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Effects of freezing rate and terminal freezing temperature on frozen croissant dough quality

Choongjin Ban [a, 1], Sangeun Yoon [d, 1], Jungwoo Han [a], Sang Oh Kim [e], Jung Sook Han [f], Seokwon Lim [g], Young Jin Choi [a, b, c, *]

[a] Department of Agricultural Biotechnology, Seoul National University, 1 Gwanakro, Gwanakgu, Seoul, 151-921, South Korea
[b] Center for Food and Bioconvergence, Seoul National University, 1 Gwanakro, Gwanakgu, Seoul, 151-921, South Korea
[c] Research Institute of Life Science and Agriculture, Seoul National University, 1 Gwanakro, Gwanakgu, Seoul, 151-921, South Korea
[d] CJ Food R&D, CJ Cheiljedang Corporation, Seoul, 152-050, South Korea
[e] LG Electronics, 51 Gasan Digital 1 ro, Geumcheongu, Seoul, 153-802, South Korea
[f] Food R&D Center, Samyang Group, 726 Baekbeom-ro, Seo-Gu, Incheon, 404-250, South Korea
[g] Department of Food and Biotechnology, Hoseo University, 79-20 Hoseoro, Asan, Chungnam, 336-795, South Korea

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ABSTRACT

Using frozen ready-to-bake dough is a very common practice in the industrial croissant production. However, the freezing process during the preparation frozen croissant dough can deteriorate its quality. In this study, we investigated the effects of the freezing rate (FR) and terminal freezing temperatures on the volume and firmness of croissants by analyzing frozen dough for yeast viability, thermal property changes, and internal microstructure integrity. Croissant dough samples were frozen at rates ranging from −0.72 to −3.56 °C min^{-1} down to final temperatures of −20, −40, and −55 °C. Our results showed that the ice crystals normally forming in the dough during freezing, causing a lower yeast viability and croissants quality, were of smaller size when a rapid FR $\geq$ −3.19 °C min^{-1} was used. Furthermore, a freezing termination temperature lower than −20 °C induced more yeast cell death, thereby deteriorating croissant quality. Therefore, we suggest that the croissant dough freezing process should be conducted with an appropriate FR down to a suitable terminal temperature. Consequently, our results are helpful to understand how the freezing procedure affects ice crystal formation and yeast viability in the frozen dough matrix and our findings can be applied to enhance bread quality in the frozen dough industry.

1. Introduction

Frozen bread dough is widely used in the baking industry, mainly due to its convenience. Dough freezing can reduce processing time and labor intensity, increase products shelf life, improve productivity, and facilitate distribution to distant locations (Chen et al., 2013). Because of these advantages, the freezing technology has been used for several viennoiseries, such as croissants (Le-Bail, Nicolitch, & Vuillod, 2010). However, the freezing process used to prepare the frozen dough can induce many negative effects on the quality of baked products compared to those baked from unfrozen dough (Ribotta, León, & Añón, 2001). Particularly, damaged gluten networks and reduced yeast viability are regarded as the main culprits for quality deterioration in bread prepared from frozen dough (Ribotta, León, & Añón, 2003). Incidentally, a number of studies have focused on how to preserve gluten networks and yeast viability from freezing injuries by sustaining the yeast gas productivity and the gas retention capacity of the gluten networks.

Many researchers have suggested that the ice crystal formation in the freezing dough could result in two negative effects. First, the ice crystals formed within yeast cells can have cell membranes be damaged during the freezing procedure and ultimately decrease their viability (Muldrew & McGann, 1990). Additionally, if the ice crystals only form in the dough matrix (and not in or through the cells), the concentration of salts, sugars, and other molecules can increase the osmotic pressure as these molecules become more

* Corresponding author. Department of Agricultural Biotechnology, Seoul National University, 1 Gwanakro, Gwanakgu, Seoul, 151-921, South Korea.
E-mail address: choiyj@snu.ac.kr (Y.J. Choi).
[1] These authors contributed equally to this work.

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concentrated in the water present outside of the cells. This results in a water outflow from the yeast cytoplasm and leading to cell death (Randez-Gil, Sanz, & Prieto, 1999). Second, the ice crystal formation and growth can physically damage the gluten networks (Baier-Schenk et al., 2005). Therefore, ice crystal formation should be properly controlled to obtain good croissants from frozen dough, which could be accomplished by tightly controlling the freezing conditions (Yi & Kerr, 2009a). Notably, the freezing rate (FR) is one of the parameters used to regulate ice crystal size in the food freezing process (Petzold & Aguilera, 2009), and many studies explored the relationship between the FR and baked products quality (Le-Bail et al., 2010). Moreover, the storage temperature is well known for its important influence on ice crystal growth during frozen storage and on bread quality after baking (Phimolsiripol, Siripatrawan, Tulyathan, & Cleland, 2008).

A slower freezing process can result in larger ice crystals in the dough than rapid freezing, and larger ice crystals are more disruptive for the gluten networks. Damaged gluten networks prevent the proofing dough from properly retaining the CO_2 gas released by the yeast cells, which can reduce the overall loaf volume of bread prepared from frozen dough. Contrastively, the slower freezing process better preserves yeast viability in the dough (Selomulyo & Zhou, 2007). Therefore, to produce good breads, the optimal FR should be determined empirically from a complex consideration of both yeast viability and gluten network integrity.

The FR is a very significant factor affecting the quality of bread baked from frozen dough, as referred to earlier. Nevertheless, as far as we know, there was no study for frozen croissant dough focusing on determining the optimal dough FR. Moreover, even in many studies for freezing process of general frozen bread doughs, the researchers have only focused on the suitable temperature for long time storage not mentioned the appropriate terminal temperature for freezing process (Yi & Kerr, 2009a, 2009b).

Despite the fact that frozen dough ice crystals nucleate and grow during the freezing stage, analyses using cooling curves under differential scanning calorimetry (DSC) were rarely used in studies assessing ice crystal formation relative to the FR. Actually, many researchers thoroughly studied the frozen dough ice crystal formation process using DSC heating curves (Bot, 2003; Chen, Jansson, Lustrup, & Swenson, 2012; Kontogiorgos, Goff, & Kasapis, 2008). Consequently, in this study, the freezing process was controlled by the FR and terminal freezing temperature of the croissant dough. Lastly, we investigated the ice crystal formation phenomenon in intact dough using DSC thermograms. Additionally, we analysed the internal structure of the dough using SEM micrographs during the cooling part of the freezing procedure to evaluate the beneficial effects of a controlled freezing method on croissant quality.

2. Material and methods

2.1. Samples preparation

Two kinds of commercial flours and white sugar were gifted by Samyang Genex Co., Korea; flour 1 was composed of 72.5% carbohydrates, 12.5% protein, 0.6% fat, 14% water, and 0.4% ashes and flour 2 was composed of 75% carbohydrates, 9.5% protein, 0.6% fat, 14.5% water, and 0.4% ashes. Fresh compressed yeast (Ottugi Fresh Yeast Gold, Ottugi Co., Ltd., Korea), eggs, unsalted butter (Samyang Genex Co., Korea), butter for rolling (Pastry Sheet Gold, Samyang Genex Co., Korea), and refined salt (Beksul, CJ Cheiljedang Co., Korea) were obtained from the local market. A dough was prepared using the following recipe: 275 g of flour 1, 150 g of flour 2, 40 g of white sugar, 6.25 g of refined salt, 20 g of fresh yeast, 100 g of eggs, 162.5 g of water, 12.5 g of unsalted butter, and 250 g of cold butter for rolling. The flours, sugar, salt, and yeast were blended for 2 min using a mixer at speed 2 (Kenwood titanium major kitchen machine, KM020, UK). Then, water and eggs were added, and the mixture was blended for 2.5 min at speed 1 before adding butter and the dough was kneaded for 3 min at speed 1. Then, the dough was placed in a 4 °C refrigerator for the first 30 min of resting. For dough layering, the cold butter spread was placed on the dough, shaped in a 30 cm by 30 cm square after resting, and wrapped with the pressed out part of the dough. The dough with the cold butter was folded three times and allowed to rest in a refrigerator for 5 min (second resting). After the second resting, the dough folding procedure was repeated twice, with resting steps of 15 and 30 min. After the fourth resting, the dough was rolled and cut into isosceles triangle shaped (base, 10 cm; height, 15 cm; and thickness, 3 mm) and each triangle was rolled until the dough overlaps three times.

Freezing system was composed of two parts: a freezer (FD-170-SF, Unique Daesung Co., Ltd., Gyeonggi, Korea) and an adiabatic box. The styrofoam adiabatic box had two large holes on opposite sides, one of which was occupied by an electric fan, and a sample loading rack at center of the box. The FR of the dough was controlled by a combination of two means, namely the temperature of the cold air of the freezer, and the convection induced by the electric fan. Additionally, the terminal dough freezing temperature was defined as the point when the temperature at the center of the dough reached either −20, −40, or −55 °C. During the freezing process, the temperature change at the center of the dough was monitored using a data logger (Agilent 34970A, Agilent Technologies Inc., Santa Clara, CA, USA). The FR of the samples was calculated on the basis of the freezing profiles showed in the Fig. 1, using the definition provided by the International Institute of Refrigeration (Bøgh-Sørensen, 2006):

$$\mathrm{FR} = (T_t - T_i)/\Delta t$$

where, T_t is the sample terminal temperature, T_i is the sample initial temperature, and Δt is the time difference to reach T_t from T_i. When the dough reached its pre-defined T_t, a frozen sample was packaged in a polyethylene bag and stored for a day in a freezer set at −18 °C.

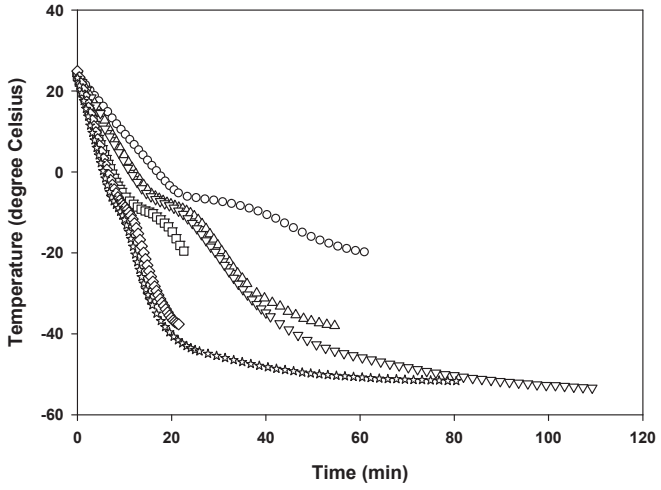

Fig. 1. Temperature profiling at the center of the croissant dough during the freezing procedure and sample coding names. The samples were coded as follows: FR1, −0.72 °C min^{-1} (open circle; −0.24 °C min^{-1} in zone of maximum ice crystal formation); FR2, −1.43 °C min^{-1} (open triangle; −0.50 °C min^{-1} in the zone); FR3, −1.50 °C min^{-1} (open inverted triangle; −0.52 °C min^{-1} in the zone); FR4, −1.84 °C min^{-1} (open square; −0.61 °C min^{-1} in the zone); FR5, −3.19 °C min^{-1} (open diamond; −1.53 °C min^{-1} in the zone); and FR6, −3.56 °C min^{-1} (open star; −2.01 °C min^{-1} in the zone).