volume by 20%. At higher concentrations of silicone (2, 5, and 10 ppm), batter expansion was reduced from the initial to the final stages of model baking. The batter containing 10 ppm of silicone had nearly a 46% decrease in final batter volume. Silicone suddenly decreased batter volume just after maximum batter volume was achieved. Model baking data indicated that the cake batters containing silicone were not capable of retaining leavening gases to the extent of those prepared without silicone.

Light Transmission Measurement

In a previous report (Mizukoshi et al 1980), batter expansion and final batter volume were reported to be governed by temperature and by the initial bubble volume in the cake batter. Final batter volume could be predicted from the temperature at which maximum light transmission (t_2) occurred. Light transmission measurements were conducted on batters containing silicone. The initial temperature of starch gelatinization (swelling) (t_1), the temperature of maximum light transmission (t_2), and the temperature at which batter expansion stops (t_4) are shown in Fig. 6. Silicone concentrations from 0 to 10 ppm did not change t_1 or t_2. Average temperatures of t_1 and t_2 were 83 and 90.5° C, respectively. On the other hand, silicone decreased at t_4, the temperature at which batter expansion ceased, from 88.5° C at 0 ppm, to 85° C at 0.5 ppm, and to 82° C at 10 ppm. These results indicate that silicone in cake batter does not affect the temperature of starch swelling or protein coagulation, but does affect the temperature at which batter expansion ceases, which is interpreted as an indicator of foam stability, ie, the ability to retain leavening gases during baking.

Foam Stability and Silicone

Foams are commonly defined as agglomerations of gas bubbles separated by thin liquid films. Foams are emulsions of gas bubbles at the discontinuous or disperse phase and a liquid or solid at the continuous phase. Two important properties—foaming ability and foam stability—are commonly used to characterize foams. Foam is thermodynamically unstable, and bubbles in foam tend to escape. At least three processes occur during the life of a typical liquid foam. The films rearrange their positions so that the numbers and the linear dimensions of bubbles change with time. Then the liquid in the lamellae and the Platesu borders flow downward. Finally, the lamellae burst (Bikerman 1973). Silicone dimethylpolysiloxane, a foam inhibitor, is insoluble in many liquids. It is strongly adsorbed at the water-air interface and breaks the foam lamella by displacing or mechanically rupturing the stabilizing films (Moilliet et al 1961).

Cake Batter and Foam Stability

We previously observed (Mizukoshi et al 1980) that as temperature increased during the early stage of baking, batter volume increased because the bubbles expanded. This was due to the increase in vapor pressure of water and air in the bubbles. Further increase in temperature causes starch swelling and protein coagulation and the sol of cake batter begins to change to a gel-like structure. Formation of the continuous gel phase restricts the expansion of the bubbles, and further increases in vapor pressure cause the gas in the bubbles to be released.

In a cake batter system, silicone is adsorbed at the bubble surface and reduces the stability of the foam film and accelerates the coalescence of bubbles, ie, a few large bubbles form from many

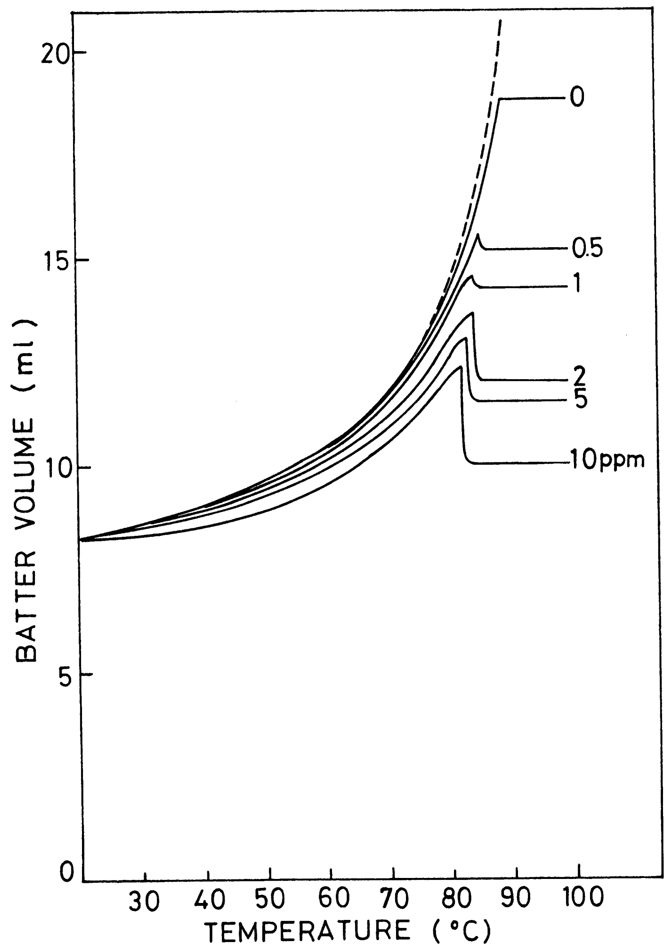

Fig. 5. Expansion of cake batters containing 0–10 ppm silicone during model baking (4.05 g batter heated in glass cylinder). The dashed line shows the ideal, calculated expansion curve.

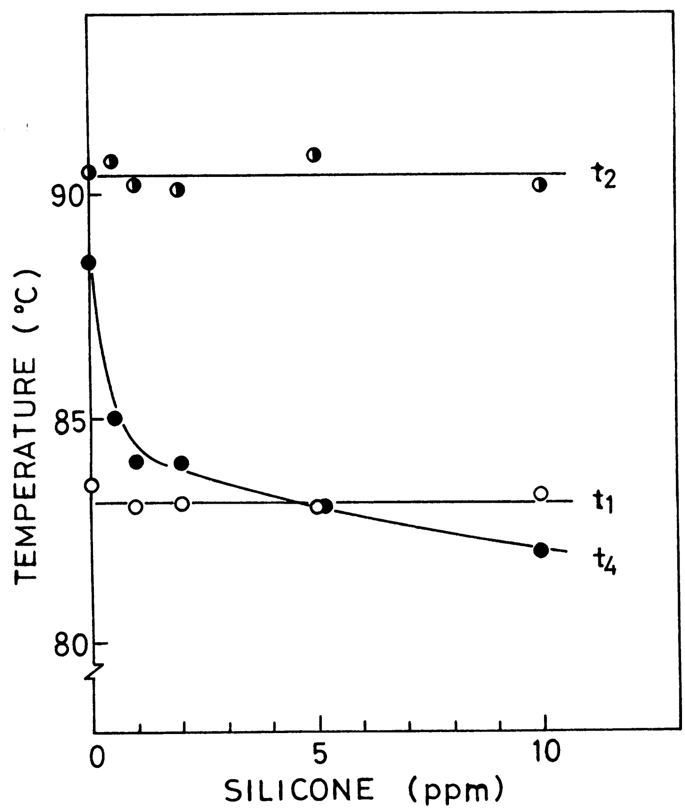

Fig. 6. Effects of 0–10 ppm silicone on the initial temperature of starch gelatinization (swelling) (t_1), temperature of maximum light transmission (t_2), and the temperature at which batter expansion ceased (t_4) during model baking.

small bubbles and then escape from the cake batter. These phenomena were observed in this study because silicone restricted the batter expansion, decreased the temperature at which batter expansion ceased, and decreased final cake volume.

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