

Effect of Gaseous Acetic Acid Treatment on Breadmaking Properties of Flour

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ABSTRACT

Cereal Chem. 76(6):898-901

Eleven different wheat flours of varying protein content were treated with gaseous acetic acid. Each wheat flour exhibited maximum breadmaking properties (bread height and specific volume) at different levels of gaseous acetic acid treatment. There was a relationship ($r = +0.7384$)

between the level of gaseous acetic acid treatment required for maximum breadmaking properties and the protein content of the wheat flour. Wheat flours with higher protein contents were more resistant to the decrease in pH value due to acetic acid treatment.

Methods of improving breadmaking quality are now being researched by many people. Acetic acid treatment of wheat flour improves its breadmaking properties (Seguchi et al 1997a). Maximum breadmaking quality was obtained adding 2–3 mL of gaseous acetic acid/kg of wheat flour. The breadmaking quality decreased at higher levels of acetic acid treatment and a bad taste of acetic acid was present. Liquid acetic acid addition to wheat flour has almost same effects on breadmaking as gaseous acetic acid treatment. However, gaseous acetic acid treatment would protect against the bacterial infection of flour in storage. The improving effects on breadmaking quality by acetic acid were due to 1) acetic acid increasing the water binding capacity and viscosity of the tailings fraction in wheat flour, mainly because of proteins in the tailings fraction (Seguchi et al 1997b); and 2) acetic acid activating a physiological property of bakers' yeast and increasing the generation of carbon dioxide gas (Seguchi et al 1997a). The level of acetic acid treatment required for different wheat flours varies and is probably due to differences in the protein content of the wheat flours.

In this study, 11 different wheat flours were treated with gaseous acetic acid and then evaluated for breadmaking quality. The level of acetic acid treatment necessary to give maximum breadmaking quality (bread height and specific volume) was determined. The protein content in the wheat flour was then correlated to the level of acetic acid applied. If a lower protein wheat flour could be improved with a lower level of gaseous acetic acid, poor breadmaking flours could be improved using this treatment. Japanese wheat flours (considered poor breadmaking flours because of lower protein content) could be improved by this acetic acid treatment.

MATERIALS AND METHODS

Materials

Eleven different wheat flours made from Western White and Hard Red Spring wheat flours were used in this experiment: Million, Kameia, Number One, and Super King (Nissin Flour Milling Co., Japan); Alps and Red Knight (Nitto Flour Milling Co., Japan); Mercury, Menkyobijin, Rikishi, Okan, and Takara (Fuji Flour Milling Co., Japan). Protein conversion was $N \times 5.7$. Ash was determined according to Approved Method 08-01 (AACC 1995) at 14.0% mb.

Gaseous Acetic Acid Treatment of Wheat Flour

Wheat flour was treated with gaseous acetic acid at room temperature. Wheat flour (1.0 kg) was packed into the column (7 cm dia, 41 cm height) and set as reported previously (Seguchi et al 1997a). Compressed air was introduced into the flour through the bottom of the column at 1.0 L/min. Variable volumes (0.25, 0.50, 1.0, 2.0, 3.0, 4.0, 5.0 mL) of 99.7% acetic acid solution were

taken into a sample bottle which was connected by tubes between the compressor and column. Gaseous acetic acid in the compressed air was introduced into the wheat flour overnight. Wheat flour and bread crumb pH values were determined by Approved Method 02-52 (AACC 1995).

Baking Method

Baking absorption of each flour was determined in a farinograph with 300 g of flour (Approved Method 54-21, AACC 1995). Wheat flour (100%), compressed yeast (2.9%), sugar (5.0%), salt (1.0%), and water (estimated from farinograph at 500 BU) were mixed in a computer-controlled National automatic bread maker (SD-BT6, Matsushita Electric Ind. Co. Ltd., Japan) with the first proof for 2 hr and 20 min at 30°C. The time for the first mixing was 15 min, then 50 min of rest, 5 min for the second mixing, and 70 min of fermentation. Dough was divided into 120-g pieces, rounded, molded, and placed in baking pans (Approved Method 10-10A, AACC 1995). The dough was proofed for 22 min at 38°C and baked at 210°C for 30 min in a model DN-63 oven (Yamato Scientific Co. Ltd., Japan). After baking, the bread was removed from the pan and cooled for 1 hr at 26°C (room temperature) and 43% rh. Bread height (mm), weight (g), and volume (cm³) were measured, and the crumb grain was evaluated visually.

Protein Content and Level of Treatment

To clarify the relationship between the protein content in wheat flour and the level of gaseous acetic acid treatment, a model experiment was conducted wherein wheat flour (10 g) and water (90 mL) were mixed by a magnetic mixer and titrated with 0.1N acetic acid solution to attain a constant pH value of 4.0. The pH was measured in a pH meter (M-11, Horiba, Kyoto, Japan).

Statistical Analysis

A statistical software package (SPSS Inc., Chicago, IL) was used. Experiments were repeated four times and the results were averaged. Analysis produced significant *F*-values by analysis of variance, followed by Duncan's multiple range test for comparison of means.

RESULTS AND DISCUSSION

Analytical Data on Wheat Flours

The protein and ash contents (14.0% mb) of 11 different flours are indicated in Table I. The protein contents varied over a wide range, from Alps flour at 8.20% to Takara flour at 16.30%. Ash contents also varied over a wide range (0.32–0.55%).

Gaseous Acetic Acid Treatment of Wheat Flours

The level of gaseous acetic acid applied to the flours varied from 0.25 to 5.0 mL/kg of wheat flour. The range of the treatment for each wheat flour was selected according to the maximum baking properties such as bread height (mm), specific volume (cm³/g), and crumb grain. The absorption (%) and pH level of each flour after acetic acid treatment are shown in Table II. The absorption

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of the untreated flour increased as protein content increased. The relative coefficient between absorption and flour protein content was $r = +0.7916$. The absorption of the flours after acetic acid treatment changed. Some slightly increased and some slightly decreased with an increase in the acetic acid level. A decrease in flour pH was observed previously (Seguchi et al 1997a).

Breadmaking Tests with Treated Wheat Flours

Table III shows the bread height (mm), specific volume (cm^3/g), and crumb pH of bread from wheat flours treated with gaseous acetic acid. Figure 1 shows bread baked with treated Takara flour (highest protein content), Red Knight flour (medium protein content), and Alps flour (lowest protein content). All wheat flours produced bread with a maximum height, specific volume, and crumb grain at various levels of gaseous acetic acid treatment. Those properties gradually decreased at lower and higher levels of acetic acid as reported previously (Seguchi et al 1997a). From Table III, it is clear that the optimum level of gaseous acetic acid required to produce bread with maximum quality varied from flour to flour. This may be due to the difference in protein content among the flours. The relationship between the level of gaseous acetic acid necessary to produce bread with maximum quality and the protein content of each wheat flour was statistically analyzed. The correlation coefficient ($r = +0.7384$) suggests a relationship between the two factors. Figure 2 shows the relationship between the level of gaseous acetic acid for a maximum specific volume and the protein content (%) in each wheat flour. The level of gaseous acetic acid for the maximum breadmaking properties proportionally increases with increases in protein content of the wheat flour.

Acetic acid produced a noticeably bad taste in the bread crumb when the level of gaseous acetic acid was $>3.0\text{--}4.0$ mL/kg. Thus, it is advisable to use flour with lower protein content and a lower level of acetic acid treatment to avoid a bad taste.

The crumb pH of the breads with maximum breadmaking properties made from all of the flours was $\approx 4.6\text{--}4.9$, and each flour needed a specific level of gaseous acetic acid. This suggests that the level of gaseous acetic acid treatment may be determined by

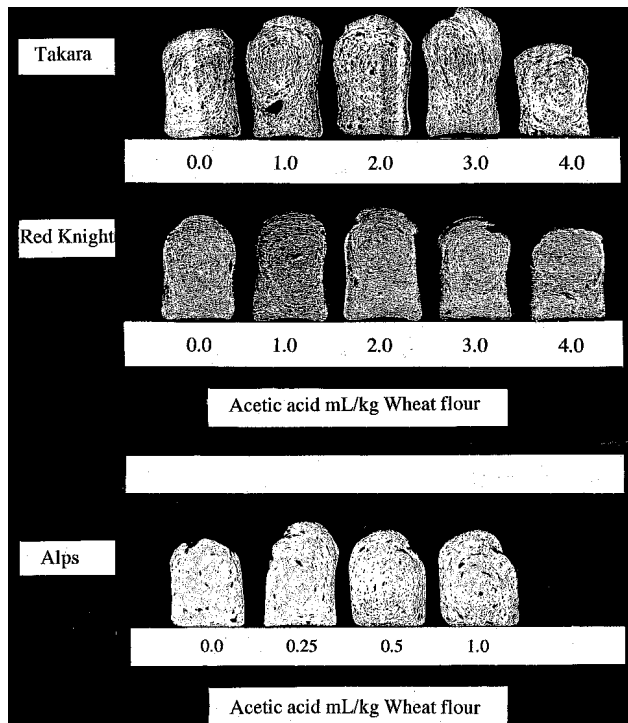


Fig. 1. Bread made with Takara, Red Knight, and Alps wheat flours (from top to bottom) treated with various levels of gaseous acetic acid.

TABLE I
Protein^a and Ash Contents (%) of Wheat Flour^{b,c}

Flour	Protein	Ash
Alps	8.2 ± 0.2	0.34 ± 0.04
Mercury	9.1 ± 0.1	0.32 ± 0.01
Menkyobijin	10.2 ± 0.1	0.39 ± 0.01
Rikishi	11.2 ± 0.1	0.33 ± 0.00
Okan	11.8 ± 0.1	0.36 ± 0.00
Million	14.7 ± 0.4	0.41 ± 0.03
Red Knight	14.8 ± 0.2	0.37 ± 0.02
Kameraia	14.9 ± 0.3	0.37 ± 0.00
Number One	15.6 ± 0.3	0.38 ± 0.02
Super King	16.1 ± 0.2	0.43 ± 0.03
Takara	16.3 ± 0.1	0.55 ± 0.01

^a N × 5.7.

^b 14.0% mb.

^c Values represent average and standard deviation of duplicates.

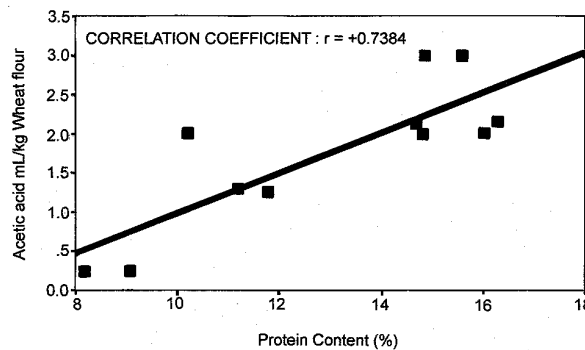


Fig. 2. Correlation relationship between protein content (%) of wheat flour and level of gaseous acetic acid (mL/kg of wheat flour) required to achieve maximum specific volume.

TABLE II
Baking Absorption (%) and pH Levels^a of Flours Treated with Acetic Acid

Flour	Acetic Acid (mL/kg)							
	0.0	0.25	0.5	1.0	2.0	3.0	4.0	5.0
Alp	51.2 (5.71)	53.2 (5.52)	51.0 (5.22)	51.0 (4.99)	...	...	...	...
Mercury	54.0 (6.20)	59.1 (6.15)	55.3 (6.19)	53.6 (5.10)	53.8 (4.85)	54.3 (4.70)	...	...
Menkyobijin	61.5 (4.90)	...	...	61.6 (4.70)	62.7 (4.50)	62.9 (4.30)	...	...
Rikishi	65.0 (nd) ^b	...	64.8 (nd)	65.9 (nd)	68.7 (nd)	68.0 (nd)	59.4 (nd)	...
Okan	63.2 (nd)	...	...	65.9 (nd)	66.3 (nd)	67.0 (nd)	67.7 (nd)	...
Million	62.6 (5.88)	...	...	57.7 (5.18)	65.0 (5.00)	66.0 (4.72)	66.3 (4.59)	63.1 (4.52)
Red Knight	69.0 (5.69)	...	...	70.0 (5.05)	70.0 (4.75)	72.0 (4.64)	72.9 (4.51)	...
Kameraia	67.9 (6.00)	...	...	69.3 (5.90)	70.0 (5.08)	69.8 (4.72)	68.4 (4.61)	...
Number One	69.6 (5.50)	...	...	66.4 (5.05)	65.0 (4.80)	61.2 (4.60)	65.5 (5.20)	67.0 (4.70)
Super King	65.4 (5.90)	...	...	62.7 (5.25)	60.0 (5.10)	64.2 (4.50)	62.3 (nd)	65.8 (nd)
Takara	62.9 (nd)	...	...	65.2 (nd)	65.2 (nd)	65.0 (nd)	65.9 (nd)	...

^a Number in parenthesis is pH value.

^b Not determined.

TABLE III
Effect of Gaseous Acetic Acid on Breadmaking Properties of Wheat Flours^a

Flour	Acetic Acid (mL/kg)							
	0.0	0.25	0.5	1.0	2.0	3.0	4.0	5.0
Alps								
Bread height (mm)	71.8 (1.6)a	75.8 (0.8)b	70.9 (1.6)a	68.0 (0.9)c	...	...	...	...
Specific vol. (cm ³ /g)	2.68 (0.02)a	2.99 (0.08)a	2.77 (0.10)a	2.77 (0.12)b	...	...	...	...
Crumb pH	4.90	4.83	4.59	4.51	...	...	...	...
Mercury								
Bread height (mm)	72.1 (3.3)bc	75.0 (1.0)bc	70.8 (2.8)a-c	67.4 (4.4)abd	63.1 (3.2)ad	58.4 (1.9)e	...	...
Specific vol. (cm ³ /g)	2.79 (0.09)bd	2.98 (0.04)c	2.75 (0.08)abd	2.67 (0.07)ab	2.63 (0.15)ab	1.83 (0.10)e	...	...
Crumb pH	5.05	5.20	5.10	5.00	4.60	4.30	...	...
Menkyobijin								
Bread height (mm)	79.1 (1.9)b	...	...	79.1 (1.2)b	84.4 (2.6)a	80.3 (3.0)b	...	...
Specific vol. (cm ³ /g)	3.40 (0.13)b	...	...	3.48 (0.05)b	3.68 (0.09)a	3.42 (0.02)b	...	...
Crumb pH	4.95	...	...	4.90	4.70	4.60	...	...
Rikishi								
Bread height (mm)	76.6 (2.5)bc	...	79.6 (0.7)b-d	80.0 (1.6)b-d	67.4 (6.3)a	83.2 (0.7)bd	54.8 (1.3)e	...
Specific vol. (cm ³ /g)	3.29 (0.17)a	...	3.68 (0.04)b	3.64 (0.04)b	3.40 (0.08)a	3.74 (0.08)b	2.43 (0.04)c	...
Crumb pH	5.20	...	...	4.87	4.70	4.60	4.49	...
Okan								
Bread height (mm)	75.5 (0.7)b	...	...	76.0 (1.2)b	79.0 (0.9)a	81.7 (2.4)a	68.3 (3.0)c	...
Specific vol. (cm ³ /g)	3.10 (0.08)b	...	...	3.64 (0.06)a	3.63 (0.13)a	4.03 (0.14)c	3.02 (0.18)b	...
Crumb pH	5.10	...	...	5.08	4.90	4.60	4.50	...
Million								
Bread height (mm)	79.4 (2.9)b	...	...	83.5 (2.3)b	89.4 (6.1)a	91.5 (0.2)a	66.7 (2.3)c	64.6 (2.3)c
Specific vol. (cm ³ /g)	3.47 (0.07)b	...	...	3.87 (0.05)a	4.00 (0.11)a	4.23 (0.10)c	2.74 (0.05)d	2.73 (0.08)d
Crumb pH	5.35	...	...	4.90	4.90	4.70	4.38	4.40
Red Knight								
Bread height (mm)	61.7 (0.4)c	...	...	68.8 (1.2)b	73.9 (0.6)a	60.1 (0.6)c	51.5 (23)d	...
Specific vol. (cm ³ /g)	2.85 (0.08)b	...	...	3.19 (0.01)a	3.33 (0.06)a	2.65 (0.07)bc	2.58 (0.14)bc	...
Crumb pH	5.55	...	...	5.15	4.88	4.55	4.45	...
Kameraia								
Bread height (mm)	62.7 (1.2)bd	...	...	62.0 (1.5)bd	59.2 (2.1)ad	84.7 (3.7)c	60.7 (0.3)abd	...
Specific vol. (cm ³ /g)	2.64 (0.10)b	...	...	2.49 (0.07)a	2.41 (0.06)ad	3.86 (0.16)c	2.31 (0.02)ad	...
Crumb pH	5.11	...	...	4.90	4.92	4.64	4.50	...
Number One								
Bread height (mm)	85.2 (2.8)b-d	...	...	82.6 (2.2)a-c	82.9 (2.1)a-c	87.0 (2.7)cd	83.8 (0.8)a-d	58.13 (3.0)e
Specific vol. (cm ³ /g)	3.95 (0.12)ab	...	...	4.02 (0.14)a-c	4.01 (0.15)a-c	4.17 (0.09)ac	3.92 (0.13)ab	2.12 (0.06)d
Crumb pH	4.90	...	...	4.90	4.75	4.40	4.70	4.50
Super King								
Bread height (mm)	92.2 (2.1)a	...	...	94.6 (1.6)b	95.9 (1.0)c	92.8 (4.1)d	...	...
Specific vol. (cm ³ /g)	4.35 (0.21)ac	...	...	4.53 (0.11)a-c	4.69 (0.10)ab	4.41 (0.15)ac	...	...
Crumb pH	5.18	...	...	4.70	4.60	4.40	...	...
Takara								
Bread height (mm)	84.2 (1.6)b	...	...	93.8 (4.1)a	92.4 (3.5)a	93.0 (2.1)a	71.5 (1.4)c	...
Specific vol. (cm ³ /g)	3.99 (0.11)b	...	...	4.50 (0.07)a	4.52 (0.08)a	4.71 (0.13)c	3.53 (0.07)d	...
Crumb pH	5.05	...	...	4.80	4.52	4.41	4.20	...

^a Values represent means of four replicates and standard deviation in parentheses. Means followed by the same letters in rows are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

TABLE IV
Amount of 0.1N Acetic Acid Required to Decrease to pH 4.0^a

Flour	Protein Content (%)	0.1N Acetic Acid (mL)
Alps	8.21 ± 0.2	23.3
Rikishi	11.2 ± 0.1	31.5
Red Knight	14.8 ± 0.2	34.0
Takara	16.3 ± 0.1	45.0

^a Titrations performed twice with average.

the strength of the buffer action of proteins in wheat flour. Flour is a relatively good buffer system (Hoseney 1994).

Change in pH Level by Addition of Acetic Acid

The results from four flours, Takara, Alps, Red Knight, and Kameraia, are listed in Table IV. The largest amount of 0.1N acetic acid solution to attain pH 4.0 was required by Takara. The order of the amount of 0.1N acetic acid solution required to reduce the pH to 4.0 was the same order as the protein content of the wheat flours (i.e., the lowest protein content wheat flour, Alps, attained pH 4.0 with the smallest amount of 0.1N acetic acid solution). The order of the amount of 0.1N acetic acid solution required to reduce the

wide range of pH values (6.0–3.5) was also the same order as the protein content of the wheat flours. This may be due to the buffering action of the proteins in the flour. From these results, we concluded that the level of gaseous acetic acid treatment for maximum baking properties was influenced by the buffering action of the proteins in the flour.

CONCLUSIONS

Eleven wheat flours of various protein contents were treated with gaseous acetic acid and baked into bread. The baking results showed that each wheat flour had its own maximum baking properties (bread height, specific volume, and crumb grain) at different levels of gaseous acetic acid treatment. The amount of acetic acid needed to achieve the maximum baking properties was correlated ($r = +0.7384$) to the protein content of the wheat flour. Titration experiments showed that proteins in the wheat flour had a buffering action against acetic acid solution, which suggests that wheat flour had a buffering action against the gaseous acetic acid. Wheat flours with higher protein contents were more resistant to the decrease in pH value due to acetic acid treatment and gave maximum baking properties.

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[Received March 1, 1999. Accepted July 12, 1999.]