A REVIEW: ADVANCE IN FROZEN DOUGH IMPROVER TECHNOLOGY OF BREAD

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Abstrak

Roti adalah makanan yang memiliki umur simpan pendek dan terjadinya perubahan kimia dan fisik selama proses penyimpanan. Salah satu cara yang dapat dilakukan untuk memperbaiki kekurangan ini yaitu dengan membuat adonan beku. Artikel ini bertujuan untuk mengumpulkan informasi yang terkait dengan proses pembuatan adonan beku, faktor yang mempengaruhi kerusakannya serta teknologi terkini dalam proses adonan beku. Adonan beku adalah adonan roti yang disimpan dalam suhu beku setelah tahap pencetakan. Metode ini dapat memperpanjang umur simpan roti dengan mencegah kontaminasi mikroorganisme pembusuk. Inovasi dalam teknologi adonan beku bertujuan untuk mengurangi perubahan fisik dan kimia seperti teknologi pembekuan berbantu ultrasound, perlakuan pendahuluan adonan beku, penambahan bahan khusus, dan kondisi penyimpanan beku.

Kata Kunci : *roti, adonan beku, penyimpanan beku*

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Abstract

Bread is food that has a short shelf life and some chemical and physical changes during the storage. One effort that can be improved these deficiencies is by making frozen dough. This article aims to gain information related to processing of frozen dough, the factors that affect its damage and the latest technology in the process of frozen dough. Frozen dough is bread dough stored in freezing after the moulding stage. This method can extend bread shelf life by preventing contamination of microorganisms. Innovation in frozen dough technology aims to reduce physical and chemical changes such as freezing technology assisted by ultrasound, pre-treatment of frozen dough, addition of special ingredients, and frozen storage conditions.

Key words : *bread, frozen dough, storage*

INTRODUCTION

Bread is one of the most widely consumed foods in the world, which provides nutritional benefits for human. The major ingredients for making bread are flour, yeast (leavening agents), water, fat, salt, sugars, and improvers such as gums, oxidizing agents, emulsifiers, reducing agents, enzyme active materials and full fat (Cauvain et al., 2003). The fresh bread characteristically presents in a nice toasted aroma, appealing golden brown crust, good slicing characteristics, soft and elastic crumb texture and moist mouth feel (Selomulyo & Zhou, 2007). However, this bread has a short of shelf life and several chemical and physical changes over the storage time, known as staling. The bread loss of freshness is determined by the rising of crumb hardness and the decreasing in flavour and aroma. Furthermore, loss of moisture and starch retrogradation caused in the firming of the crumb (Selomulyo & Zhou, 2007). These changes will affect the quality of the product and consumer acceptance. Frozen dough is considered as one of methods that are expected to address these problems.

Nowadays, frozen dough has been used commonly in industrial bakery since it can improve the quality of dough, increase the capacity of production, reduce the costs such as labor cost and increase the public demand for the availability of fresh baked bread in market at

any time (Yuru & Xianlun, 2011). The advantages of the frozen dough make it popular for instance, in the United States; more than a half percentage of bakeries used this method (Gelinas et al., 1989; Berglund et al., 1991). Further, Kulp et al. (1995) shown that the production of frozen dough increased dramatically in one decade due to the growth of bakeries and retail shops. Despite that fact, the freezing process is still faced with physical and chemical damages in the dough which affects the quality of product for instance, the gradually decrease either of the dough strength or of the retention capacity of CO_2, the declining of yeast activity due to long fermentation, and the decrease of loaf volume compare to conventional bread (Mezaize et al., 2010). Hence, the comprehensive understanding is needed regarding formulation, specific treatment, storage time, temperature, in order to enhance the quality of the final bread and minimize in the undesirable physical changes.

Therefore, this article provides an overview of the factors associated with deterioration of frozen dough during freezing and frozen storage. Additionally, the several latest frozen dough improver technology that aims to improve the quality of frozen dough of bread are discussed.

LITERATURE REVIEW

A. Dough and Bread Production

Dobraszczyk et al. (2006) stated that the first production of bread was found in ancient Egyption as fermented bread made by wheat flour and baked in clay oven. At that time, the consumption of bread was limited due to expensive and only for special event. However, nowadays, bread has become a staple food in many countries which provides nutrition for large of population in the world. This trend occurs due to the growth of bakeries and retail shops and the increase in public demand for the availability of fresh baked bread in market at any time (Yuru & Xianlun, 2011). In order to meet market demand, the bread has been produced on industrial scale. Generally, in bread manufacturing, the process consists of eight stages, namely, mixing, fermentation, molding, proofing, baking, cooling and packaging (Figure 1).

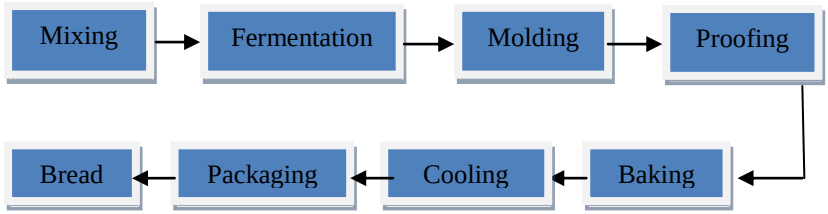

Figure 1. Bread processing with conventional dough (Ashgar et al., 2011)

Figure 1 depicts that bread-making process begins with mixing stage. This stage is homogenization of the ingredients, which generates gluten formation as a result of mechanical energy during mixing action. The next stage is fermentation process, which uses yeast such as *Saccharomyces cerevisiae.* Then, followed by molding stage for individual loaf in order to get the uniformity and smooth in surface. Each loaf will have optimized volume after proofing. Moreover, baking stage is done to develop desirable flavor and color of bread by maillard reaction. Finally, cooling and packing stages end the process.

However, this unfrozen dough bread making process have some limitations, especially in terms of shelf life, freshness and also contamination by molds during storage. Hence, freezing treatment is used in production of frozen dough. In addition, the formulation of unfrozen dough is different with frozen dough. However, the characteristic and basic formulation is basically the same. The ingredients of dough and bread processing are discussed below:

1. **Flour**

   Flour is the most important ingredient in processing of bread because it contains protein, which is able to trap and retain carbon dioxide gas. The more protein in flour, the ability in trapping and retaining C02 gas and the larger volume of bread also improved. Also, the flour contains starch, fibre content and other important physicochemical properties (Cauvain & Young, 2006).

2. **Yeast**

   Yeast is a leavening agent. Saccharomyces cereviciae is the most common yeast for used in bread making. It ferments sugar in anaearobic environment producing carbon dioxide (CO2) that causes the increase of the volume of dough. The larger of dough volume is produced by the higher percentage of yeast under dough

formulation. This phenomenon is achieved by higher accumulation of carbon dioxide gas from yeast fermentation activity (Meziani et al., 2012a, 2012b). Also, the yeast produces aromatic compounds that contribute to the flavor and aroma in bread (Kamel & Stauffer, 1993).

3. Other Ingridients

Water, sugar, salt and fat are the other ingredients that commonly added in bread dough are discussed. Firstly, water plays an important role in solubilizing and dispersing the ingredients over the mixing stage, developing gluten in bread and fermented dough, and also in eating quality (Cauvain & Young, 2006). In addition, it performs as a lubricant and contributes in rising hydrogen bonding and hydrophobic interactions with protein (Miller, 2006).

Secondly, sugar is essential source of energy used by yeast over the fermentation stage which converts to CO_2. Sugar can also creating in desirable crust colour and flavor (Sahlstrom et al., 2004). This ingredient has ability as anti-staling which prevents starch recrystalization (Levine & Slade, 1990). However, sugar also can give negative impact in bread production such as can prevent activity of yeast, the addition of high amount of sugar can prevent the activity of yeast (Cauvain et al., 2003).

Moreover, salt has several functions in bread dough for instance, contributing to the flavor, strengthens the gluten, and controlling both the action of yeast and volume of loaf, increasing the stability of dough, firmness and capacity to hold fermentation gas. Also, it can increase the gelatinization temperature of starch (Chinachoti et al., 1991; Kamel & Stauffer, 1993). However, the salt can inhibit formation of gluten over mixing step (Cauvain et al., 2003).

In addition, fat is used to improve the gas retention of dough that can increase the volume and softness of bread (Cauvain et al., 2003). The fat also can improve dough handling and crumb appearance as well as contributing to the flavor of bread (Stauffer, 1993).

B. Frozen Dough

Frozen dough is a bread dough which is stored in freezing temperature (around -35 ºC to -40 ºC) after moulding stage and also, needs other stages such as thawing (ice crystal melting

process) and proofing stage. This method can extend the shelf life of bread by preventing the contamination of microorganism spoilage. However, the bread dough should be frozen quickly in order to prevent contamination of yeast which is destructive to storage ability (Gelinas et al., 1989).

There are two types of frozen dough namely, unfermented frozen and prefermented frozen dough. The unfermented frozen dough (U-FD) is manufactured by several steps. Firstly, the dough is prepared, shaped and frozen as result in frozen dough. Furthermore, the frozen dough has to be thawed, fermented then followed by baking process. Additionally, U-FD products are similar to the conventional dough products (Omedi et al., 2016). This type of dough conducts slow freezing treatment, which has limitation in terms of frozen shelf life due to the increase in the time taken for thawed dough to proof the desirable volume prior to baking (Bruinsma & Giesenschiag, 1984; Inoue & Bushuk, 1991; Omedi et al., 2018).

According to Lebail (2006) prefermented frozen dough also has similar process stages to conventional dough in bread making method. However, in pre-fermented frozen dough making, the fermentation step is discontinued before dough completely rises, and then followed by freezing step. This freezing step applies high freezing rate. Moreover, the prefermented frozen dough is more susceptible to structural damage from ice crystal compared to unfermented dough (Rassanen, 1998).

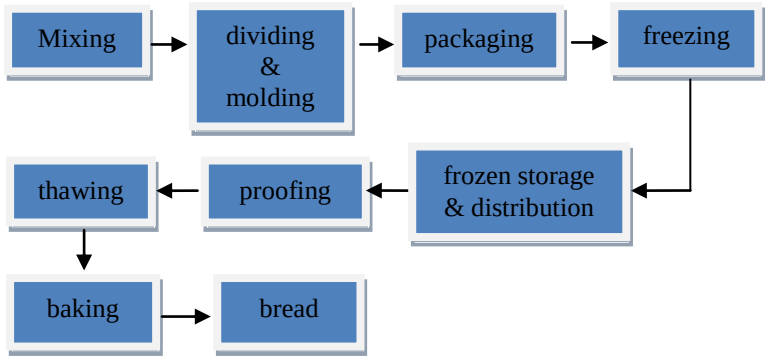

Figure 2. Bake off frozen dough process (Best, 1995)

Best (1995) suggested that frozen bakery products could divide into three groups such as baked off frozen dough, pre-baked and fully baked products. The off baked frozen dough is started from mixing step, divided and moulded, then frozen. Also follow by, thawed, proofed and baked before consumption (figures 2). Moreover, the pre-baked product requires proofing and partially baking before freezing stage and also, needs thawing and short final baking. In addition, the fully baked product is simply reheated before consumption.

Frozen dough has been used for long time because it provides a lot of benefits in bread industry, for instance it can retain the freshness of bread once distribution in a market. Also, the bread industry can increase the capacity of production due to the resistance of spoilage microorganism and extension of bread shelf life. However, there are several negative changes and reductions in sensory quality of bread dough during storage time such as volume's declining and stalling.

Factors affecting deterioration of frozen dough

During frozen storage, the quality of bread dough deteriorates gradually due to physical and chemical reactions in the frozen dough. The factors, which affect the quality of frozen dough observed as follows:

1. **Ice crystal**

   Freezing is the phenomenon of crystallization of liquid water into ice. During the frozen storage, the temperature fluctuation can lead to water migration throughout the temperature gradients. The components of the liquid stage in frozen dough are in metastable phase. The changes due to water transfer may cause moisture loss in several dough components for instance when the cell membranes of yeasts intact or resist the passage of ice which lead to driving force to dehydration of the cells by osmotic pressure. Simultaneously, pH change, osmotic pressure, and water migration are induced by freezing which affect the quality of frozen dough (Casey & Foy, 1995; Kulp et al., 1995).

   In addition, during fermentation concentration of acid and crystallization of salt may decrease the pH values. This

can lead to localized dough areas that affect the stability of dough. The solid ice phase also changes, from small crystal form to large crystal form. When salts precipitates, a complex series of pH modify take place. Hence, interference of some bonds in dough is affected by dehydration and may influence the functionality of dough (Casey & Foy, 1995; Kulp et al., 1995).

2. **Protein and gluten network**

The greater amount of protein in wheat, the more protein content in flour produced from it, especially gluten that has ability to trap and retain carbon dioxide gas (CO2) by construction network (Cauvain et al., 2003). The formation of ice crystal during freezing can damage the gluten network by breaking disulfide bonds. This phenomenon occurs due to inability of gluten to hold CO2 causing the damage of gluten networks and resulting declining volume of the dough (Anon et al., 2004).

3. **Yeast activity**

Saccharomyces cerevisiae is a yeast strain that extensively has been used as ingredients in frozen dough. According to Wang et al. (2017), yeast viability and activity in frozen dough system decrease during freezing and storage temperature. In order to minimize these losses, specific yeast strains have been developed in steamed frozen dough product (Omedi et al, 2018). However, this freeze tolerant yeast still affected by the freezing and storage temperatures. Certain losses in yeast capacity are still found even through controlled temperature and rapid processing (Takano et al., 2002).

Frozen dough increases the susceptibility of yeast cell damage because the yeast in a dough system is in osmotic pressure or in a state of active fermentation. Moreover, during active fermentation cell have a thinner plasma membrane as dormant cells; therefore, they become more susceptible to cell damage. Also, the organic compounds are concentrated in the aqueous phase during freezing which can generate autolysis cells of yeast (Stauffer, 1993; Casey and Foy, 1995). In addition, adding yeast

concentration in dough formulation and using additional substance are once of method that can increase the ability of yeast cells to retain breakdown.

4. Starch

Retrogradation of starch (amylopectin) is one of the main causes of bread staling (Schiraldi and Fessas, 2010). However, according to research conducted by Sahlstrom & Brathen (1997) indicated that there is minor correlation between retrogradation of starch with bread stalling. Retrogradation is the aggregation of amorphous starch chains in helical forms, some of which can develop into crystal. According to common examination on the correlation of starch and retrogradation, the rate of retrogradation shows association with mechanical firming in conventional bread storage. Therefore, it have been assumed that recrystallization of starch lead to staling or firming of bread (Cauvain et al., 2003).

Another study conducted by Yi and Kerr (2009) depicted that there is linear correlation between storage time and bread staling, in which the longer of storage time in low temperature, the greater staling occur in bread.

C. Advances in Frozen Dough Technology

During storage, frozen dough has loss of baking quality. Hence, several innovations in dough frozen technology has been found in order to reduce the economic losses resulted from physical and chemical changes of dough such as pre-treatment technology (pre-fermentation), ultrasound assisted freezing technology (UAF), biotechnology and enzyme technology, and frozen storage condition.

1. Pre-treatment Technology (Pre-fermentation)

The aim of this technology is to bring a frozen product directly from freezer to the oven. It called ovenrise which can reduce energy compared to the frozen partially baked technology which has two stages of baked (Le-Bail et al., 2010).

Rassanen (1998) indicated that the shorten of pre-fermentation affected the loaf volume which increased 20%

percents. Also it increased the uniformity of pore structure and creates thicker network of gluten in the region of gas bubbles. In other study, Le-Bail et al. (2010) comes up with the same point of view that the pre-fermentation contributes to one third of dough expansion. Also, the combination between high freezing rate and decreasing level of pre-fermentation can prevent the loss of bread volume induced by processing. However, during the refrigeration, the volume of dough decreased. This phenomenon occurs due to the lower internal pressure of gas cells contained in the dough. Hence, adding baking powder during pre-fermentation can assure expansion over the baking.

The latest study conducted by Gabric et al. (2011) observed that the final dough and bread volume decreased as the degree of pre-fermentation increased. However, applying chilling stage in 4°C for 120 minutes before freezing reduced the loss in volume of bread.

2. Ultrasound-Assisted Freezing (UAF) Technology

The expansion pressures induced by the large ice crystal which are formed either during food freezing or freezing storage process may damage the structure of food. Hence, it can cause deterioration of the structure frozen food (Hu et al., 2013). The new novelty in dough frozen technology such as ultrasound-assisted freezing(UAF) can address the deterioration in quality of frozen food, therefore we do not need to use food additives. Nowadays, a lot of food industry develop concept of 'go green' which meets with this method. It consists of three stages, namely liquid-state temperature decrease stage, phase transition stage, and solid-state temperature decrease stage (Hu et al., 2013).

The latest study conducted by food Hu et al. (2013) showed that using UAF method in making frozen dough contributed to similar quality of frozen dough as conventional food freezing method. The UAF process increased extensively the elasticity of dough. However, this method has a little impact on the flavour of dough. In addition, even though this method has a little drawback, the results of this study presented beneficial

information in food processing regarding application of UAF in the future.

3. Additional Fibers as Improver of Frozen Dough

Flour contains dietary fibres can enhance the nutritional value in frozen dough. According to experiment conducted by Leray et al (2010) investigated that fibre-enriched in frozen dough had strong correlation to gluten network and yeast strength. Moreover, this experiment shown that the frozen dough with additional fibre was more resistance either in freezing process or storage conditions. Hence, fibber-enriched in frozen dough had double benefits not only in improving the nutrition value but also increased in resistance during freezing. In addition, the addition of 5% fibres in frozen dough is able to protect yeast cell in extensive storage time and also can support gluten network (Filipovic et al., 2008).

According to the latest study conducted by Ding et al. (2015), Ice Structuring Proteins (ISP) isolated from barley that added to frozen dough can enhance tolerance to freeze. The ISP raised the apparent specific of heat of dough after freezing. It also increased freezing, and range of melting and glass transition temperature. Similar results were depicted that ISPs isolated from oats and barley anti freezing proteins (BaAFP-1) reduced the melting enthalpy and freezable water content of fresh dough after freeze–thaw cycles (Ding et al., 2015 ; Zhang et al., 2015).

4. Mixing Ingredients

Minervini et al. (2012) indicated that addition of honey, sucrose, trehalose, and skim milk in frozen dough can improve the performance the final baked products and also decrease the degree of toughness. Moreover, the optimization of sensory quality of frozen dough can be obtained by mixing those ingredients in appropriate concentration and formulation.

5. Enzyme Technology Ingredients

Several researches have been observed that addition of glucose oxidase enzyme (Gox) in dough can increase tenacity and elasticity and mitigate in dough extensibility (Rosell et al., 2003; Bonet et al., 2006; Davidou et al., 2008; Steffolani et al., 2011). Also, other research stated that it had no correlation or

negative effect in loaf volume; but it improved crumb texture and strength (Raisah et al., 2005; Steffolani et al., 2011).

On the other hand, in latter study conducted by Steffolani et al. (2011) indicated that the dough with added Gox contributed in a larger bread volume compared to dough without added Gox. Also, the deterioration during frozen storage was lower than dough without addition of enzyme. It shown that this enzyme contributes in development of gluten network and dough strength. Glucose oxidase carries out oxidation process which result in increasing of gluten network durability; therefore, it can hold the destruction effect of ice crystal formation.

In the same experiment conducted by Steffolani et al. (2011) depicted that the addition of Pentosanase (Pn) in frozen dough was contributing in greatest volume and the lowest crumb firmness in the final product. This phenomenon occurred due to Pn enzyme activity in cell interface which can increase the expansion capacity without gas loss so can enable a higher expansion over proofing.

6. Frozen Storage Condition

Controlling and monitoring temperature of storage room play an important role to optimize the quality of frozen dough and minimize the deterioration of frozen dough.

a. Freezing Rate

The freezing rate is an important aspect to determine the final quality of frozen product. The high freezing rate will form ice microcrystals that cause the less integrity of gluten network, which bring down in physical damage leaded by freezing (Angiolani et al., 2008). Also, the high rate of freezing influences the yeast population in dough which can reduce their population significantly as result of intracellular freezing and low tolerance of yeast in freezing condition. Moreover, the declining quality of dough and increasing of hardness of bread occur due to the low yeast population in dough (Meziani et al., 2012a). Hence, it is necessary to apply the appropriate freezing rate that can lead to preserve of yeast population as well as maintain gluten network which result in desirable texture of baked products.

b. Temperature and Time

During frozen storage, the stability of temperature is very important because fluctuation of temperature can lead to recrystallization ice crystal and formation of ice crystal. This occurs due to the declining performance of gluten network in holding CO2. (Phimolsiripol et al., 2008). Moreover, The study conducted by Phimolsiripol et al. (2008) depicted that the fluctuation of temperature accelerated inability of yeast activity in gas production, lowering weight and volume, and also producing high stalling. On the other hand, the stable temperature can preserve viability of yeast for 112 days length of storage. Hence, the changes of temperature over the storage is maintain not less than 3°C. In addition, frozen dough which is stored in freezing temperature around -35 ºC to -40 ºC can extend the shelf life of dough due to the prevention of spoilage microorganisms contamination (Gelinas et al., 1989).

Long periods of storage of frozen dough in freezing temperature will affect the water holding capacity of frozen dough. Long term frozen storage condition can cause the small ice crystal form into large ice crystal and weaken, in fact sustain to damage the gluten network (Xu et al., 2008). In order to preserve high quality sensory of frozen dough and also extend shelf life of frozen dough, pre-treatment, additional ingredients, ultrasound irradiation process, and controlling of storage temperature is important to apply. However, the determination of duration of storage time also needs to be considered.

CONCLUSION

Frozen dough is a bread dough which is stored in freezing temperature (around -35 ºC to -40 ºC) after moulding stage, it follows by another stages. This method can extend the shelf life of bread by preventing from contamination of spoilage microorganism. However, this bread has short of shelf life and several chemical and physical changes during the storage time, known as stalling. Hence, several innovations in dough frozen technology has been developed in order to reduce the economic losses due to physical and chemical changes of

dough for instance ultrasound-assisted freezing technology, pre-treatment of frozen dough, addition specific ingredients, and frozen storage condition.

Ultrasound-assisted freezing had improved the quality of frozen food without adding additives in frozen dough. This novelty not only improved the dough as their elasticity but also had less impact in the dough flavour. Moreover, the pre-treatment of frozen dough contributes to one third of dough expansion. Also, additional specific ingredients such as fibers and enzyme increased in resistance of frozen dough during freezing process and storage conditions. Controlling and monitoring temperature of storage room can optimize the quality of frozen dough and minimize the deterioration of frozen dough.

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