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Effect of freezing treatments and yeast amount on sensory and physical properties of sweet bakery products

Smail Meziani [a,c,*], Messaouda Kaci [a], Muriel Jacquot [a], Jordane Jasniewski [a], Pablo Ribotta [b], Jean-Marc Muller [c], Mohamed Ghoul [a], Stéphane Desobry [a,*]

[a] Nancy-Université, ENSAIA–INPL, Laboratoire d'Ingénierie des Biomolécules (LIBio), 2 Avenue de la Forêt de Haye, 54505 Vandœuvre-lès-Nancy Cedex, France
[b] Universidad Nacional de Cordoba, Instituto Superior de Investigacion, Desarrollo Servicios en Alimentos, ISIDSA, Av. Filloy s/n, Cuidad Univerditaria-CP, 5000 Cordoba, Argentina
[c] Coco LM Company (Maison Alsacienne de Biscuiterie), 7 rue Émile Schwoerer, 68000 Colmar, France

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ABSTRACT

The frozen bakery market has grown significantly in developed countries over the past decade.

Of the available preservation technologies, freezing has been recognized as an excellent method of preserving the quality characteristics of bakery products. The aim of this work was to study the influence of freezing conditions (−20, −30, −40 °C and cryogenic immersion) and yeast content on the sensory and physical properties in the final baked product (Kougelhopf).

Physical parameters such as specific volume, moisture, hardness, gas cells distribution and size were determined experimentally. A sensory evaluation (appearance, color, flavor, taste, texture and overall acceptability) was performed in Kougelhopf obtained from fresh and frozen sweet doughs.

The experimental results showed that high freezing rates were correlated with more extended damage, yeast activity loss and lower Kougelhopf specific volume.

The freezing rate also influenced the gas cells number and size. It was shown that increasing yeast in frozen sweet doughs improved the overall quality of Kougelhopf compensating for the loss of yeast activity during the freezing process. Kougelhopf produced from sweet dough with higher yeast content (DY) presented a higher specific volume, whereas freezing rate increases its hardness. Sensory tests confirmed that experimental results were detected by panelists.

1. Introduction

The frozen bakery market has increased significantly in developed countries in recent years. Baking terminals have proliferated in public places such as supermarkets, bakery shops, airports (Le Bail and Goff, 2008). This technology allows for a time lag between frozen dough and selling step and several advantages have been recognized among them the standardization of the final product quality (Bárcenas and Rosell, 2007).

The quality of fresh bakery products is often related to its crust (thickness, crispiness, color, and taste) and to the crumb structure (flavor, soft texture, size of the cells). However, bakery products have a short shelf-life, and the loss of freshness influence negatively the product's quality and consumer acceptance, expressed by a number of chemical and physical changes (staling). Indeed, the appearance, odor, color, texture and flavor attributes are used to determinate sensory properties of bakery products (Stone and Sidel, 2004). The product sale will certainly be a failure if some of these attributes do not meet consumer expectations. Each product has its characteristic sensory profile combining specific attributes.

The variety of frozen bakery products has increased significantly since their introduction to the market; this list includes breads and rolls, croissants, muffins, cakes, cookies, pastries, laminated dough, pizza (Decock and Cappelle, 2005).

However, each one of frozen bakery products has advantages and drawbacks. A major problem of the part-baked and fully baked frozen bakery product is crust flaking probably due to the intensity of thermo-mechanical shock during chilling–freezing and final baking (Le Bail et al., 2005). Carr et al. (2006) reported their products had a rougher crust and very compact crumb caused by freezing. The main competitor of the partly-baked and fully baked frozen bakery product is the unfermented frozen dough.

Despite the drawbacks, the frozen unfermented product has better prospective for the industry. However, unfermented frozen dough often exhibits a specific volume decrease manifested by an increase proofing time compared to fresh dough products during freezing and long frozen storage (Añón et al., 2004). Several

* Corresponding authors. Address: Nancy-Université, ENSAIA–INPL, Laboratoire d'Ingénierie des Biomolécules (LIBio), 2 Avenue de la Forêt de Haye, 54505 Vandœuvre-lès-Nancy Cedex, France. Tel.: +33 3 83 59 58 70; fax: +33 3 83 59 57 72. (S. Meziani).
E-mail address: smail.meziani@ensaia.inpl-nancy.fr (S. Meziani).

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authors suggested that the formulation and processing parameters such as freezing and thawing rate (Le Bail et al., 1998), frozen storage time (Lu and Grant, 1999) and mixing time (Rouille et al., 2000) influence significantly the bakery product quality obtained by frozen dough.

These parameters can act either independently or synergistically to reduce the yeast activity resulting in reduced gas production (Rosell and Gomez, 2007) or damage to the dough structure due to poor CO_2 retention (Wolt and D'Appolonia, 1984) and poor baking performance. Havet et al. (2000) found a 20% decrease of bread specific volume obtained from dough frozen at −20 °C (3 m/s air velocity). Several studies have shown that the freezing rate was directly related to the ice crystals size causing the disruption on dough gluten network during freezing (Havet et al., 2000; Inoue and Bushuk, 1996; Kulp, 1995; Spiess, 1980).

The freezing rate plays an important role in the final quality of frozen product, two opposite effects are observed. A high freezing rate allows the formation of ice microcrystals, which do not affect the gluten network integrity, which reduces physical damage (disturbance and dehydration of gluten network) induced by freezing, ultimately to the extent that the starch granules appear to be associated with the network gluten (Angioloni et al., 2008). Nonetheless, rapid freezing might fatally compromise the yeast activity.

Olivera and Salvadori (2009), suggested that slow freezing formed large size ice crystals causing the disruption of dough gluten network during freezing. Meziani et al. (2012) shown the dependence of fermentation activity and integrity of the gluten network with freezing rate, which controls size and location of ice crystals resulting in research of a compromise between freezing rate nor too fast to reduce yeast viability, nor too slow to form large ice crystals that could perforate gluten network.

The sensory characteristics of bakery products are heavily influenced by their formulation; the presence of some ingredients such as butter gives a characteristic flavor to the final product. In addition to the raw materials used, the manufacturing process substantially alters the sensory properties of bakery product.

In addition, the limit of expansion of these gas cells is related directly to their stability, due to coalescence and the eventual loss of gas when the bubbles collapse. The rheological properties of the gas cells will therefore be important in maintaining stability against premature failure during baking, and also in relation to gas cell stabilization and gas retention during proofing, and thus to the final structure and volume of baked product (Dobraszczyk and Morgenstern, 2003). Two mechanisms are involved in the destabilization of the gas cells during proofing, disproportionation and coalescence. Disproportionation (analogous to Ostwald ripening in emulsions) involves a proposed diffusion mechanism by which CO_2 migrates from smaller gas cells to larger ones. Gas cells coalescence is caused by the rupture of the thin dough films, which results in gas loss and an irregular crumb structure (Kokelaar and Prins, 1995). Textural properties of bakery products are most often measured, because of the strong correlation between crumb firmness and quality and consumer acceptance. Carson and Sun (2001) studied six types of bread and showed the existence of a strong correlation between the instrumental results (cohesiveness, springiness, adhesiveness) and those sensory analysis. The sensory evaluation development is a lengthy and costly for manufacturers, which strongly encourages correlation studies instrumental-sensory. They would provide simple instrumental measurements for the prediction of sensory descriptors.

According to the literature, freezing consequences on baking performances of bakery products can be corrected by adjusting the yeast amount or the strain choice. However, the taste and texture of product could be negatively affected by adjusting the processing parameters (freezing rate). Several papers already dealt with bread (Gabric et al., 2011; Gonzales-Barron and Butler, 2006; Van Duynhoven et al., 2008).

Most of these studies were interested to bread dough produced from a basic formula. This work is distinguished by the complexity of sweet dough formulation (high fat and sugar content) and use of cryogenic immersion to achieve freezing rates ultra-fast. These factors influence intrinsic dough properties. The milk and lipids contained in sweet dough which can contribute to cryoprotection, while sugar enhances yeast's growth before freezing (Meziani et al., 2012; Wolt and D'Appolonia, 1984). To elucidate this point, frozen sweet doughs were prepared by in the same conditions different freezing treatment. Similarly, use of natural additives like whey proteins, surfactants and enzymes are also gaining importance to control the water redistribution problems in the frozen doughs' structures (Asghar et al., 2011). No study on freezing rate and formulation effect on sweet dough properties with complex recipe have been published. Kougelhopf matrix was chosen in this study for its manufacturing process similar to that of bread and complexity of its dough recipe.

Kougelhopf is a southern German, Austrian, Swiss and Alsatian term for a marble cake or Bundt cake; recognizes itself easily with high grooved form. The cake crust is light brown, sprinkled with icing sugar and decorated with almonds on top. Its tender and brioche crumb is strewn with raisins.

The objectives of this work were (i) to study the influence of freezing conditions and yeast quantity on physical, textural and sensory characteristics of fully baked sweet product Kougelhopf and (ii) to compare these parameters to those obtained from fresh Kougelhopf and (iii) to define the best freezing treatment and formulation for Kougelhopf.

2. Materials and methods

2.1. Materials

Two types of sweet doughs were used SY (simple yeasted dough) and DY (double yeasted dough) to produce Kougelhopf sweet dough. The dough formulas used in this study were: wheat flour (1000 g), UHT semi-skimmed milk (500 g), butter (300 g) sugar, (200 g), eggs (130 g), salt (20 g), and compressed yeasts *Saccharomyces cerevisiae* (Lesaffres, France) (25 or 50 g), respectively for SY and DY doughs. The ingredients and recipe were provided by Coco LM Company (Colmar, France).

2.2. Experimental procedure

All ingredients were stored at +4 °C before use and were mixed in a bread machine (Moulinex Ow 5000, France) for 10 min at low-speed (40 rpm) and at a high-speed (80 rpm) during 10 min with butter. Dough temperature was 23 ± 2 °C after mixing.

After resting for 20 min at room temperature, the sweet dough was divided and molded into 60 g pieces (3.5 cm diameter).

A part of sweet dough was frozen in a pilot-scale freezer CRN 504 SP manufactured by Didatec Technology, France. The freezer was monitored to produce three different air-blast temperatures −20, −30 and −40 °C. The sweet dough was removed from the pilot-freezer when the center temperature reached −20 °C.

The remaining was immersed into liquid nitrogen until the dough core temperature reached −20 °C.

Thawing was carried out in a cold chamber (Sanyo MIR-253, Japan) at +4 °C during 16 h. Immediately, after thawing, the different samples were put in silicon molds and proofed at 28 °C and 85% relative humidity for 180 min in a stove (Sanyo MIR-253, Japan).

After that, the dough pieces were baked for 28 min in an oven (Eurofours 25-02T03-1 Gommegnies, France) at 185 °C with baking

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steam during the first minute. Then, baked Kougelhopf were kept at ambient temperature (25 °C) for 1 h.

2.3. Physical assessment

After 1 h of cooling at 25 °C and 50% RH, Kougelhopf samples were subjected to the following analysis: moisture content, specific volume, porosity parameters.

2.3.1. Moisture content

Moisture of samples was determined according to AOAC Official Method 935.25 (AOAC, 1995): approximately 5 g of Kougelhopf, placed in a previously weighed container were dried in a forced convection oven (WTB binder Amilabo, Germany) at 103 °C until they reached a constant weight (24 h). The samples were cooled in a desiccator and weighed by an analytical balance (sensitivity 0.01 mg).

The moisture content (in percentage) of the sample was calculated according to Eq. (1):

$$M(\%) = (W_i - W_f)/W_i \times 100 \quad (1)$$

where W_i is the initial sample weight, W_f is the final sample weight and M (%) is the percentage moisture content, in wet basis. The moisture content measurements were done in triplicate using three different specimens from the same sample.

2.3.2. Porosity analysis

A preparation procedure was established to assess the distribution size and number of cells gas formed during proofing. After a thawing step (frozen sweet doughs) or mixing for fresh dough, disks of dough were placed in Petri dishes during 180 min of proofing (Fig. 1A). The images were acquired using a flatbed scanner (HP Scanjet G4050 Photo Scanner) with a resolution of 4800 × 9600 dpi, and images were saved as TIF. On the other hand, ten Kougelhopf (SY and DY) pieces for each sweet dough (fresh and frozen doughs) were sliced transversely using an electric slicer to obtain 20-mm thick slices (Fig. 1B). Five central slices of each Kougelhopf were scanned on one side using the same method mentioned previously.

Images were analyzed by Image J (Image Tool 1.43U 2010, National Institutes of Health, USA) according to Gonzales-Barron and Butler (2006). Each image was converted to gray-level image (eight bits). Number of cells per cm^2, cell's size and total area were calculated to evaluate the changes in gas cell size and distribution during baking. After thawing, a petri dish was placed on top of fresh and frozen doughs and after 3 h proofing, the images were acquired using the same method cited previously.

2.3.3. Specific volume

The Kougelhopf made from fresh and frozen doughs were evaluated for their weight, volume and volume to weight ratio. The volume of Kougelhopf samples was measured by rapeseed displacement as described by Havet et al. (2000).

2.3.4. Texture profile analysis (TPA)

The textural parameters were carried out on seven samples Kougelhopf fresh and made from frozen dough (−20, −30, −40 °C and liquid nitrogen). Texture profile analysis (TPA) was used to evaluate freezing treatment effect on textural changes of Kougelhopf (Olivera and Salvadori, 2009), using a universal testing machine (LRX-LLOYD tensile-compression, Ametek, UK) equipped with a 40 mm probe (P/40). One slice of 25 mm thick slices for each test sample is used and the end slices of Kougelhopf were discarded (AACC, 2006).

The double compression cycle was carried out at test speed of 60 mm/s, with a distance of 40% of compression and a resting period of 60 s. Hardness represented by the peak force during the first compression cycle. The testing temperature was 22 ± 1 °C.

2.4. Sensory evaluation

Tests were carried out in a sensory room with 24 analysis boxes. The sensory evaluation of Kougelhopf samples was done by 150 untrained panelists (84 male and 66 female, between 20 and 59 years old). All panelists were students or employees of the INPL (Institut National Polytechnique de Lorraine) and Coco LM Company.

A piece (50 g) (Fig. 1C) of each baked Kougelhopf sample was given to each panelist at room temperature (22 ± 2 °C). Pieces were presented in random order and identified with 3-digit codes.

The panelists were asked to evaluate the samples of Kougelhopf made from fresh and frozen doughs (−20, −30 and −40 °C), 2 h after baking for appearance, color, flavor, taste, texture and overall acceptability.

No sensory evaluation was studied in Kougelhopf made from dough immersed in liquid nitrogen, because the dough volume was not developed.

The score sheets required the judges to rank their 4 samples from least (=1) to most (=4) pleasant for each attribute (Meilgaard et al., 1999). The rank sum of each sample was used to calculate Friedman value (F). Comparing it with values given in the Friedman test (level of significance = 0.05), it can be concluded whether there is an overall difference among all the Kougelhopf samples.

2.5. Statistical analysis

ANOVA and five-sample comparison analyses were performed in all results using the statistical program Microsoft EXCEL

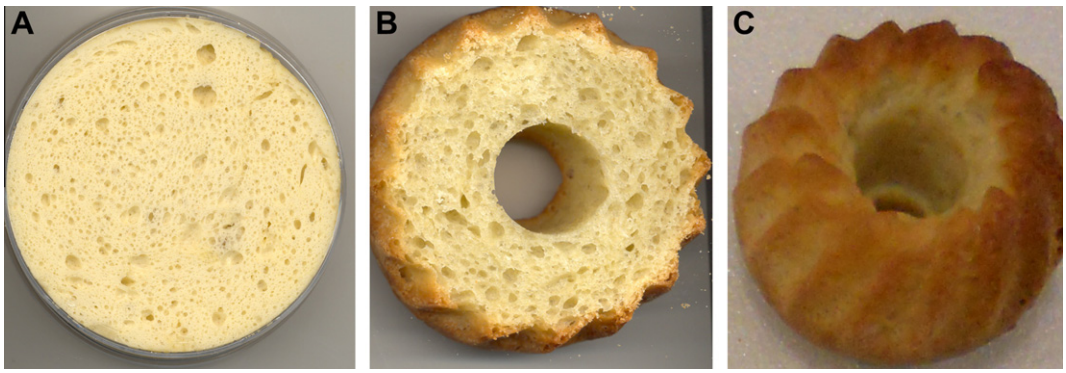

Fig. 1. (A) Sweet dough (B) slices of Kougelhopf (C) Kougelhopf used in sensory analysis.

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software (2007), at a confidence interval of 95%. The means between Kougelhopf samples in sensory analysis were compared by the Friedman test (Meilgaard et al., 1999).

3. Results and discussion

3.1. Physical and textural analyses

Kougelhopf samples obtained by both sweet doughs (SY and DY) frozen at −20, −30, −40 °C and liquid nitrogen were evaluated for their water content, specific volume and hardness. Results presented in Fig. 2 show the Kougelhopf moisture was not statistically different for the SY and DY Kougelhopf samples obtained by the different freezing treatments.

The specific volume of Kougelhopf obtained from sweet doughs frozen at −20, −30, −40 °C and liquid nitrogen grouped in Fig. 3. Statistical analysis showed significant difference ($P > 0.05$) between SY and DY Kougelhopf samples obtained by sweet doughs frozen at −20, −30 and −40 °C, but no significant difference was found between sweet doughs (SY and DY), fresh and frozen in liquid nitrogen. Indeed, decrease in the specific volume of Kougelhopf obtained from SY dough frozen at different freezing treatment was observed. The specific volume decreased significantly ($P < 0.05$) by 17%, 28%, 40% and 68%, respectively, between the fresh Kougelhopf (SY sweet dough) and Kougelhopf obtained from SY dough frozen at −20, −30, −40 °C and liquid nitrogen. However, the specific volume of Kougelhopf obtained from frozen DY dough was stayed constant compared to the control (DY fresh Kougelhopf) despite freezing, except sweet dough frozen in liquid nitrogen decreased (70% decrease).

These findings show that the Kougelhopf obtained from DY sweet dough (high yeast content) compensates the loss of the yeast activity during freezing.

These results were in accordance with Havet et al. (2000) that observed the decrease in bread specific volume by 20%, 27% and 28% for −20, −30 and −40 °C, respectively.

When analyzing frozen sweet doughs, yeast survival decreased with freezing rate increase (data not shown), resulting in a decrease in CO_2 production (Meziani et al., 2011).

Various authors have studied the freezing effect on bread (El-Hady et al., 1996; Giannou and Tzia, 2007) and reported that gas production considerably decreased from dough frozen for −40 to −120 °C with a mixture of air and liquid nitrogen.

The effect of freezing rate on Kougelhopf specific volume occurred during freezing could be explained by changes in yeast activity expressed by reduction of viable cells numbers as well as losses in the ability to produce gas, but also by changes occurring into the gluten network induces loss the gas retention capacity to retain sweet dough. Ribotta et al. (2003) suggested that the yeast activity can be modified by freezing and thawing steps.

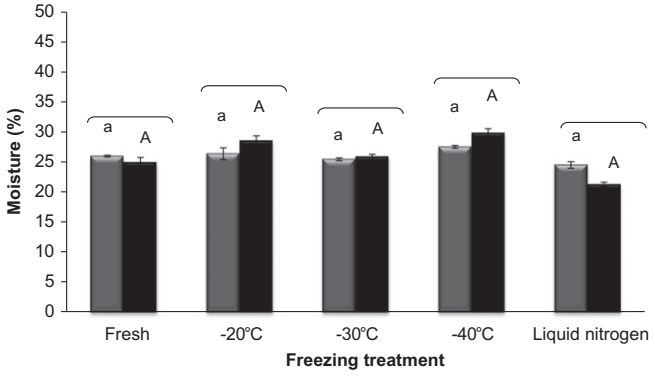

Fig. 2. Moisture content of Kougelhopf samples (■) SY and (■) DY according to freezing treatment. (a, b, c) Same letters within SY Kougelhopf samples do not significantly differ ($P < **0.05$). (A, B, C, D) Same letter within DY Kougelhopf samples do not significantly differ ($P < 0.05$). * Differ significantly between SY and DY Kougelhopf samples ($P < 0.05$).

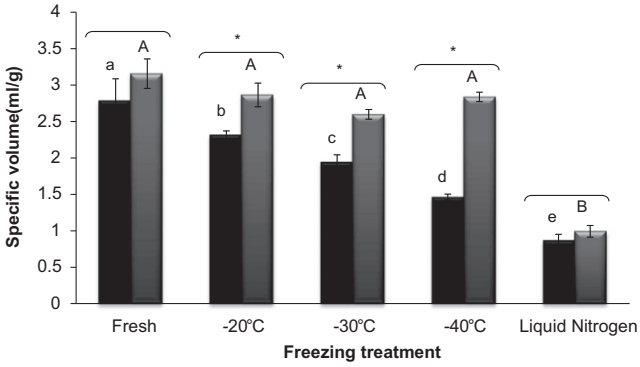

Fig. 3. Specific volume evolution of Kougelhopf obtained by (■) SY and (■) DY according to freezing treatment. (a, b, c) Same letters within SY sweet dough do not significantly differ ($P < 0.05$). (A, B, C, D) Same letter within DY sweet dough do not significantly differ ($P < 0.05$). * Differ significantly between SY and DY sweet doughs ($P < 0.05$).

The freezing rate strongly influences the frozen dough quality. Indeed, a slow freezing rate preserves the fermentative activity and ensures a high yeast activity but the gluten matrix structure is altered by the high ice crystals formed during slowly freezing (Le Bail et al., 1998). However, high freezing rate promotes a formation of small ice crystals which preserves the rheological properties of gluten network (Phimolsiripol et al., 2008). On other hand, the rapid freezing rate induces a decrease of the yeast population caused by intracellular freezing. For this reason, a compromise of freezing rate is needed to freeze the dough, slowly enough to maximize yeast activity but fastly enough to limit dough weakening.

On the other hand, the recipe of Kougelhopf sweet dough is made with high amounts of sugar and fat (butter) which reduce water activity and expose yeast cells to high osmotic pressure during freezing-thawing steps. The yeast exposure to hyperosmotic stress leads to rapid dehydration of cells limiting their CO_2 production correlated with a decrease in specific volume (Hohmann, 1997).The freezing rate must be slow enough to avoid the crystals ice formation in the cell, while quick to minimize the cells exposure to the effects of solution concentration caused by water crystallization.

Structure of Kougelhopf samples obtained by frozen sweet doughs was influenced by freezing and thawing steps, as shown in hardness results in Fig. 4. The hardness of Kougelhopf (SY frozen sweet dough) increased significantly ($P < 0.05$) by 37%, 53% and 67% for −20, −30, −40 °C and liquid nitrogen, respectively compared to fresh Kougelhopf (SY fresh sweet dough) but no significant difference ($P > 0.05$) was found for Kougelhopf hardness obtained by DY sweet dough frozen at slow freezing rate only liquid nitrogen led to hardness increase compared to air blast freezing.

In the present study, the hardness is conversely correlated to Kougelhopf specific volume ($R^2_{SY} = -0.975$, and $R^2_{DY} = -0.960$).As shown by correlation coefficients of both sweet doughs (DY and SY), the hardness increase versus freezing rate due to development of Kougelhopf volume during proofing. As seen in the previous paragraph, the specific volume depends on yeast activity, the Kougelhopf samples obtained from both sweet doughs (SY and DY) frozen in liquid nitrogen shows a low specific volume and a compact texture probably responsible for higher hardness values (1.72 N and 1.86 N for DY and SY, respectively). Furthermore, the significant

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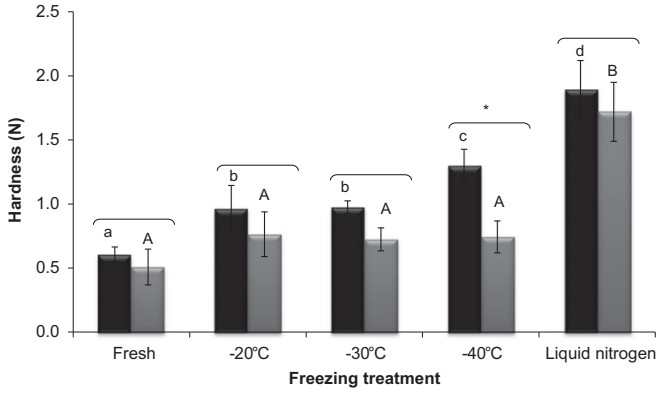

Fig. 4. Hardness evolution of Kougelhopf obtained by sweet doughs (■) SY and (■) DY according to freezing treatment. (a, b, c) Same letters within SY sweet dough do not significantly differ ($P < 0.05$). (A, B, C, D) Same letter within DY sweet dough do not significantly differ ($P < 0.05$). * Differ significantly between SY and DY sweet doughs ($P < 0.05$).

difference ($P < 0.05$) in hardness values between SY and DY sweet doughs frozen at −40 °C could be associated with a good development of DY dough specific volume with aerated texture.

On the other hand, the hardness increase could be partly explained by dough elasticity decrease due to the size of ice crystals formed during freezing (Angioloni et al., 2008).

3.2. Comparison of gas cell distribution in frozen sweet doughs and Kougelhopf samples baked form these sweet doughs

During proofing and baking the growth of gas cells determines the expansion of the sweet dough and therefore the ultimate volume and texture of the baked product (He and Hoseney, 1991). The results of size and cells distribution of Kougelhopf samples and frozen sweet doughs SY and DY were grouped in Tables 1 and 2. From the obtained results, it appeared that the cells observed in the Kougelhopf samples have a larger diameter than in the frozen sweet doughs. Whereas the gas cells number were higher in the fresh Kougelhopf dough samples than in the frozen sweet doughs. For example, an increase of 5%, 16%, 20% and 14% was found for SY fresh sweet dough and SY sweet doughs frozen at −20, −30, −40 °C and liquid nitrogen, respectively. Increasing of gas cells size observed during baking could be related to the normal expansion of gas cells as well as to the Ostwald ripening process, where large cells develops at the expense of smaller due the increase in gas overpressure in the small gas cells (van Vliet, 2008). As a result the coalescence involves the fusion of gas bubbles through the rupture of the thin film between them. In 2contrast, no significant effect ($P > 0.05$) was observed on the number of gas cells for both sweet doughs (SY and DY).

The number of gas cells in the SY frozen sweet doughs increases according freezing rate, except sweet doughs frozen at −40 °C and liquid nitrogen. Same trend was observed for DY frozen sweet doughs. The gas cells number increases considerably by 20%, 12% and 17% for sweet doughs frozen at −20, −30, −40 °C, respectively.

However, the sweet doughs frozen (SY and DY) in liquid nitrogen contains less number of gas cells, this is characterized by a small specific volume compared to fresh sweet doughs (SY and DY).

These results indicate that dough texture is affected by the freezing rate by increasing the number of cells but reducing the size. This can be explained by the formation of ice crystals during freezing, the size depends on the freezing rate. The ice crystals mechanically damage the structure of gluten network of the frozen dough resulting poor retention of gas produced during proofing, causing in a compact matrix (Bárcenas and Rosell, 2007). On the other hand, the distribution of gas cells is correlated with the yeast activity (Baardseth et al., 2000).

3.3. Result of sensory evaluation

The panelists evaluated the appearance, color, flavor, taste, texture and overall acceptability of Kougelhopf samples obtained by both frozen sweet doughs (DY and SY). Fig. 5 summarizes the total rank sums results of all the Kougelhopf (SY and DY) attributes. These attributes were subjected to Friedman's test (O'Mahony, 1986).

Overall, the yeast amount did not affect the taste and aroma attributes of Kougelhopf (DY), however, DY doughs showed improved attributes, as appearance, texture and global acceptability, compare to SY doughs. The Friedman test results performed for each attribute of fresh Kougelhopf (SY and DY) showed that there was no significant difference ($P > 0.05$) among samples of all the attributes indicating that the sensory quality is similar.

Table 1
Physicochemical characteristics of sweet dough frozen at −20, −30, −40 °C, liquid nitrogen.

	SY (dough simple yeasted)		DY (dough double yeasted)	
	Average diameter (mm)	Cells (cm^2)	Average diameter (mm)	Cells (cm^2)
Fresh	1.92 ± 0.15^{A}	17.87 ± 1.39^{a}	2.06 ± 0.12^{A}	19.31 ± 1.27^{a}
−20 °C	1.66 ± 0.17^{A}	22.82 ± 2.02^{b}	1.87 ± 0.14^{A}	23.17 ± 1.83^{b}
−30 °C	1.71 ± 0.19^{A}	21.81 ± 1.89^{b}	1.89 ± 0.09^{A}	21.64 ± 1.02^{b}
−40 °C	1.28 ± 0.23^{B}	15.95 ± 1.27^{b}	1.81 ± 0.05^{A}	22.58 ± 1.11^{b}
Liquid nitrogen	1.13 ± 0.14^{B}	12.86 ± 1.09^{c}	1.18 ± 0.25^{B}	12.93 ± 0.91^{c}

Within column values with the same following letter do not differ significantly from each other ($P \leqslant 0.05$).

Table 2
Physicochemical characteristics of Kougelhopf samples (frozen sweet dough at −20, −30, −40 °C, liquid nitrogen and fresh dough).

	Kougelhopf SY (dough simple yeasted)		Kougelhopf DY (dough double yeasted)	
	Average diameter (mm)	Cells (cm^2)	Average diameter (mm)	Cells (cm^2)
Fresh	2.02 ± 0.14^{A}	15.07 ± 1.21^{a}	2.43 ± 0.11^{A}	17.93 ± 2.04^{a}
−20 °C	1.98 ± 0.09^{A}	21.29 ± 1.14^{b}	2.12 ± 0.17^{B}	19.60 ± 1.86^{a}
−30 °C	1.93 ± 0.08^{A}	20.25 ± 1.01^{b}	1.98 ± 0.13^{B}	19.76 ± 1.52^{a}
−40 °C	1.61 ± 0.10^{A}	12.60 ± 0.95^{c}	1.95 ± 0.09^{B}	18.01 ± 1.04^{a}
Liquid nitrogen	1.32 ± 0.11^{B}	12.12 ± 1.55^{c}	1.23 ± 0.16^{C}	12.92 ± 1.33^{b}

Within column values with the same following letter do not differ significantly from each other ($P \leqslant 0.05$).

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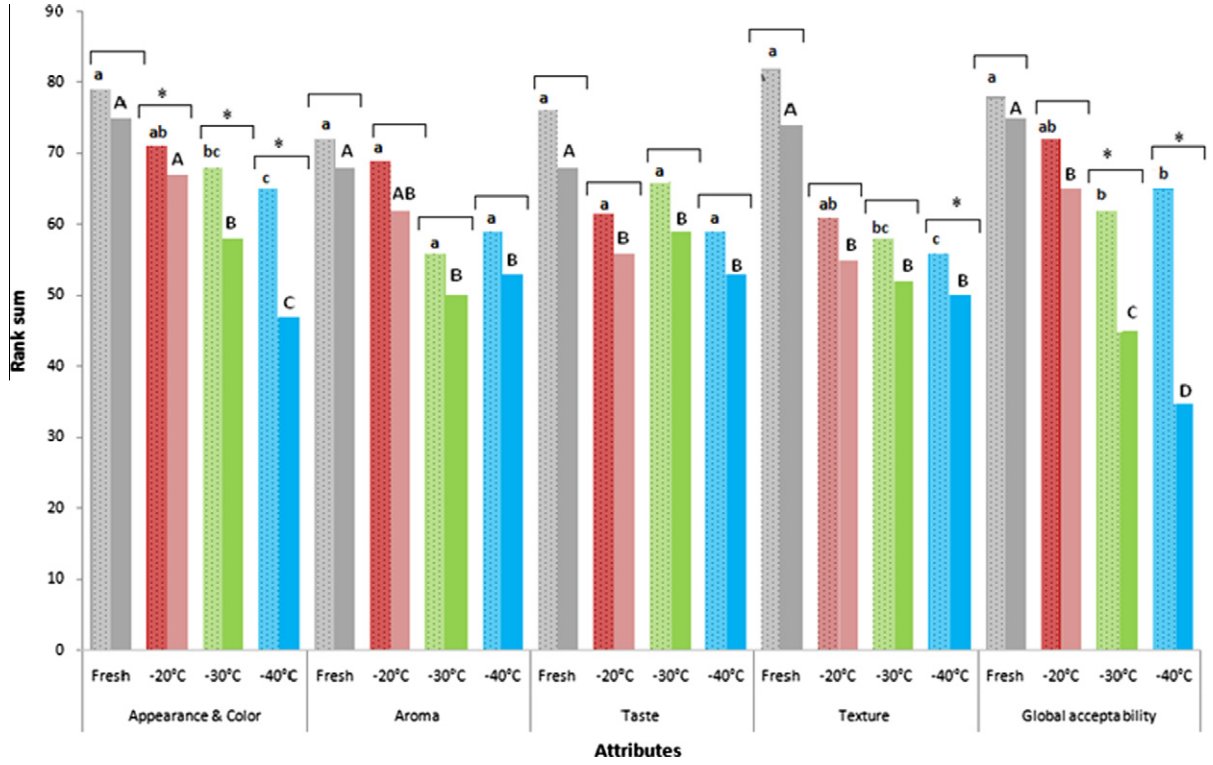

Fig. 5. Rank sum scores for savory Kougelhopf produced by SY (□) and DY (⁘) sweet doughs according freezing treatments: Fresh (■), −20 °C (■), −30 °C (■) and −40 °C (■). (a, b, c) Same letters within SY sweet dough do not significantly differ ($P < 0.05$). (A, B, C, D) Same letter within DY sweet dough do not significantly differ ($P < 0.05$) * Differ significantly between SY and DY sweet doughs ($P < 0.05$).

The Kougelhopf obtained by SY sweet dough frozen at −40 °C was evaluated with the lowest total rank sum of appearance and texture due to low specific volume and porosity and high hardness, respectively. This is confirmed with the lowest total rank sum of overall acceptability and 7% of all panelists liked this product (SY at −40 °C).

However, Kougelhopf DY (with a double yeast level) obtained by frozen sweet doughs, the total rank sum declines slightly after freezing step as compared to fresh Kougelhopf SY and DY, in general, the all attributes remain stable indicating that the panelists, during the period, considered Kougelhopf sample obtained by DY frozen sweet doughs to be similar to fresh one.

4. Conclusion

From the results of this present study, we can conclude that the sweet bakery product (Kougelhopf) obtained by frozen doughs showed a lower specific volume substantially compared to fresh one. This decrease is widely observed for high freezing rate (liquid nitrogen). However, the specific volume of Kougelhopf obtained from frozen DY dough was stayed constant compared to the control (DY fresh Kougelhopf) despite freezing. The study confirmed that yeast amount compensates the loss of the yeast activity during freezing.

The textural properties of sweet dough were affected by freezing rate. The Kougelhopf obtained from frozen dough in liquid nitrogen have a compact texture. These modifications are attributed to ice crystals action formed during freezing whose size and localization is governed by the rate of freezing.

The experimental results confirmed the correlation between instrumental analysis (physicochemical) and sensory analysis for Kougelhopf.

The sensory results showed that the Kougelhopf obtained from frozen DY doughs had the same characteristics (specific volume and all sensory attributes were confused) than the fresh products and panelists did not perceive any yeast aftertaste in Kougelhopf DY despite the yeast quantity added.

In this study, the Kougelhopf obtained from DY dough frozen at −30 and −40 °C (rapid freezing) had given overall, better results regarding fermentative activity, rheology and sensory properties.

Finally, further studies are needed to determine if the differences between both formulations remain after long frozen storage.

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