# Gas Retention of Different Cereal Flours[1]

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**ABSTRACT**

Wheat, rye, rice, and corn flours were compared for their bread-baking properties. Only wheat flour formed a viscoelastic dough and produced a light-textured loaf. Differences in gassing power among the four cereal flours were not sufficient to explain the differences in loaf volume. Measurement of $CO_2$ released from doughs using an electric resistance oven showed that over the periods of fermentation, proofing, and baking, wheat flour dough retained gas until heated to 72°C during baking, whereas the other doughs started releasing gas during fermentation or proofing. The flours released gas as follows, in decreasing order: corn, rice, rye, wheat. Loaf volume was in the reverse order, indicating that the gas retention ability of dough mainly determined the loaf volume of these cereal flours.

Wheat flour is unique among cereal flours. It can form a viscoelastic dough that retains gas produced during fermentation and the early stages of baking. This ability to retain gas results in light-textured products. Wheat gluten proteins are believed to be primarily responsible for the uniqueness of wheat flour dough (Finney and Barmore 1948).

Although rye flour is second only to wheat flour in its ability to retain gas, the extent of gas retention is limited. Johnson and Bailey (1925) found that rye flour dough produced gas at a high rate, but its ability to retain gas was low. Rye flour contains a much greater amount of pentosans (8%) than does wheat flour (3%). It is believed that rye flour pentosans are functionally more important than is protein, and the viscosity of rye dough is extremely important to baking quality (Drews and Seibel 1976).

On a worldwide basis, rye flour is used to a great extent in making bread. However, pure rye doughs tend to be sticky, and the breads are very dense and compact. Therefore, rye flours are usually blended with various amounts of wheat flour for bread production in Canada and the United States (Drews and Seibel 1976).

As for other flours, rice flour is mainly consumed as boiled rice, whereas corn flour (as a human food) is mainly used for production of tortillas, snacks, and breakfast cereals. The proteins of rice and corn flours do not develop a film on mixing, nor can their doughs retain gas (Nishita et al 1976). Therefore, rice or corn cannot be substituted directly for wheat in a yeast-leavened product without formula modifications. Various gums and surfactants have been used successfully in breads made with wheat starch and other cereal flours and starches (Kulp et al 1974). Nishita et al (1976) found that the gum hydroxypropyl methylcellulose enhanced gas retention in a bread made with 100% rice flour.

Although it is well known that wheat flour dough can retain gas, whereas the other cereal flour doughs cannot, little or no data in the literature support this common concept. The objective of the present study was to demonstrate and document the differences in gas retention of wheat, rye, rice, and corn flour doughs and the relationship between gas retention and loaf volume.

## MATERIALS AND METHODS

A commercial bread flour was obtained from Ross Mills (Wichita, KS), rye flour from Bay State Milling Co. (Winona, MN), and corn flour from Lauhoff Grain Co. (Danville, IL). Rice flour was purchased at a local international store. The protein and ash content of the four flours are listed in Table I.

The activity of α-amylase in cereal flours was determined by falling number, using AACC Method 56-81B (AACC 1983). Each sample was measured in duplicate. Malted barley flour was used to bring all the flours to about 220 falling-number units.

A DSI Gasograph 12 was used to determine gas production. Samples were prepared by the method described by Rubenthaler et al (1980). Each sample was measured in duplicate. Gas production, in gasograph units, was determined over 4 hr of fermentation time.

Preparation of dough generally followed AACC method 10-10B (AACC 1983); the details are described elsewhere, as is the procedure for measuring $CO_2$ release (He and Hoseney 1991).

## RESULTS AND DISCUSSION

### Baking Properties

More water was needed for rye, rice, and corn flours than for wheat flour to form a dough. Corn flour had the highest water absorption—13% above that of wheat flour (Table II).

Wheat flour gave a viscoelastic dough with nice handling properties. Rye flour was readily hydrated during mixing; however, the dough produced was very sticky and difficult to handle. Rice or corn flour did not hydrate as readily as did rye flour and needed a longer mixing time to form a cohesive, short mass.

The bread quality of wheat flour was largely different from that of the other cereal flours (Fig. 1). Wheat flour produced a light, leavened loaf with large volume. Rye, rice, and corn flours

**TABLE I**
**Analysis and Baking Properties of Four Cereal Flours Studied**

| Flour | Type or Variety | Protein (%)[a] | Ash (%)[a] | Loaf Volume ($cm^3$) | SD ($cm^3$) |
|---|---|---|---|---|---|
| Wheat | Commercial bread flour | 11.50 | 0.48 | 932 | 11.5 |
| Rye | Pure light | 8.20 | 0.38 | 244 | 4.8 |
| Rice | Medium grain | 7.00 | 0.34 | 200 | 9.1 |
| Corn | CCF 600 | 7.70 | 1.70 | 179 | 9.5 |
| Wheat | Diluted with starch | 7.0 | ··· | 707 | 12.6 |

[a]Based on 14% moisture.

**TABLE II**
**Dough Properties of Four Cereal Flours Studied**

| Flour | Water Absorption (%)[a] | Mixing Time (min) | Dough Properties | Gas Production (gasograph units) |
|---|---|---|---|---|
| Wheat | 60 | 4.20 | Viscoelastic | 65 |
| Rye | 66 | 1.00 | Very sticky | 56 |
| Rice | 66 | 2.00 | Cohesive, short | 50 |
| Corn | 73 | 2.00 | Cohesive, short | 64 |

[a]Based on weight of the flour.

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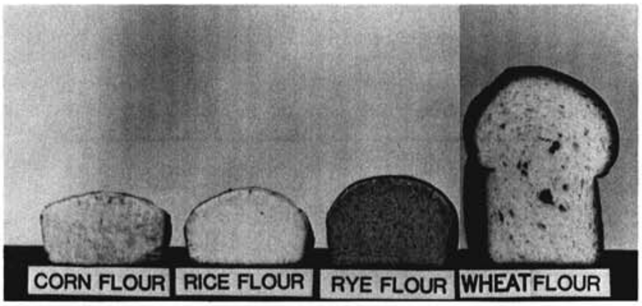


**Fig. 1.** Loaves made from corn, rice, rye, and wheat flours.

gave very dense, small loaves. Rye flour gave the largest loaf volume, with a slightly porous texture, followed by loaves made from rice and corn flours.

Loaf volume is determined by two factors: the amount of gas produced by and retained in a dough. To elucidate which was primarily responsible for the difference in loaf volume between wheat flour and the other three flours, their gassing power and ability to retain gas were studied.

### Gassing Power

Wheat and corn flours had essentially the same gassing power; rye flour had a lower gassing power and rice flour the lowest (Table II). This might be because certain nutrients required for yeast fermentation are low in rye and rice flours. The lower gassing powers of rye and rice flours may contribute to their smaller loaf volumes. However, the difference in gassing power between wheat and rye or rice flours is much smaller than are the differences in loaf volume. Corn flour had the same gassing power as did wheat flour but gave the smallest loaf volume. Therefore, gas production apparently is not a major factor affecting loaf volume.

### Gas Retention Rate

Little $CO_2$ was lost from any of the doughs at the beginning of fermentation (Fig. 2). This might be the period of $CO_2$ saturation in the aqueous phase of dough. After 35 min of fermentation, corn and rice flour doughs started to lose $CO_2$, but wheat and rye flour doughs did not. Corn flour dough lost $CO_2$ at a faster rate than did rice flour dough.

During proofing, all the doughs lost more $CO_2$ than they did during the first hour of fermentation. However, wheat flour dough still had a very slow rate of gas release, about 5 $\mu$mol/min. Rye flour dough retained gas well at the beginning, but the rate of release increased with time. By the end of proofing, the rate was about 17 $\mu$mol/min. For the rice flour dough, the rate of gas release became fast only a few minutes after proofing began and essentially remained constant thereafter (about 22 $\mu$mol/min). Corn flour dough had the greatest rate of gas release, 27 $\mu$mol/min, and remained constant during proofing.

Therefore, the ability of wheat flour dough to retain gas at room temperature was outstanding—far better than that of rye, rice, or corn flour doughs. Among these three, rye flour dough retained the most gas, corn flour dough the least.

### Baking

When baking started, the rate of gas loss from corn flour dough immediately increased to its maximum (Fig. 3). At 55°C it started to decrease markedly until $CO_2$ was depleted. The general patterns of gas loss from rice and rye flour doughs were similar to that of corn flour dough. The order of gas loss at the beginning of baking was (in decreasing order) rye, rice, and corn flour doughs. The temperature at which $CO_2$ was depleted within dough was (in decreasing order) rye, rice, and corn flour.

The fast release of gas from corn or rice flour dough when baking started was probably attributable to $CO_2$ vaporization from its aqueous phase, because the solubility of $CO_2$ decreases with increasing temperature. The delayed release of $CO_2$ from rye flour dough may be attributed to the high viscosity in the aqueous phase because of its high pentosan content.

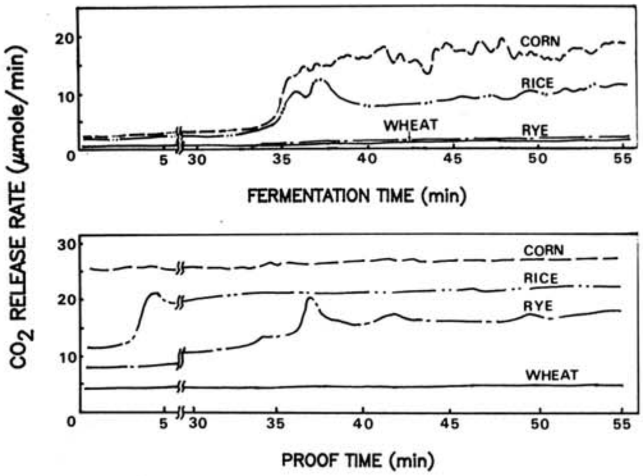


**Fig. 2.** Rate of $CO_2$ loss from doughs made from corn, rice, rye, and wheat flours during the first hour of fermentation and during proofing at room temperature (23°C).

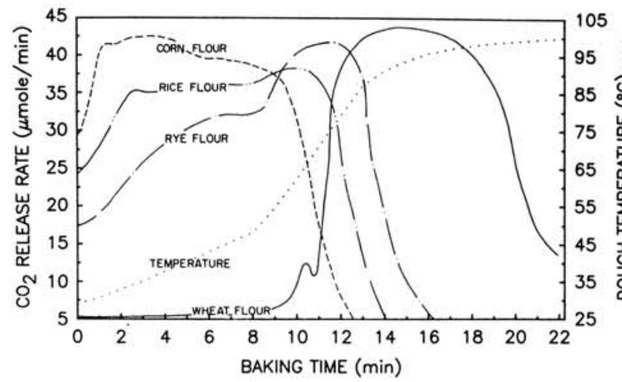


**Fig. 3.** Rate of $CO_2$ loss from doughs made from corn, rice, rye, and wheat flours during baking.

Wheat flour dough essentially retained gas until about 72°C; then the rate of gas loss increased sharply, reaching its maximum at about 88°C. What causes the change in gas retention in wheat flour dough will be discussed in a future report.

## CONCLUSIONS

Of the four cereal flours tested, only wheat flour gave a viscoelastic dough. After baking, large differences were evident in the quality of bread produced by wheat flour compared with that of the other three cereals. Rye, rice, and corn flours gave very dense, small loaves. The effect of gassing power on loaf quality seemed insignificant. The major factor causing the differences in bread quality was the unique ability of wheat flour to retain gas. Although the protein content of the flours varied among rye, corn, and rice flours (all lower than that of wheat flour), wheat flour diluted with starch to 7.0% protein still gave a larger loaf volume did the other flours.

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