STUDIES ON PAN-CAKE BAKING. III. EFFECTS OF pH, MIXING TIME, AND MOISTURE LEVEL ON THE QUALITY OF PAN-CAKE FROM RECONSTITUTED FLOUR

M. SEGUCHI and J. MATSUKI, Laboratory of Food Chemistry, Food Research Institute of Morinaga & Co., Minamifutsukamachi, Mishima, Shizuoka, Japan 411

ABSTRACT

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Cake flour was fractionated into water-solubles (5.31%), gluten (5.38%), tailings (15.0%), and prime starch (73.0%) with acetic acid. Pan-cake with quality equal to that from parent flour was baked when the pH of batter using acid-fractionated flour components was higher than 5.20. Similar quality restoration was effected when gluten was mixed to full development at the optimum liquid level.

Relatively little information is available regarding the expansion of pan-cake and formation of cell structure (1,2). It has been shown that wheat lipids, particularly the polar-lipids fraction, are important in pan-cake baking (3); however, the role of main components such as the starch and gluten fractions is unclear. In order to study the role of these components, it is necessary to have the experimental techniques of flour fractionation, reconstitution of flour, and a baking test with the reconstituted flour.

The role of pH in cake formulation and cake production has not been emphasized except in the paper by Ash and Colmey (4). Dependency of the gluten matrix to pan-cake expansion was little known (2). Our present study shows the importance of gluten matrix formation from gluten particles in cake expansion. It is also shown that both pH and the amount of water are important to form reconstituted pan-cake.

MATERIALS AND METHODS

The cake flour used in this study was brand name Ⓚ Alps, milled by Nitto Milling Co. Ltd., from Western white wheat. The protein content was 7.2% and ash was 0.39% at 12.8% of moisture. The flour had been treated with 0.06 g of chlorine gas per 100 g flour.

Acetic Acid Fractionation of Wheat Flour

Acetic acid fractionation of the flour was performed by the method of Sollars (5). The gluten and tailings fractions were lyophilized and ground for 10 min in a mortar grinder, and then sifted through a 30-mesh wire sieve before use. The prime-starch fraction was air-dried at room temperature. Water-solubles fraction was concentrated to 1/10th volume at 30° C in a flash evaporator and stored at 3° C until used.

Reconstitution and Pan-Cake Baking Test

The fractions, except water-solubles fraction, were blended in the same proportions as found in the original flour and sifted three times through a 30-mesh sieve. The water-solubles fraction (50 ml) and water (45 ml) were then added to this mixture and mixed with a flat beater in a Kitchen Aid Mixer (Hobart Mfg. Cl. Model K 45) at a speed of 205 rpm until the gluten was fully developed, as confirmed by microscopic observation. The reconstituted batter was equivalent to 100 g of original flour at 14% moisture. The pH of the batter was adjusted by the addition of NaOH solution with mixing. Then 20 g powdered sugar, 1.6 g of sodium bicarbonate, and 2.4 g of sodium acid pyrophosphate were added and mixed for 30 sec at 112 rpm. Pan-cakes were baked as described previously (6).

RESULTS AND DISCUSSION

Flour and Flour Fractions

Acetic acid fractionation data for the original wheat flour are summarized in Table I.

Effect of Batter pH on Baking Properties

After acetic acid fractionation, the pH of each fraction except gluten was lower than that of the original flour batter. The pan-cake baked from batter containing

TABLE I
Analytical Value of Ⓚ Alps Wheat Flour and Its Fractions

Material	Yield %	Protein %	Lipid %	Ash %	Moisture %	pH
Original flour	100.0	7.20	0.95	0.39	12.8	5.30
Fraction						
Water-solubles	5.31	...	...	6.38	14.0	4.47
Gluten	5.38	73.4	4.80	2.80	14.0	5.55
Tailings	15.0	2.16	0.28	0.228	14.0	4.54
Prime starch	73.0	0.22	0.10	0.127	14.0	4.52

TABLE II
Pan-Cake Volume for Various pH Values of Reconstituted Batters

pH Value	Pan-Cake vol cc
Original flour	457.0
3.85	370.0
3.95	365.0
4.05	360.0
5.20	443.8
5.30	446.3
10.0	445.0

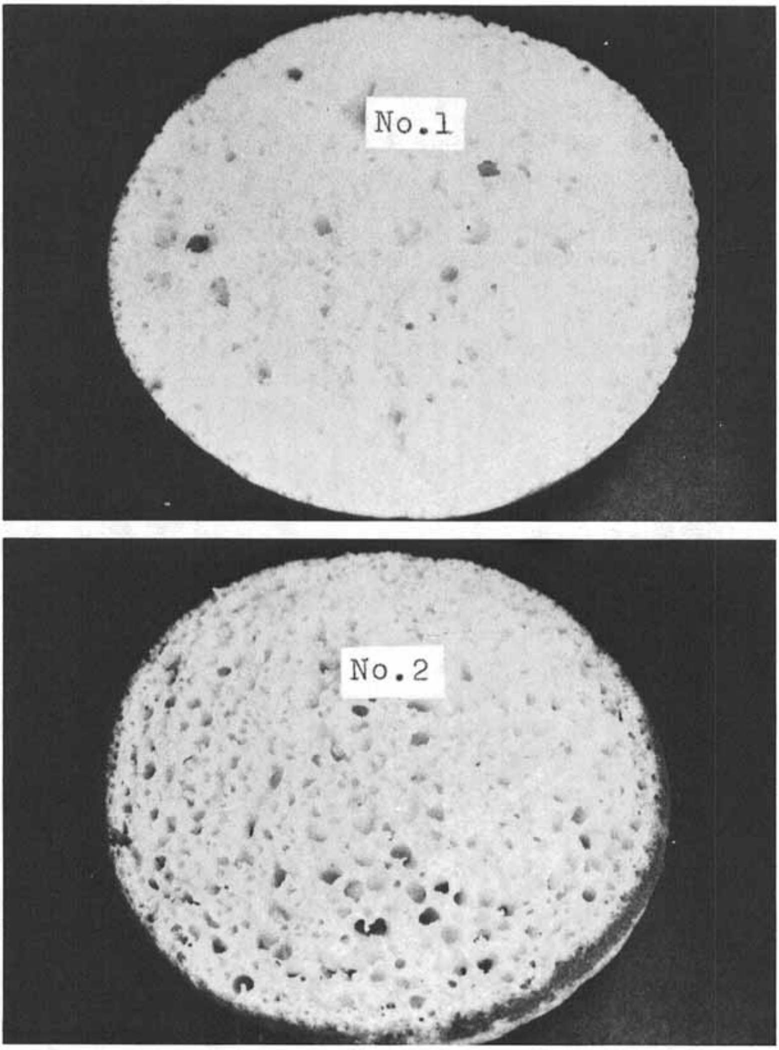

Fig. 1. Pan-cake baked from reconstituted batter at pH 4.05 (No. 1) and pH 5.20 (No. 2).

acid-fractionated components had the sour flavor of acetic acid, and its volume and structure were not restored to the original. The center of the upper surface of the product baked with pH-nonadjusted reconstituted batter was always sunken. Normally the expansion of the batter starts at the outer edge and gradually continues to the center of the upper surface. When the pH value of the reconstituted batter was adjusted with NaOH solution to a value of 5.20 to 10.0 and baked, the product closely resembled that baked from the original flour (Table II).

Cake volume and structure were restored to original measurements when near- or above-pH 5.20 batter was used. Figure 1 compares the appearance of pan-cake crumb from pH 4.05 batter and pH 5.20 batter. The crumb of pan-cake from pH 4.05 batter was very soft and resembled cotton. Restoration of crumb structure may be attributed to the change in rheological properties of protein in batter caused by the change in concentration of [H^+] which decreased the solubility of protein. Pan-cake baked with pH 10.0 reconstituted batter had very soft texture and good volume; color of the cake crumb was slightly yellow, which might be due to carotene.

Effect of Gluten Development

When original flour was used in pan-cake baking, gluten development occurred after only a 30-sec mixing; however, it took about a 20–30-min mixing for gluten development with reconstituted batter after neutralization of acetic acid. Microscopic observation showed that gluten particles were observed among starch granules before development but, after development, gluten absorbed water and formed a matrix among starch granules (Fig. 2). Pan-cake

TABLE III
Pan-Cake Volume Response to Increased Mixing Time

Mixing Time min	Pan-Cake vol cc
0	360.0
8	358.8
16	440.0
24	446.3

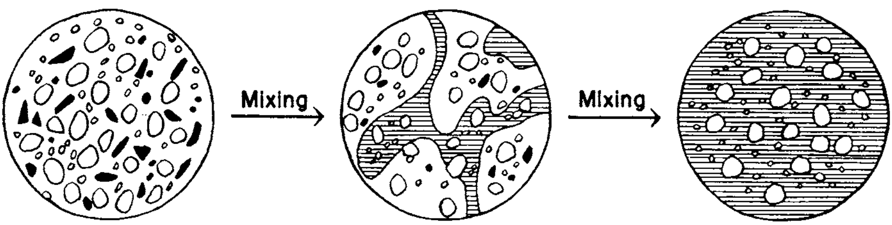

Fig. 2. Model of microscopic observation of gluten development.

properties baked with such gluten-developed reconstituted batter were restored to those of the original (Table III).

Watery and creamy reconstituted batter changed rapidly to a gummy consistency with gluten development which occurred between an 8 and 16 min mixing, with a corresponding rapid increase in cake volume. Table III shows the relation of mixing time and cake volume.

Cake structure before gluten development was composed of homogeneous minute cells which might be due to the leakage of gas from the batter. However, after gluten development, it was composed of nonhomogeneous larger cells produced by the trapping of gas by the gluten membrane. Most cells increase in volume with gluten development, resulting in the increased cake volume. Similar results were obtained when pan-cake with original flour was made without such vigorous mixing (6) due to the protein in whole flour rapidly absorbing water and forming a gluten matrix.

Effect of the Amount of Water

It has been known that the amount of water in pan-cake baking with original flour was important in order to get maximum pan-cake characteristics (7,8). When reconstituted flour after neutralization of acetic acid was used, the amount of water was more critical.

To achieve maximum pan-cake performance, it was necessary to change the ratio of water to flour and to repeat the baking test. This relation is indicated in Table IV. Pan-cake volume was maximum at a specific ratio of water to flour.

When the amount of water was higher than optimum, most of the leavening gas escaped from the surface of batter after one min of the start of baking. The resulting pan-cake had low volume, gummy structure, and was composed of homogeneous small cells which might be attributed to the soft and smooth gluten matrix.

At the optimum liquid condition, the leakage of gas after one min of baking was relatively small and the surface film of batter gradually began to increase by inner gas pressure with baking time. After 5–6 min of baking, the batter surface became smooth and expanded slowly from the outer edge to the center. When the amount of water was lower than optimum, leakage of gas from the surface of batter was not so evident and batter began to expand without film formation on the surface; this occurred because the batter was so stiff that there was excessive resistance to gas leavening, resulting in a rough-surfaced cake. This rough

TABLE IV
Pan-Cake Volume Response to Increased Liquid Level

Liquid Level %	Pan-Cake vol cc
66.0	425.0
70.9	432.5
75.3	435.0
79.7	455.0
84.1	445.0
88.5	440.0

surface disappeared and changed to a smooth and bulging surface with the increase of water up to the level which was optimum for batter viscosity and gas retention. Further increments of water made the center of the surface collapse because of the decrease in batter viscosity, while cell structure at the bottom of the cake disappeared and changed to starch-gel layer. With pan-cake baking by reconstituted flour, it was possible to restore original quality when batter pH was adjusted to above 5.20 and when batter was well mixed until the development of gluten under the optimum ratio of water to reconstituted flour. These facts suggested the importance of batter pH and gluten matrix formation in pan-cake baking under optimum ratio of water to original flour.

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