Development of Cake Structure: Influence of Ingredients on the Measurement of Cohesive Force During Baking[1]

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ABSTRACT

The maximum cohesive force developed in a high-ratio cake formulation was measured during the actual baking process. The magnitude of this force was influenced by the level of the most important batter ingredients and appeared to result from the opposing action of those ingredients that toughen and those that tenderize. The data confirm previously published findings on the roles of certain cake ingredients.

Specific ingredients such as starch, protein, lipids, and emulsifiers contribute significantly to the development of the structure of a layer cake (Howard 1972, Russoe and Doe 1970, Wootton et al 1967). The extent to which various ingredients contribute to cake structure has been measured by many approaches, including recording physicochemical changes in model batter systems (Donovan 1977) and measuring characteristics of the final product (Frazier et al 1974). Recently, Kissell and Yamazaki (1979) used time-lapse photography to record changes occurring during the baking process. Although such approaches show distinct differences in the effects of various ingredients, they have either studied some physical condition or observed cake development by viewing the external cake appearance.

Recently, an article by Voisey et al (1979) described an experimental baking oven in which a smooth metal probe could be inserted into a standard 200 × 40-mm cake pan holding 400 g of cake batter to a depth of 24 mm and in which the probe was made to move vertically through the baking batter by a servomotor located outside the oven above the batter. This oven was equipped with thermocouples that were inserted into the cake batter, a device for measuring cake height, and an electronic means for continuously recording the force associated with the resistance to the movement of the probe as a function of baking time. These authors demonstrated that resistive or cohesive forces measured during baking were a function of the ingredients present in a cake formulation and were sensitive to changes in the level of such ingredients. These cohesive forces could not be attributed to effects of any one factor. Rather, several factors probably act together to develop the structure of the finished cake. The present report is an

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extension of the work of Voisey et al (1979) and further explores the effects of some ingredients, important to producing a final cake structure, upon the cohesive or resistive forces measured within the baking cake.

MATERIALS AND METHODS

The cake formula was: cake flour, 95 g; white granulated sugar, 120 g; salt, 2.5 g; double-acting baking powder, 5 g; egg white powder, 7 g; skim milk powder, 15 g; water, 163 g; vanilla, 2.5 g; and an oil mixture, 2.5 g. The oil mixture (liquid shortening) contained 83% oil, 14% propylene-glycol monostearate (PGMS), and 3% stearic acid. To evaluate the effects of different levels of selected ingredients, sucrose, powdered egg white, the oil mixture, and the stearic acid and PGMS in that mixture were added to the formula at their normal levels of addition (100%) and at 0, 50, and 150% of their normal level. Only one ingredient at a time was varied. The batter was mixed in a Hobart Mixer (model N50) with a wire whip at a speed setting of 2. After 2 min, the sides of the bowl were scraped down with a rubber spatula; mixing was then continued for 2 min. The batter density was measured and 400 g were placed in a 200 × 40-mm greased aluminum cake pan to a depth of approximately 24 mm. Cakes were baked individually in the experimental baking oven according to Voisey et al (1979) for a period not exceeding 25 min. The development of cohesive or resistive forces within each baking cake was recorded continuously as a function of time on a 10-mV strip chart recorder. The density of each formulated batter was calculated by dividing the weight of a measured volume of batter by the volume of the measuring vessel. Volume index and cake symmetry were determined according to method 10-91 (AACC 1976).

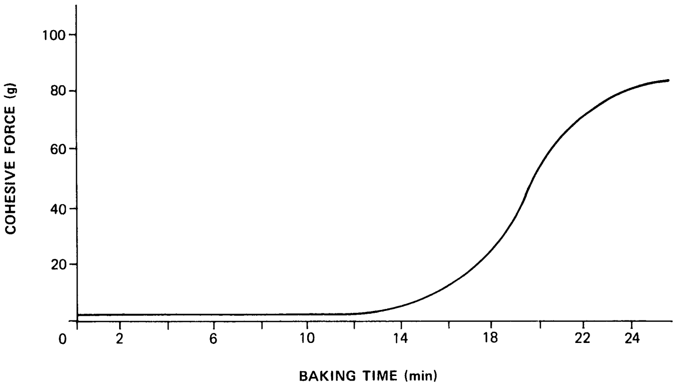

Fig. 1. Development of cohesive force as a function of baking time for a control cake batter.

RESULTS AND DISCUSSION

Table I depicts the effects of different levels of selected ingredients upon batter density, maximum cohesive force, volume index, and symmetry of layer cakes. The control cake showed acceptable volume and symmetry and resulted from a batter exhibiting significant air incorporation. This level of air incorporation was greater than levels in previously published literature for layer cakes (Howard 1972) and was due to the wire whip that replaced the normal beaters.

The data in Table I clearly indicate the role of PGMS in enhancing air incorporation and contributing to cake symmetry. In the absence of this ingredient, the cake was dense and had poor symmetry. A high cohesive force was also recorded. Adding PGMS at a level 50% of that of the control cake markedly improved the batter density and volume index of the cakes and lowered the cohesive force. However, cake symmetry was still poor. PGMS added at a level 50% above that of the control did not significantly influence batter density, cohesive force, volume index, or cake symmetry.

The utility of stearic acid as a high-temperature stabilizer is also demonstrated. The absence of stearic acid did not affect air incorporation but did influence the value of the cohesive force, the volume index, and cake symmetry.

Stearic acid added at 50% of the level used in the control did not improve the physical cake characteristics. As was observed for PGMS, stearic acid at the 150% level did not significantly alter the physical cake characteristics relative to the control. In both cases,

TABLE I
Physical Characteristics of the Batters and Cakes[a]

Ingredient Varied[b]	Level (%)	Batter Density (g/ml)	Maximum Cohesive Force (g)	Volume Index (cm)	Symmetry (cm)
PGMS[c]	0	1.13	162	6.06	0.08
	50	0.46	56	12.89	0.04
	100[d]	0.51	64	12.36	0.50
	150	0.59	74	11.89	0.68
Stearic acid	0	0.65	150	7.34	−0.16
	50	0.61	144	7.34	−0.22
	100[d]	0.51	64	12.36	0.50
	150	0.53	65	12.11	0.40
Oil Mixture	0	1.07	200	6.22	0.08
	50	0.52	76	9.94	−0.94
	100[d]	0.51	64	12.36	0.50
	150	0.43	33	10.69	−0.56
Sugar	0	0.47	200	10.83	−0.48
	50	0.47	99	11.93	1.32
	100[d]	0.51	64	12.36	0.50
	150	0.57	33	8.06	−2.00
Egg white	0	0.44	25	7.38	−0.24
	50	0.46	41	11.37	0.12
	100[d]	0.51	64	12.36	0.50
	150	0.49	98	12.00	0.16

[a] Results represent the average of three cakes.
[b] All other ingredients held constant.
[c] Propylene-glycol monostearate.
[d] Control.

the cohesive force was lowered and the volume index and cake symmetry were markedly improved.

The total amount of oil mixture contained both PGMS and stearic acid. The maximum cohesive force was progressively reduced as the level of oil mixture was increased, indicating a tenderizing role for the liquid shortening ingredients. Batter density remained constant, but volume index rose to a maximum before declining. If liquid shortening was omitted from the cake formula, no air was incorporated, and the cake was very dense and showed a high cohesive force.

Good air incorporation was obtained at all levels of added sucrose, and volume index was affected only at the highest sucrose level. Symmetry was very susceptible to sugar level but was not linearly correlated. Like liquid shortening, sucrose exhibited an overall tenderizing effect. Maximum cohesive force was negatively correlated with increasing levels of shortening ($r = -0.90$) and sucrose ($r = -0.95$); the relationships between cohesive force and volume index for these ingredients were $r = -0.89$ and 0.31, respectively.

Egg white protein exhibited an opposite and toughening effect in contrast to shortening and sucrose. A high positive correlation ($r = 0.987$) was found between the level of this ingredient and maximum cohesive force and a somewhat lower relationship between cohesive force and volume index ($r = 0.74$). For all cakes, the maximum cohesive force occurred near the end of the baking cycle but, as Fig. 1 clearly shows, this force is progressively developed as a function of baking time. Cohesion began to develop around 12 min from the start of baking and rose slowly for the next 3 min; a rapid rise in force followed and tended to level off in the last 5 min of baking. Thus, although the final value for cohesive force may well be associated with the shearing of the finished cake, that portion of the force-time curve between 12 and 20 min implies that cohesive force is associated with the progressive development of internal cake structure.

In this study, only sugar, oil mixture (liquid shortening), and egg white were varied; the flour-water ratio remained constant throughout. Obviously as the levels of some ingredients change, competition for available water will vary. The flour will therefore also contribute to a firming or toughening effect, and this effect, in combination with that of egg white, will be moderated by the presence of sugar and liquid shortening.

The results presented here confirm previously reported findings for the roles of certain cake ingredients but introduce the measurement of cohesive force associated with the development of cake structure during the baking process. This cohesive force appears to result from the opposing action of toughening (flour, egg whites) and tenderizing (sugar and shortening) ingredients. The present study does not suggest what the optimum value of this force should be for the development of acceptable cake structure. This would probably be a function of each particular cake formulation and would also have to be considered in terms of the sensory attributes of the cakes, which were not part of the present study. We suggest, however, that such a value exists and that its measurement can provide useful information about the influence of formula ingredients on the formation of cake structure.

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