The Basic Theory Needed for a Further Development of Frozen Dough Technology

Yoshifumi Inoue

Japan Institute of Baking, Tokyo, Japan

I. Introduction

Freshly baked bread and rolls possess a desirable flavor and texture. However these highly desirable attributes diminish rapidly with a lapse of time after baking. This problem and its accompanying economic losses have traditionally forced bakers to do midnight or early morning baking to provide the consumer with fresh bread on a daily basis. These factors have also limited the distance over which baked products can be transported from a large automated bakery.

Some of these problems can be overcome by using frozen dough, which can be quickly transformed into fresh-baked product in a small local bakery. Many such bakeries are now located in large grocery stores and contribute significantly to overall sales by attracting customers to the store.

The use of frozen dough for the production of bread and rolls has several advantages over conventional processing. It eliminates night or early morning labor, decreases the need for highly skilled bakers, reduces processing space and equipment, and increases the variety of baked items that can be produced in a single bakery. On the other hand, frozen dough encounters processing stresses during freezing, frozen storage, and thawing to which conventional non-frozen dough is not subjected. Accordingly, for optimal product quality from frozen dough, special attention must be paid to the selection of ingredients, optimization of formulas and processing conditions. This article summarizes the basic theory needed for a further development of the frozen dough technology in future.

Corresponding author:
Yoshifumi Inoue
Japan Institute of Baking, 6-19-6 Nishikasai, Edogawa-ku, Tokyo 134-0088, Japan
Tel: 03-3689-7571
Fax: 03-3689-7574
E-mail: yoshifumi-inoue@jibt.com

2. Factors determining baking properties of frozen dough

The most important baking property of frozen dough is oven spring power, which is determined by its gas producing and gas retention power. The gas producing power is attributed to yeast activity in the dough. CO_2 released from yeast during processes before baking is not only expanding the dough but also improving viscoelastic properties of gluten networks in the dough. The gas retention power is attributed to viscoelastic properties of gluten networks and the number of gas cells in the dough. The number of gas cells determines cell wall thickness in the dough and the baked products, so that it affects oven spring power of the dough and quality of baked goods from the dough significantly as shown in Fig.1. If yeast activity in the dough decreased considerably, expansion speed of the dough before baking will be too slow and result weaken gluten network in the dough. If formation and growth of ice crystals are occurred in the dough, gluten networks in the dough will be also weakened. In these cases, weakened gluten networks cause a decrease in the number of gas cells in the dough during expansion. A decrease in the number of gas cells in the dough also occurs during freezing and thawing processes due to behavior of CO_2. These are the factors that would cause damage in frozen dough. So that, maintenance of yeast activity, elasticity of gluten network, and the number of gas cells in the dough can be considered as the basic of frozen dough technology.

3. Maintenance of yeast activity

1) Effects of fermentation before freezing

As pioneer researchers on frozen dough, Kline and Sugihara(1) clearly showed that fermentation in dough prior to freezing reduces subsequent freeze tolerance of the yeast. To minimize loss of yeast activity resulting from pre-freezing fermentation, the dough should be frozen after the minimized fermentation process as shown in Regular Yeast in Fig.2 . The reason for this loss of activity due to the fermentation is presumed that with onset of fermentation, the yeast cell membrane becomes more sensitive to damage by freezing than dormant yeast cells[2)]. The products of fermentation, ethanol and other volatile organics, have been demonstrated to decrease the tolerance of the yeast

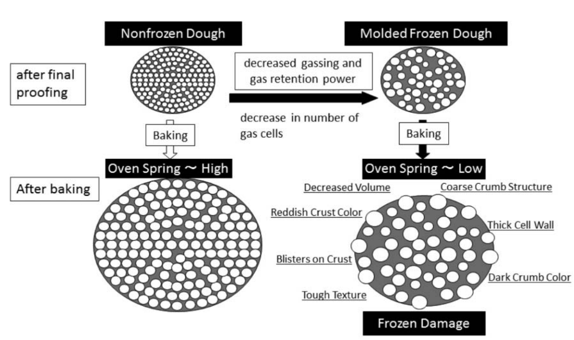

Figure 1. A model showing inappropriate way of frozen dough practice easily decrease gassing power and gas retention power of the dough, and deteriorate bread quality from the dough.

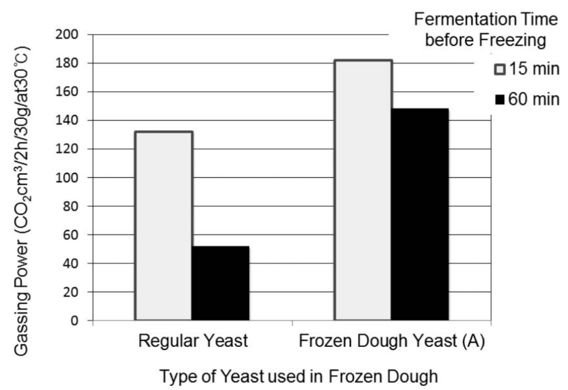

Figure 2. Effects of fermentation prior to freezing on regular and frozen dough yeast in dough.

to damage during freezing and frozen storage(2).

2) Development of frozen dough yeast

New freeze-tolerant yeast has been developed and is available commercially in some countries(3). This type of yeast is called as frozen dough yeast and possesses a higher freeze tolerance than regular bakery yeast (Fig. 2). This type of yeast can be frozen in the dough, that is prepared with a considerable fermentation prior to freezing, for prolonged periods of time without significantly losing its activity.

3) Effects of freezing rate and temperature

Rapid freezing is generally recommended for foods to minimize damage due to ice crystallization. However, this does not appear to apply to frozen dough, where extremely rapid freezing seems to have a detrimental effect on yeast activity(4). It is postulated that the formation of intracellular ice crystals, invariably lethal to yeast cell membrane, is unavoidable(5). Accordingly, the rate of cooling of the dough in a freezer is recommended to be slower than 1.5℃/min.

4. Maintenance of gas retention power

1) Effects of ice crystals on gluten net work

A fast freezing rate that can minimize the size of ice crystals should not be used for frozen dough preparation in order to maintain yeast activity in the dough. So that, it is recommended to consider that substantial growth of ice crystals occurs during frozen storage of frozen dough, and the gluten network will be weaken due to the growth(6). Accordingly, special attention must be paid to minimize the temperature fluctuation of frozen dough during frozen storage and shipping. The fluctuation would significantly enhance growth of ice crystals and thus weaken gluten network of the dough.

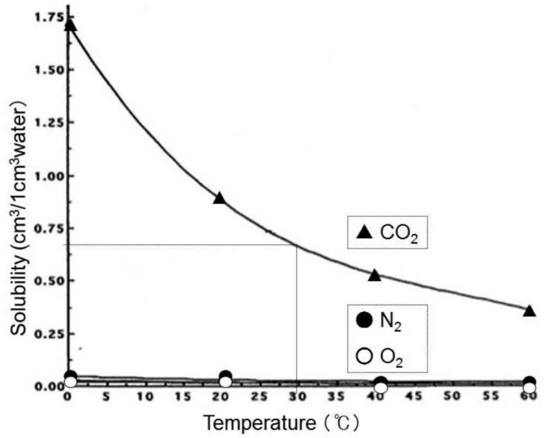

Figure 3. Effects of temperature on solubility of CO_2, N_2, and O_2 in water.

2) Effects of solubility change of CO_2 during freezing process

Solubility of CO_2 in gas cells in the dough to the water phase at the cooling step in a freezer increases approximately 2.5 times (Fig.3), and the change would deteriorate baking properties of the dough by decreasing the number of gas cells in the dough(7). In order to avoid the deterioration, fermentation prior to freezing, which accumulates CO_2 in gas cells, must be minimized.

3) Effects of diffusion of CO_2 during thawing in a retarder

Frozen dough is usually thawed for overnight at a refrigerated temperature in a retarder. According to this practice, time required for baking in the

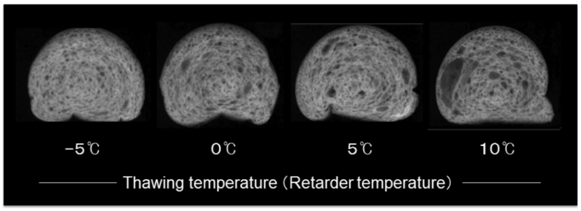

Figure 4. Effects of retarder temperature at overnight thawing process on gas cell structure of roll from the thawed dough pieces.

baking day can be reduced considerably. However, the thawed dough in a retarder stays at a refrigerated temperature for approximately 10 hours, and the dough would deteriorate baking properties of the dough by decreasing the number of gas cells in the dough due to diffusion of CO_2 from small gas cells to large gas cells(7). In order to avoid the deterioration, the gas cell structure of the dough to be frozen should be as even as possible. The lowest retarder temperature, which is slightly above the freezing point of the dough, is recommended (Fig.4).

5. Basic and modified procedures for frozen dough preparation

Basic procedure for frozen dough preparation has been developed through the findings listed above. The point of it is the preparation of the dough to be frozen with minimized fermentation of yeast in the dough. The dough should be fully developed by mixing, and maximum amount of l-ascorbic acid should be added to mature the dough. Pentosanase or diacetyl tartaric acid esters of monoglyceride, that improve oven spring of the dough with reduced numbers of gas cells, should be added. If dough weakening due to growth of ice crystals occurs significantly, the use of stronger flour or the addition of vital gluten is recommended(8). The dough should be frozen quickly without losing yeast activity in the dough, and then should be stored and shipped with minimized temperature fluctuation. The retarder temperature for over night thawing is recommended to be as low as possible to minimize the decrease of gas cells in the dough.

If frozen dough is prepared exactly following the basic procedure, bread and rolls with a high quality can be baked more easily and with shorter time in a local bakery than conventional practice. However, consumers may feel that flavor and texture of the baked goods are different from standard products, because the dough was prepared by minimized fermentation process. If improvement of the flavor and texture is needed, the addition of fermented sponge dough, flour brew, or sour dough to the mixing stage of the basic procedure is recommended. The use of frozen dough yeast that can be frozen after a prolonged fermentation can significantly improve the stability of the modified frozen dough.

6. Conclusion

Through scientific researches and industrial experiences, the basic frozen dough technology has been established and used in baking industry all over the world. Frozen dough is not only used in oven fresh bakeries, but also used in satellite bakeries for providing baked goods to 14,000 convenience stores in Japan. The role of frozen dough in baking industry will be more important in future with further development of the technology.

REFERENCES

1. L. Kline and T.F. Sugihara, Factors affecting the stability of frozen bread doughs. Ⅰ. Prepared by straight dough method, Bakers Dig. 42(5): 44 (1986).
2. Y. Tanaka, Freezing injury of baker's yeast in frozen dough, J. of Japanese Society for Food Science and Technology 28:

100 (1981)
3. A. Hino, H. Takano, and Y. Tanaka, New freeze-tolerant yeast for frozen dough preparation, Cereal Chem. 64: 269 (1987)
4. O. Neyreneuf and B. Delpuech, Freezing experiments on yeasted dough slabs. Effects of cryogenic temperatures on the baking performance, Creal Chem. 70: 109 (1993).
5. P. Mazur, Physical and temporal factors involved in the death of yeast at sub-zero temperatures. Biophys. J. 1: 247 (1963).
6. Y, Inoue and W. Bushuk, Studies on frozen doughs. Ⅰ. Effects of frozen storage and freeze-thaw cycles on baking and rheological properties. Cereal Chem. 68: 627 (1991).
7. P. Sluimer, Principles of fermentation interruption in wheat bread production. Getreide Mehl Brot 1: 18 (1981).
8. Y, Inoue and W. Bushuk, Studies on frozen doughs. Ⅱ.Flour quality requirements for bread production from frozen dough. Cereal Chem. 69: 423 (1992).