

## Utilization and characteristics of starch in bread processing

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Dough containing corn starch or potato starch can expand the same as standard dough, but dough containing sweet potato starch does not expand easily. Corn starch-bread allows extension of the dough with gas, keeps the gas in the dough, preserves gas release the same as standard dough and leads to a normal loaf volume. However, the corn starch-dough does not contain gluten like wheat flour because the characteristics of corn starch are almost the same as wheat starch, and bread containing corn starch may be used like a rusk. Potato starch-bread could expand the same as standard bread up to 2 hours of incubation, but formed holes in the top of dough with excessive gas and produced a low loaf volume after 3 hours. Whether starch-bread can expand is dependent on the type of starch used.

### Introduction

Many attempts have been made to popularize bakery products because they are an easy, convenient and inexpensive means of taking in hygienically prepared, ready-to-eat nutrition<sup>1)-8)</sup>.

In general, wheat flour (hard flour) is used in bread processing. Wheat flour and water are mixed together, and the protein content forms a complex, known as gluten, the elastic properties of which are responsible for the moulding properties of the dough and its ability to retain the carbon dioxide produced by yeast fermentation during proof and to give a bold, well-risen loaf on baking.

On the other hand, many starches such as corn starch, sweet potato starch and potato starch are industrially produced from corn, sweet potato and potatoes, respectively.

However, the utilization and characteristics of starch in bread processing have not yet been documented. Starch may be used in bread making even though it does not contain gluten.

We describe herein the relationship between starch and dough expansion due to baker's yeast in starch-bread processing.

### Materials and Methods

#### 1. Materials

Wheat flour "Kameria" and dry yeast "Super kameria" were obtained from Nisshin Flour Milling Co., Tokyo, Japan. Corn starch and potato starch were obtained from Nacalai tesque Co., Kyoto, Japan. Sweet potato starch was obtained from Sanwa starch Co., Nara, Japan. Table 1. shows the composition of the wheat flour and starches.

Table 1. The composition of wheat flour and starches

Wheat flour or starch	Concentration (%)				Lipid
	Water	Protein (Gluten)	Carbohydrate Non-fibrous	Fibrous	
Wheat flour (Hard flour)	14.5	11.7	71.4	0.2	1.8
Sweet potato starch	17.5	0.1	82.0	0	0.2
Potato starch	18.0	0.1	81.6	0	0.1
Corn starch	12.8	0.1	86.3	0	0.7

Data from *Carbohydrates in food* (Marcel Dekker, Inc, New York)<sup>9)</sup> and *Determination of food carbohydrates 2<sup>nd</sup> ed.* (Elsevier Applied Science, London and New York)<sup>10)</sup>.

## 2. Measurement methods

Table 2. shows the ingredients of standard bread (bread containing wheat flour) and starch-bread (bread containing starch). Wheat flour was replaced by starch in dough which was mixed, fermented at 30°C for 150 min and then baked at 180°C for 20 min. The experiments on gas production and dough expansion were done on a small scale. The loaf volume was measured using the rapeseed displacement method.

**Table 2.** Ingredients of standard bread and starch-breads

Ingredient	Amount (g)		Ratio (%)
	Small scale	Large scale	
Wheat flour or Starch	5.6	84	100
Sugar	0.3	4.5	5.4
Butter	0.2	3.0	3.6
Dried non-fat milk	0.1	1.5	1.8
Salt	0.1	1.5	1.8
Water	3.6	54	64.3
Dry yeast	0.06	0.9	1.1
Total	10.0	150	—

The wheat flour or starch was added to the dough, mixed, fermented, and then baked into bread.

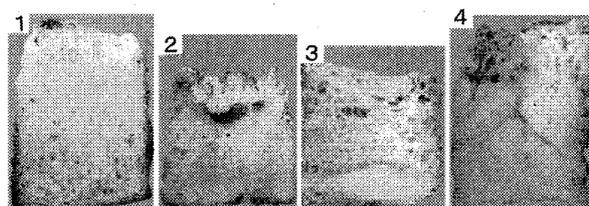
## 3. Gas production and dough expansion

Portions of 10 g of standard dough and starch-dough, which were prepared from the ingredients shown in Table 1., were placed in flat-bottomed tubes (φ26 mm x 117 mm) or syringes (for 50 ml; φ28 mm x 100 mm). The expansion of the dough in the flat-bottomed tubes was measured by determining the height of the dough during dough development (fermentation) at 30°C for 5 hours. Gas production of the dough in the syringes was calculated by measuring the accumulation of carbon dioxide.

## Results and Discussion

### 1. Characteristics of starch-bread

As shown in Fig. 1. and Table 3., the loaf volumes of the breads containing corn starch-dough were almost the same as those of standard bread. The loaf volume of potato starch-bread was lower than corn starch-bread, and



**Fig. 1.** Photographs of standard bread and starch-breads

1, standard bread (bread containing wheat flour); 2, sweet potato starch-bread; 3, potato starch-bread; 4, corn starch-bread. Starch-bread contained each different starch in the place of wheat flour. Photographs show the middle cutaway view of each loaf.

**Table 3.** The loaf volume of standard bread and starch-breads

	Loaf volume (ml)
Standard bread	356
Sweet potat starch-bread	229
Potato starch-bread	270
Corn starch-bread	359

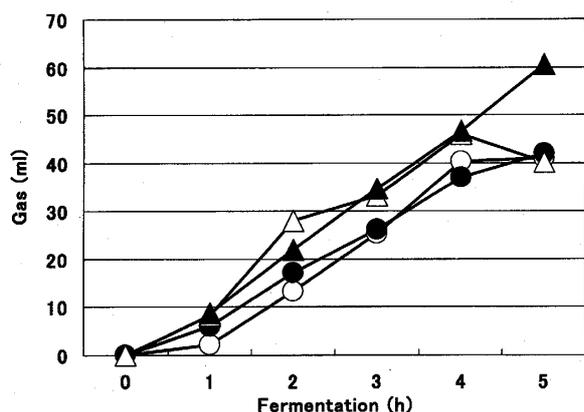
Standard bread contained wheat flour and starch-bread contained each respective starch in the place of wheat flour.

that of sweet potato starch-bread was about 0.6 times that of standard bread.

### 2. Effects of starch-dough on gas production

The production of gas during fermentation (dough development) in starch-bread processing was investigated. To estimate the effects of starch utilization in dough on gas production by alcohol fermentation, wheat flour was replaced by starch in the dough (Table 2.) with dry baker's yeast. Each dough was incubated anaerobically at 30°C.

Figure 2. shows the effects of starch-dough on gas production. The corn starch-bread dough produced a lot of gas, and the sweet potato starch-bread and potato starch-bread produced the same amount of gas as standard bread after 5 hours. Therefore, the gas production with baker's yeast starch-bread was almost the same as standard bread.



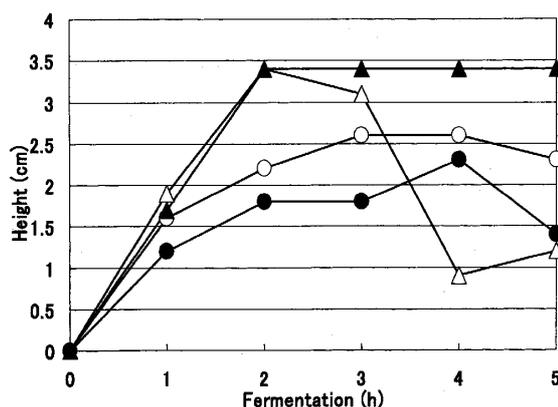
**Fig. 2.** Effect of starch-doughs on gas production  
 ○, standard dough; ●, sweet potato starch dough; △, potato starch dough; ▲, corn starch dough. The gas production of the dough was calculated by measuring the accumulation of carbon dioxide during fermentation at 30°C for 5 hours.

### 3. Effects of starch-dough on expansion

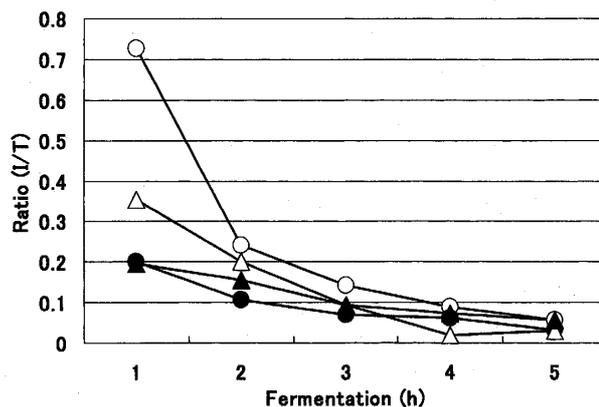
The standard dough and starch-doughs were expanded by incubation at 30°C for 5 hours. The volumes (height in cm) of the corn starch-dough and potato starch-dough were found to be higher than those of standard dough after 2 hours of incubation, as shown in Fig. 3. The expanded corn starch-dough maintained the same volume (height in cm) for 5 hours. On the other hand, the expansion of potato starch-dough decreased after 2 hours, in spite of an increase in gas production (Fig. 2.). The sweet potato starch-dough expanded less than standard dough.

As shown in Fig. 4., the ratio of internal gas (I) to total gas (T) of the standard dough was higher than those of starch-doughs. And the ratio (I/T) of potato starch-dough was higher than that of corn starch-dough and sweet starch-dough up to 2 hours, but decreased after 4 hours of incubation.

Gas production, dough expansion and the ratio (I/T) of potato starch-dough were at good levels for 2 hours, but worsened after 5 hours of incubation. On the other hand, those of corn starch-dough maintained good levels for 5



**Fig. 3.** Effect of starch-doughs on expansion  
 ○, standard dough; ●, sweet potato starch-dough; △, potato starch-dough; ▲, corn starch-dough. The expansion of the dough was measured by determining the height of the dough during development (fermentation) at 30°C for 5 hours.



**Fig. 4.** Ratio of internal gas to total gas production  
 ○, standard dough; ●, sweet potato starch-dough; △, potato starch-dough; ▲, corn starch-dough.

hours. Sweet potato starch-dough had bad levels up to 5 hours.

Table 4. shows the comparative properties of some commercial starches. Corn starch is almost the same as wheat starch in amylose content, amylopectin content, lipid, puffed volume, hardness, liquidity and X-ray-diffraction pattern. Therefore, it was concluded that dough containing corn starch expanded in the same way as standard dough even though it did not contain gluten because the characteristics of corn

starch are similar to wheat starch (Fig. 5(1), (2)).

**Table 4.** Comparative properties of some commercial starches

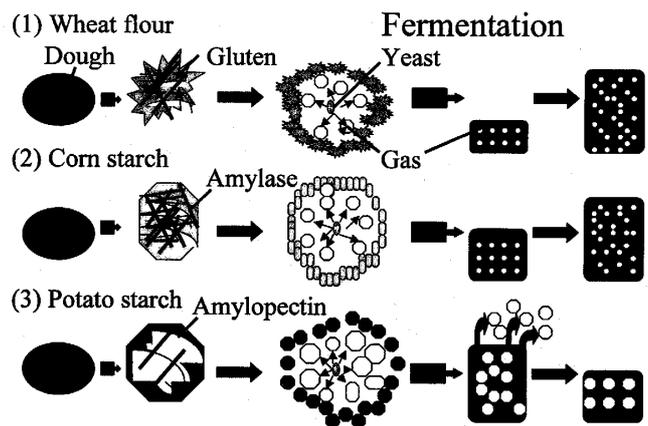
	Wheat Starch	Corn starch	Potato starch
Amylose(%)	30	28	20
Amylopectin(%)	70	72	80
Lipid(%)	1.8	0.7	0.1
Degree of amylose polymerization(Standard)	1180	990	4920
Granule size( $\mu\text{m}$ )	2-38	9.2	15-100
Puffed volume(ml/g)	3.8	3.8	7.2
Hardness(kg/cm <sup>2</sup> )	12.0	13.0	8.0
Viscosity [8%](BU)	0-420	80-780	1560-2500
Liquidity(%)	2.1	2.1	3.9
X-ray-diffraction pattern	A	A	B

Data from *Carbohydrate in food* (Marcel Dekker, Inc, New York)<sup>9)</sup> and *Determination of food carbohydrates 2<sup>nd</sup> ed.* (Elsevier Applied Science, London and New York)<sup>10)</sup>.

On the other hand, potato starch is not the same as wheat starch in many ways. Amylopectin is responsible for the moulding properties of dough and its ability to retain gas produced by yeast fermentation. The amylopectin content of potato starch is higher than that of wheat starch and corn starch. Therefore, it was concluded that dough containing potato starch expanded in the same way as standard dough up to 2 hours because the amylopectin in the potato starch allowed extension of the dough with gas, keeping the gas in the dough, and then forming holes in the top of dough. With excessive gas, the gas exited the dough, followed by a sharp fall in gas production. As a result, there was a low loaf volume after 3 hours (Fig. 5(3)).

In general, wheat flour is used in bread making because it contains gluten. Gluten, a specific and unique substance formed in the dough obtained from ordinary wheat flour, is characterized by physical properties such as cohesion, elasticity, and considerable stretchability.

However, dough containing corn starch expanded the same as standard dough, though it



**Fig. 5.** Scheme of the development mechanism of dough containing starch

(1), standard dough (dough containing wheat flour); (2), corn starch-dough; (3), potato starch-dough.

The dough containing corn starch expanded in the same way as standard dough though it did not contain gluten, because the characteristics of corn starch are similar to those of wheat starch. On the other hand, potato starch is not the same as wheat starch in many ways. Amylopectin is responsible for the moulding properties of dough and its ability to retain gas produced by yeast fermentation. The amylopectin content of potato starch is higher than that of wheat starch and corn starch. Therefore, the dough containing potato starch expanded the same as standard dough, up to 2 hours. The amylopectin in potato starch allowed extension of the dough with gas, kept the gas in the dough, and then formed holes in the top of dough due to excessive gas. When the gas exited the dough, there was a sharp fall in gas production. As a result, a low loaf volume resulted after 3 hours.

does not contain gluten. However, the corn starch-bread was hard to the touch like a rusk.

Therefore, we summarized that ① dough containing corn starch or potato starch can expand the same as standard dough, but dough containing sweet potato starch does not expand well, ② corn starch-bread allows extension of the dough with gas, keeps the gas in the dough, preserves gas release in the same way as

standard dough and leads to a normal loaf volume even though the corn starch-dough does not contain gluten like wheat flour. This is because the characteristics of corn starch are almost the same as wheat starch, and bread containing corn starch may be used to make hard bread like rusks, ③ potato starch-bread can expand the same as standard bread up to 2 hours of incubation, but formed holes in the top of dough with excessive gas, and produced a low loaf volume after 3 hours, ④ starch-bread expansion is dependent on the type of starch used. Plants grown for starch production include corn, sorghum, tapioca, arrowroot, sago, potato, wheat, and rice. Because the properties of these starches are different, it is interesting to make bread with various starch types.

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