Frozen Bread Dough; a Smart Technology

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Abstract

Bread making is based on several simple unit operations, basically kneading, fermentation and baking; however, it is still a quite complex process and bread quality can be strongly affected by minor details. The market of bread production is roughly shared at 50-50 between the industry market and the artisanal market, even though the frontier between these two players is not very easy. Different strategies have been developped by the industry to extend the shelf life of bread or to interrupt the bread making process. Freezing for example has been used form the 50s to extend the shelf life of bakery products. It was first applied to fully baked products and then to frozen dough which appeared as an interesting strategy to interrupt the bread making protocol. This paper presents a review on key issues of the frozen dough technology.

I. Introduction

Bread making has attracted several innovations in terms of technology. Conventional direct bread making is very demanding in terms of skills and of time. With the growing demands from consumers towards freshly baked products, the concept of semi-prepared products has appeared and is growing very quickly on the bakery market. The corresponding technologies called "Bake Off Technologies" [1] (BOT) encompass several baking processes and technological routes based on the interruption of the baking process at selected stages. Refrigeartion is often sollicitated to extend the shelf life of these semi-finished products. BOT permit to keep the technological and time consuming operations at the industry level offering convenience to the baking stations and freshly baked bread all day long to the consumer; it could

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Table 1. Terminology and acronyms of the conventional and Bake Off Technology bread making processes. (Published in [1]"New Food", Issue 3, 2006, Le Bail et al., Russell Publishing Ltd.)

NAME	ACRONYM	Brief description of the process
Fully Baked Unfrozen Conventional Direct Bread Making	FB-U	Main steps are Mixing - Rest - Dividing - Shaping - Fermentation - Baking - Refrigeration
Fully Baked Frozen	FB-F	The bread is obtained from FB-U process and is frozen
Partially Baked Un-Frozen	PB-UF	The bread is obtained from FB-U except that baking is stopped before crust colouration. Bread is packed, cooled and stored at room temperature
Partially Baked Frozen	PB-F	The bread is obtained from FB-U except that baking is stopped before crust colouration. Bread is cooled and is frozen in packaging at freezing conditions (i.e; - 20°C)
Unfermented Frozen Dough	U-FD	Dough is prepared as for FB-U; the rest period is shorter and care is taken to prevent excessive fermentation before freezing, which is done ASAP after shaping. A slow freezing is usually recommended.
Fermented Frozen Dough	F-FD	Dough is prepared as for FB-U; the fermentation is started and is stopped before full development. The fermented dough is then frozen. A quite rapid freezing is usually recommended. Baking is most of the times done in one single operation (frozen - ready to bake) or after thawing

thus be presented as a win-win strategy. It is estimated that in Europe the market share of BOT is growing by more or less around 10%/year meanwhile the overall bread consumption is almost constant.

Among the main technologies of bread making as listed in Table 1. Un-fermented Frozen dough (UFD), Partially Baked Frozen Bread (PBF) and Partially Baked Unfrozen (PBUF) are maybe the most used technologies. Nevertheless, in the case of the European market, the UFD is in the average less used than PBF and PBUF mainly because UFD requires skilled personnel eventhough it permits to produce products with a quality comparable to direct baking. PBF or PBUF don't require highly skilled personnel and breads can be available for retail within around one hour.

Bread produced by the industry if different from country to country. It represents 80 % of the bread tonnage in Great Britain, 48% in Spain, 35% in Germany ...[2]. On the opposite, in France traditional craft bakery represents 70% of the production; however, the market share of bread and bakery products produced by industry in France is increasing progressively similarly to most other European countries. The industrial production in France was in 1997 frozen dough (57%), frozen part-baked bread (18%) and fresh bread (i.e. white sandwich bread) 25% [2]. Between 93 and 97, the fresh bread decreased from 33% to 25% whereas for the same period part-baked bread increased from 15 to 18%. This evolution is still up to date. The evolution of selected categories of bread produced in industrie between 2006 and 2011 in the 27 European member states is shown in Figure 1 showing a substantial growth of the part baked

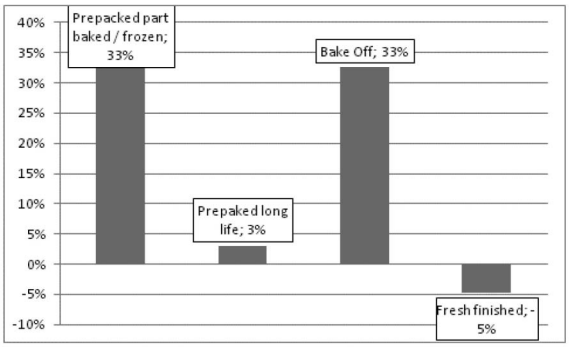

Figure 1. Evolution between 2006 and 2011 of selected types of bread based on the industry bread market in the 27 European member states (representing 61% of the total bread market in 2006). (based on data provided by www.girafood.com). The evolution is based on bread tonnage.

products and of the bake off technologies.

2. Terminology related to bread making and consumers perception

Different names are proposed regarding the yeasted frozen dough technology. The frozen dough is usually yeasted with bakers yeast (*Saccharomyces cerevisiae*). The term "Dormant dough" is used in USA, Australia and some other countries. The term dormant has been extrapolated from the concept of dormant starter culture. The term "Green dough" is sometimes used in Europe for yeasted frozen dough. It is also used for example to describe dough which is becoming hard for different reasons (low temperature ...).

The perception of consumers towards frozen products is very dependent on the country and on the habit of the population in terms on food consumption. A frozen food may even be perceived by some population as afood which has lost its nutritive value. Regarding the case of bakery product, the image of "frozen bread" is associated to products coming from the industry whih address on an arbitrary basis an image of low quality. Indeed, the quality of frozen bakery products is very close to the one of freshly made products. The recent and permanent growth of franchises vending shops (baking stations) shops and bakeries, which very often use mostly frozen products demonstrates clearly that the quality of these products are able to meet the consumers expectations. In 1993, the French government has established the "Décret Balladur" (a "Décret" is similar to a law), which has established the base of the "pain de tradition française"[3]. One of the major consequence of this "décret"is that it has restricted the usage of "Boulangerie" (bakery shop) to the case of vending shops in which the bread is prepared in the shop, starting from flour and with a very restrictive list of ingredients. This "décret" also forbids the use of the freezing technology. On the opposite, the slow baking movement established in Germany in the 2000's to protect craft bakers considers freezing as an acceptable technology.

In France, where the consumer is maybe more demanding on the quality of the bread than in other countries, because of the cultural heritage, frozen dough represents around 50% among the different technologies used for BOT in the case of bread. Indeed, the frozen yeasted dough is the semi finished product which is the most capable of reaching the level of quality of the conventional bread prepapred directly. The only constrains of the frozen dough lies in two major points. On one hand, there is a need of skilled personnel to prepare the product, in particular regarding the fermentation. On the other hand, the time for preparation will be at minimum 2 hours including baking. However, specific prefermented products permit to shorten the preparation time; they are very well adapted to viennoiseries and puffing pastries

for example and are minimally applied to bread.

3. Formulation and mixing steps

Bread made of frozen dough is some times affected by the decrease of both yeast activity and dough rheology, which in turn impair the global baking performances. There is an abundant amount of literature on the field and companies specialized in designing baking ingredients have developped improvers adapted to each case. Besides, numerous studies have been undertaken to improve the cryoresistance and the storage tolerance of frozen dough. The major process parameters that interact with the baking performances are the formulation, the freezing rate and the storage conditions. Most bread (but not all) produced in industry are using baking aids. A basic cocktail consists in ascorbic acid to enhance the cohesion of the gluten network and therefore gas retention performance of the dough and enzymes (mainly alpha-amylase) to favour the release of sugars which in turns help the CO2 production by yeast. Alpha-amylase may also interact with staling; it has a depolymerisation impact on starch polymers and in turn tends to inhibit starch retrogradation. Added gluten can also be used to strengthen the dough rheology.

Emulsifiers are some times used in conjunction with small amount of lipids (shortening) to promote gas retention by the dough. These ingredients improve the gas retention in the dough thanks to a reduction of the surface tension of the liquid film surrounding the gas cells. It also tends to make a foamy crumb structure with small and evently distributed gas cells and tends to minimise the thickness and crispiness of the crust. A crispy crust and an irregular alveolation of the crumb are associated with quality of French baguette. Thus, quite few studies (mainly French) have been done on frozen dough without shortening.

Rouillé et al. [4] for example studied the effect of mixing time, ascorbic acid and alpha-amylase with hemicellulasic activity on the baking performance of French baguette. The use of an experimental design yields surface responses showing the synergistic effect of these process parameters. The higher bread volume was obtained with higher levels of mixing time (16 minutes) and ascorbic acid (300 mg/kg flour, which is the maximum amount allowed by French regulation). The enzyme, which was evaluated in this study, gave higher volume with the maximum level as well (200 mg/kg flour).

[5] used a model dough (flour and water only) and observed that the amount of the liquid phase in the dough was strongly correlated to the quality of the flour. The higher the protein content was the higher the freezable water was. He concluded that reducing the water content of frozen dough can reduce ice crystal coarsening during storage. Therefore, the reduction of the water content in frozen dough formulation has been recommended by several authors and is applied in the industry. More recently [6] observed a strong increase of the amount of the freezable water in the dough during storage (+30% after 8 weeks). This was interpreted by disruption of certain bonds in the gluten network affecting the dough functionality. Therefore, the use of hydrocolloids is often considered to improve the freeze tolerance of frozen dough as shown by [7]

4. Degree of freezing

During freezing, the amount of frozen water increases until reaching a fixed amount of ice corresponding to the freezable water. The evolution of the percentage of frozen water (based on the amount of freezable water) in the case of a dough

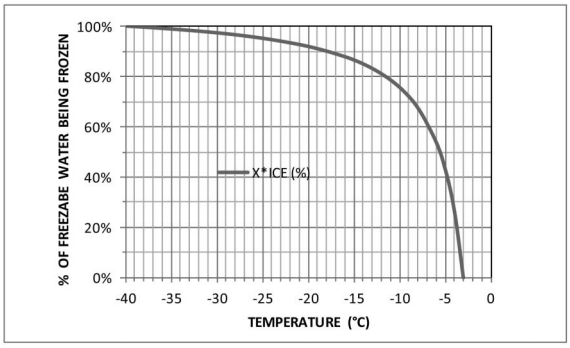

Figure 2. Evolution of the amount of frozen water (% of the total freezable water) in the case of a bread dough with initial freezing point of -3° C. It has been assumed that 100% of the water was frozen at -40°C.

with an initial freezing temperature of -3°C (as an example) is shown in Figure 2. The methodology used is based on reference [8]. Based on the guide edited by the International Institute of Refrigeration [9], it can be considered that a food is fully frozen when at least 80% of the freezable water is frozen or if the temperature is below -12°C (considering the most restrictive criteria). Based on theses criteria, it appears that frozen dough can be considered as frozen at a temperature of -12°C, both IIR criteria are reached at the same temperature level (-12°C). However, storage at lower temperature is strongly recommended such as -18°C (0 °F) which corresponds to a storage temperature considered in most countries.

5. Freezing rate

Freezing is known to have a negative effect on yeast activity. A first important recommendantion lies in that the fermentation before freezing must be limited as much as possible. Starting the fermentation will in particular start to reduce the trehalose contained in the dough which is lnown to act as a cryoprotectant [10-15]. [14] shown that a 5% content was sufficient to obtain a high cryoresistance. Lowering the dough temperature to around 20°C and reducing the rest period before dough shaping and freezing are simple solutions to minimize the onset of fermentation. The freezing rate is also an important point and is often associated with the freezing condition like cryogenic of air blast freezing [16]. However, a numerical value can be given to the freezing rate. [17, 18] calculated a freezing rate from the cooling rate during freezing (unit was $K.min^{-1}$ or $°C.min^{-1}$). [18] showed that a higher freezing rate was obtained at centre of a cylindrical geometry such as a doughs stick yielding a lower yeast activity at center of a dough stick. Indeed, several researchers have showed that yeast activity was better preserved with a slow freezing rate. [16] gave the most obvious demonstration of it whereas [18] showed that the higher freezing rate ($4m.s^{-1}$ with air at -40°C) gave the smaller bread volume in comparison with the slower freezing rate ($1m.s^{-1}$ with air at -20°C). [19] studied the impact of "long freezing" and "short freezing" conditions on the baking performances of frozen dough. Two flours (strong and weak) were considered. The "short freezing" condition consisted in withdrawing the dough stick from the freezer (-30°C, air velocity 4 $m.s^{-1}$) when its centre temperature was -5° C, which is just below the initial freezing point. In the case of "long freezing", the dough sticks were withdrawn when -15°C was reached at centre of the geometry. Then freezing was completed in a storage chamer at -18°C. The "short freezing" condition gave the better score in term of bread volume whereas the long freezing yielded -22% of volume difference against the unfrozen bread volume score (strong flour). These results were explained by the fact that in the short freezing condition the centre of the geometry undergoes a relatively slower freezing rate than

in the long freezing condition in particular at center of the geometry. In practice, it can be recommended to use moderate freezing temperature (-30°C - not lower) and moderate air velocity and also to withdraw the dough from the blast freezer once it is rigid enough to be manipulated. Freezing can then be completed at a slow rate in the frozen storage.

The freezing process also affects the dough rheology. A compression-relaxation test was used by [17]. A sphere was applied against a dough sample (1 $cm.min^{-1}$) for 30 s and the following relaxation was logged over a period of 30 s. The difference between the maximum and the residual force was increased by 33% between conditions #1 and #3 (air temperature was - 20°C and air velocity was 1 and 3 $m.s^{-1}$ respectively). This result was interpreted as a reduction in the elasticity of the dough with increasing freezing rate. This analysis is confirmed by the results from [20] or from [6].

6. Frozen storage

The rate of ice crystal growth during storage is related to temperature level and fluctuation. The temperature level will interact with the degree of mobility of water and the fluctuation will participate to the preferential melting of the smaller ice crystals due to their lower free energy. In the case of frozen dough, the amount of frozenable water seems to increase with storage duration as shown by [6]. As explained earlier, this phenomenon was explained to some water bounded to the gluten, which was continuously liberated and collected by ice crystals. This phenomenon related to a decrease of yeast activity with storage as shown by [17] result in a decrease of the baking performance with increasing storage(increase of the proofing time and decrease of the loaf volume). A specific study was realised by [21] who compared three storage conditions. Condition #1 was a very stable storage temperature; condition #2 was corresponding to temperature fluctuation of the walk-in storage cabinet used during this study. Condition #3 was similar to #2 except that 24 hours before proofing, the dough sticks undergoes a rupture of the cold chain (temperature increase to -8°C at core). As a result, the baking performance (bread volume) was in the mean equivalent after 37 days in condition #1 or 12 days in condition #3. In most of the studies available in the literature, a significant evolution of the baking performance (in term of yeast activity or dough rheology or bread volume) is observed during the 2-4 first weeks of storage.

7. Aroma of bread made from frozen dough

There are not so many studies available on the aroma of bread made from frozen dough. Selected parameters and bread properties interact with the global aroma perception of bread as shown in Figure 3. In her PhD, [22] studied the impact of the freezing process on different bake off technologies such as frozen dough, frozen part baked bread and full baked frozen bread. After having secured the adapted methodology and the most representative extraction method [23, 24], an indepth study on the impact of inuline as an added fiber has been carried out. Results [25, 26] showed that no detectable differences were observed in particular between a control bread and a bread made of frozen dough. Even though this study was carried out with a short term frozen storage, it is much likely that results obtained with bread made from frozen dough can be extrapolated to longer storage periods.

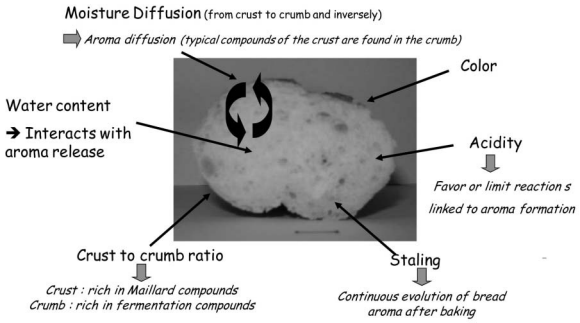

Figure 3. Schematic representation of selected parametr which may inlfuence the global aromatic perception of bread (from [27] - C. Rannou - oral presentation at ICC conference - Madrid - June 2008).

8. Conclusion

Frozen dough is very convenient technology, which permits to produce fresh bread in baking stations with minimum know-how and equipment. However, freezing process and frozen storage tend to affect the initial properties of dough rheology and the yeast activity, resulting in a lower baking score (reduced bread volume in comparison with non frozen dough). Recent results showed that the formulation and the storage conditions have a major impact on the baking score. Nevertheless, the control of the freezing rate during the freezing process appears as an important parameter. It has been shown that a short freezing time followed by an equilibration period in the storage cabinet yielded in a significant improvement of the baking score in comparison with deep freezing. Deeper investigation on the storage tolerance of frozen dough would help in preserving the benefit withdrawn from a good control of the freezing process.

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