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Functionality of Different Surfactants and Ingredients in Frozen Dough

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Abstract: Surfactants are widely used in bakeries as dough strengtheners and dough improvers but there is a wide range of compounds available according to their mode of action that could potentially improve the quality of not only the simple breads and doughs but also of frozen dough. These types of product usually have a short shelf-life when compared with normal bakery products. With the increase in modernization and new trends in food products, consumers are becoming more and more aware and conscious about their diet and therefore their health as well. The quality of frozen dough bakery products could be improved by the use of different additives including surfactants, hydrocolloids, gum additives etc. These additives help to improve the quality of the frozen dough bakery products and increase the shelf-life. Several ingredients can be used for the production of frozen dough bread, the most important of which are flour, yeast and water. Bread improvers play an important role in both the dough and finished loaf volume, and aid dough development, improve the gas retention of the dough, improve dough tolerance to mechanical shock, speed up dough maturity, improve dough machine ability, reduce the rate of crumb firming bread staling, improve crumb structure and texture of the loaf, and improve loaf volume.

Key Words: Surfactants, frozen dough, bread, ingredients

Introduction

The use of additives has become a common practice in the baking industry. The need for their use arises due to the fact that numerous benefits are associated with their use, which not only result in improving the bread quality but also in an increase in shelf-life. Since its inception, the baking industry has undergone several evolutionary steps, which have resulted in proper handling, storage of dough under freezing conditions and ease in production and transportation. In the last decade, the production of frozen dough has increased greatly because of direct sales to consumers and the growing number of in-store bakeries. Due to this rapid increase in the frozen dough related market products some problems have arisen, and surfactants, hydrocolloids and other compounds that usually have water binding properties are also employed in frozen dough production. There is a lack of information about the effectiveness of these additives when freezing is applied during bread making. It is an established fact that all the compounds that interact with water can affect the quality of the resulting product.

Several ingredients can be used for the production of bread, the most important of which are flour, yeast and water. As soon as dough is properly baked into bread, a product with superior quality and sensory features occurs. Fresh bread usually presents an appealing brownish and crunchy crust, a pleasant roasty aroma, fine slicing characteristics, a soft and elastic crumb texture, and a moist mouthfeel. However, fresh bread is a product with a short shelf-life and during its storage a number of chemical and physical alterations occur, known as staling. As a result of these changes, bread quality deteriorates gradually as it loses its freshness and crispiness while crumb firmness and rigidity increase. The pleasant aroma vanishes and the flavor brings out a stale feeling. Those preservation problems in combination with the increasing market demands and the complexity of the traditional bread making procedure, which requires night or early morning labor, lead to the development of several technologies in order to improve the preservation of bakery products. Meanwhile, several additives were introduced in order to increase the shelf-life of bread and enhance its quality, retain ability, sensory perception or even nutritional value. Over the past few years, the bakery industry has exploited the advantages and applications of freezing technology in several foods and developed a special interest on it in order to meet the need for products with increased shelf-life from both ordinary consumers and food service industries.

Frozen bakery products are expected to be characterized by quick preparation time and affordable price, and look and taste as if they are fresh and home made. However, the use of freezing conditions in bread making presents several problems that should be carefully considered in order to assure/retain the quality characteristics of bread. As far as the production of bread from frozen dough is concerned, consumers expect products with satisfactory quality and sensory characteristics that should not differ much from fresh ones. Both ingredients and production technology used should be studied in order to ensure a product's safety and induce minimum impact on the quality of the final product.

The objective of this work was to study the effect of surfactants and different ingredients that influence the quality characteristics of bread and other bakery products (pizza etc.) made from frozen dough and highlight the main points that differentiate it from that traditionally baked. Keeping in view these facts, a review about the functionality of these additives and about the use of different ingredients in frozen dough systems is presented in this article.

Surfactant as additives in breads

Breadcrumb made from flour possessing extra strong dough properties was stronger than that made from conventional flour. Destruction of crumb structure by compression resulted in the elimination of most of the differences in mechanical properties between flour types and thus crumb structure plays a critical role in the external properties of breadcrumb (1).

There is also a difference in the formulation in the frozen dough bread and the formulation is shown in the Table.

Changes in the quality of bread are affected more by frozen storage than by the thawing method used. Thawing methods had a significant effect on investigated physicochemical parameters of the product; however, a statistically significant effect on sensory quality of thawed bread could only be found after 2 days of storage at room temperature rather than directly after thawing. Bread that underwent microwave thawing was generally better quality in comparison with that air blast thawed (2).

Table. Formulation of frozen dough bread.

Ingredients	Quantity
Flour	100 g
Sugar	4.0 g
Salt	1.0 g
Shortening	5.0 g
Ascorbic Acid	100 ppm
Yeast	3 g
Water	According to water absorption capacity

For good bread making, the dough must have sufficiently high viscosity and be extensible for a sufficient long time during oven rise. The viscosity requirement was met by virtually all doughs, and thus did not discriminate between flours with poor and with satisfactory baking performance. Fermentation stability of frozen prefermented dough with some flours with decreased amounts of water improved both the fermentation stability and form ratio of breads baked after 7 days of frozen storage of dough. Thawing for 1 h at 38 °C, 90%-95% R.H., and proofing to a constant height at 32 °C, 90%-95% R.H., were determined to be optimum conditions for frozen doughs. Stability and the mechanical tolerance index of the dough were improved by the addition of whey solids, as were the external and internal characteristics of the bread. The addition of whey solids also had a retardation effect on bread staling and extended its keeping quality by 2 days. Frozen dough quality is affected by grain protein content. Doughs made from high protein flours have increased dough strength and larger loaf volumes when baked from frozen or fresh dough products. Dough strength decreased markedly in dough that had undergone freezing and thawing. A reduction in dough strength also led to a reduction in loaf volume (3-8).

Samples stored in frozen conditions supplemented with diacetyltartaric acid ester of monoglycrides, gluten and guar gum can produce breads of greater volume and more open crumb structure than those prepared with the base formulation, i.e. with no additives. Crumb firmness increased with frozen dough storage and bread aging time at 4 °C. A decrease in the amount of glutenin subunits of high molecular mass was observed by electrophoresis of the SDS- soluble protein aggregates extracted from the frozen dough. This result suggested that the protein matrix of the bread underwent depolymerization during storage in frozen conditions (9).

Tolerance to degradation when frozen was largely due to its lower gas retention decrease. This lower decrease in gas retention when frozen was mainly due to its high breaking force when thawed, which was attributed to its resistance to glutathione, a reducing agent that leaked from freeze-damaged yeast cells. During the cooling stage of a bread loaf, consistent changes in the moisture content occur, which contribute to a temperature gradient within the bread. Usually the interior of the bread has more moisture than its outer layers. This results in a difference in vapor pressure between the crust and crumb, resulting in moisture migration during the cooling stage. Part of the moisture travels from the crust to the surrounding atmosphere. This mass transfer resistance that exists at the interface between the bread crust and the atmosphere around it influences the rate of moisture migration (10,11).

Water distribution changes usually occurred during extended frozen storage and freeze thaw cycles and these may contribute to the extended proofing time and reduced loaf volume of frozen bread doughs. Ice crystallization itself could contribute to the weakening of the three-dimensional protein network responsible for gas retention in dough, which could cause weakening of the dough and contribute to excessively long proof times (12-14).

The effect of sodium stearoyl-2-lactylate (SSL), diacetyl tartaric acid esters of monoglyceride (DATEM), glycerol monostearate (GMS), and distilled glycerol monostearate (DGMS) surfactant gels on dough’s rheological characteristics and quality of bread was investigated. Overall, the surfactant gels improved the farinograph and extensograph characteristics of wheat flour, but the improvement was reduced to some extent with the presence of shortening in the gels. Alveograph data indicated that dough properties improved with the addition of surfactant gels. Shortening in gels showed a varying influence on the dough alveograph properties of wheat flour. The results indicated that the surfactant gels changed the rapid visco-analyzer characteristics of wheat flour, and the presence of shortening in gels further altered the characteristics. All surfactant gels improved the volume, specific volume, texture, and overall quality scores of bread, but the improvement varied for different surfactants. By increasing the addition of shortening in gels, although the quality characteristics further improved, the response to surfactants decreased with increasing shortening content (15).

The difference in dough expansion rate is attributed to the difference in protein content. Each wheat variety inherits the quality of protein from its parents. Both protein content and quality are important factors in determining the rate and capacity of water absorption by flour, thus indirectly contributing to the retention of freshness in bread. In some studies the impact of honey in frozen dough bakery products was also studied and its use in bread indicated that honey used at a level of 4%-6% (flour basis) improves the rheological properties of frozen doughs, protects gluten proteins from damage during freezing, significantly improves dough strength and decreases staling. Honey also has a desirable effect on the color development of the crust and crumb of frozen doughs and consumers prefer the color of breads made from frozen doughs containing 6-8% honey. An important finding was that consumers liked equally breads either fresh or made from frozen doughs to which honey is added at levels of 6%-8% (16-18).

The use of the Hard Red Spring wheat cultivar Grandin and hydrophilic gums such as carboxymethyl cellulose (CMC), gum arabic, kappa carrageenan and locust bean gum at 3 different levels each on doughs stored frozen for up to 16 weeks was studied. Doughs with locust bean gum gave a lower proof time, indicating better retention of baking quality. Doughs with locust bean gum gave a significantly lower proof time compared with the other treatments and the control. CMC gave the second lowest values, followed by gum arabic treatment. Addition of kappa-carragenan increased the proof time compared with the control (14,19).

The difference in the processing line of fresh and frozen dough is shown in the Figure.

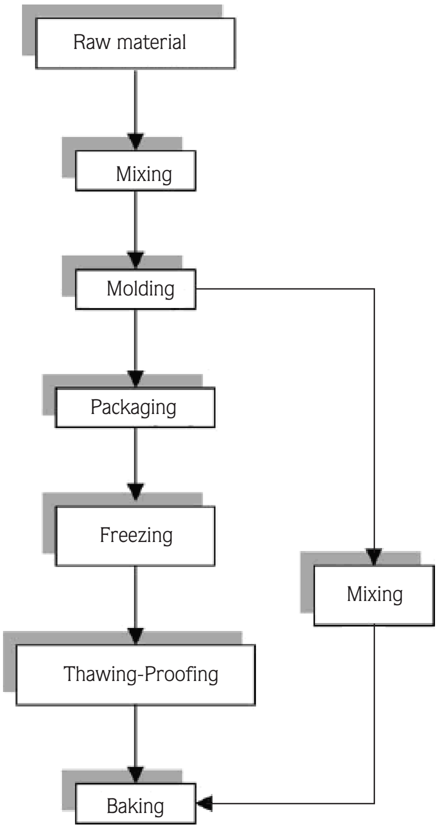

Figure. Frozen dough process flow diagram.
Continuous line frozen dough production
*Dotted line represents the ordinary baking line

Effect on Frozen Dough Pizza

Extended storage caused gradual deterioration in the food quality. Fluctuating temperature had detrimental effects on the texture and flavor of the frozen pizza. With the exception of riboflavin, thiamine and ascorbic acid, the nutrient quality of the pizza was maintained for up to 12 months at –30 °C and for up to 6 months at –10 °C. Fluctuating temperature reduced the bacterial counts of the frozen pizza (20).

Pizza bases can be prepared by forming a portion of dough into a required shape, leaving this dough, coating this with an edible water barrier surface and then baking. The coating such as crystal gum prevents the movement of moisture from any topping subsequently used on the base. Quality was determined immediately after freezing as well as after frozen storage. Pizzas can be kept at –10 °C for 20 weeks and rapid freezing of pizza produced a product slightly better in quality than the slowly frozen product. The slight quality improvement gained by rapid freezing of pizza was lost during storage (21,22).

Flour type and dough retardation time also affect the sensory characteristics of pizza crust. Dough retardation time significantly affects the sensory characteristics. The pizzas were frozen and stored at 3 and 10 °C. Sensory evaluation was conducted every day for 8 days. The sensory shelf-life of pizza was approximately 5 days at 10 °C and 6 days at 3 °C. The pizzas were unacceptable after 7 days at either temperature (23-25).

Functionality of Ingredients in Frozen Dough

The typical formulation for frozen dough differs somewhat from that of non-frozen doughs. However, the basic dough characteristics are essentially the same. The effects of essential dough ingredients on dough processing are discussed in the following sections.

Flour Quality

Flour is the basic ingredient in the production of bakery goods. There are various types and qualities of flour with different protein quantities and qualities. Because of a process of freezing, storing, and thawing, flour for frozen doughs should have a good strength and high protein content (26,27).

In many cases, flours from hard wheat varieties, with a protein content of 11%-14%, are recommended for use in frozen dough products. The flour with the higher protein content (13.2% on flour basis) caused higher values in volume, especially with increasing storage time. Flour with lower protein content, as used in frozen doughs, could be strengthened using vital gluten (28-30).

Glutenin played a predominant role in the baking quality of frozen doughs. The gliadin and starch fractions contributed significantly to frozen dough quality but not as much as the glutenin fraction. The contributions of the water-soluble fractions to frozen dough quality are usually minimal (31).

Better quality frozen dough products could be obtained by the use of very strong flours, instead of weaker flours. High quality protein (strength) flour seemed to be more important for frozen doughs than total protein content. Thus, both a sufficient quantity and quality of protein is needed in flour to produce good quality baked goods from frozen doughs (27,32,33).

Water Absorption

Water is another essential ingredient in bread making. During the mixing process, added water becomes distributed between the flour components, such as gluten, starch and pentosans. The rest of the added water remains as "free" water and forms the so-called water phase. Soluble compounds such as salts, sugars, and soluble proteins are dissolved, and yeast cells are dispersed in this water phase. Since free water is damaging in a dough system and yeast is sensitive to water during freezing and thawing cycles, lower levels of water absorption are desirable for frozen doughs. The amount of water absorbed into the dough is mainly controlled by the quality of flour. Therefore, the type and quality of the flour are key factors in water absorption. High quality flour ensures maximum water absorption and retention of the moisture during dough processing for baked products (34-37).

Since free water damages the dough system and yeast is sensitive to water during freezing and thawing cycles, lower levels of water absorption are desirable for frozen doughs. Loaf volumes not only depend on the amount of water added to dough, but also on the mixing time applied. Furthermore, baking adsorption and mixing time are interdependent. Therefore, for the best loaf volume both baking adsorption and mixing time should be optimized (38,39).

Yeast

Yeast has 3 fundamental functions in dough systems. It produces carbon dioxide by fermentation, which expands the dough to the required volume. It also develops the dough through the action of fermentation on the gluten structure. Moreover, it provides flavor through the production of complex chemical compounds as by-products of the fermentation process (35,37).

A yeast level used in the baking process is around 3% (on flour basis). A level of yeast in the dough directly affects the rate of gas production. Furthermore, the yeast level used in dough processing depends on the bulk fermentation time and dough temperature. The longer the bulk fermentation time the lower the yeast level should be. As dough temperature increases, so does the rate of gas production until the optimum temperature at about 40 °C is reached. Above that temperature a progressive thermal killing of the yeast can be observed (40).

The major problem of frozen doughs is the performance of the yeast (41-44). Therefore, a higher level of yeast is recommended (4%-6% on flour basis), in order to compensate for the loss of yeast viability during freezing, frozen storage, and thawing (28,29,45-47). Much higher levels of yeast (6%-8% on flour basis) have a deleterious effect on the flavor and aroma of baked goods prepared from frozen doughs (48).

Salt

The salt normally used by bakers is table or cooking salt (NaCl). On average, bakers use 1.5%-2% salt based on the weight of the flour. The primary function of the salt in fermented baked products is to add flavor (34). Salt also has some technological functions, such as to increase dough stability, firmness, and capacity to retain fermentation gases. Salt has a specific effect on fermentation: the higher the concentration of salt, the lower is the rate of fermentation with the same yeast level, and vice versa. Moreover, salt has a strengthening effect on the gluten network during fermentation of the dough (34,35,37).

Sweeteners

The most common sweetener in the baking industry is sucrose even though brown sugar, dextrose, maltose, molasses, corn syrup, and invert sugar are frequently used in baked goods. In addition, the perceptible sweetening effect varies between various sugars (37).

Sugar is often added to fermented products for flavoring reasons and to promote a pleasant crust color. Moreover, added sugar provides a good grain and improvement in the crumb and crust of baked goods (37,49). Sugar is the basic source of energy, which yeast converts into carbon dioxide during dough fermentation. Even though doughs can be made without sugar, an average amount of sugar is 3%-6% based on the weight of the flour. The sugar concentration chosen depends on the type of product and desired crust characteristics (35,37).

Sugar levels used in frozen doughs also depend on the type of product the bakery is producing. A slightly higher concentration of sugar (8%-10% on flour basis) than in conventional baking is recommended for frozen dough production. The higher level of sugar in frozen doughs is desirable because of the hygroscopic properties of sugars, which increase the amount of water absorbed. Therefore, the amount of "free" water in dough is decreased and can reduce the yeast damage before the final baking (29).

Shortening

Different types of shortening are used in baked foods, such as standard fats, oils, and other shortening combinations. In general, shortening improves the crumb properties of baked bread and the dough volume. Moreover, the texture of baked products is changed to give a shorter and softer bite (34,37). Doughs containing shortening continue to expand during baking for a longer time. Therefore, the final volume of baked products is larger with added shortening (Junge and Hoseney, 1981). The addition of shortening at a level of 0.7%-1% of the flour weight is required for significant improvements in frozen dough production and bread quality (34). A higher shortening level is recommended for good quality frozen doughs and incorporation of shortening as 40% oil in water (O/W) emulsion system improved particularly frozen dough stability and final loaf volume (5,28,46).

Ascorbic Acid

Oxidants are used to improve the structure and loaf volume of the dough, and to increase dough strength. Because of the death of yeast cells during frozen storage, reducing substances (particularly glutathione) are formed, which lead to some gluten weakness as a result of weakened disulfide bridges that are essential in stabilization of the gluten network (29,41).

Therefore, more oxidants are needed to compensate for this reducing action in the frozen dough production. Ascorbic acid has been widely used as an oxidant in the baking industry. The amount used for good dough processing is 10-200 ppm, based on flour weight, and it depends on the desired effects on the quality of baked goods (35,47,49). The combination of ascorbic acid and potassium bromate is often used to improve the quality of baked goods, because it has been shown that it allows even greater improvement than ascorbic acid alone (13,31).

Conclusion

Frozen dough products are relatively sensitive in nature although great benefits are associated with their production like ease of transport, comfort in baking and reduction in the processing time of the end product. Major problems are usually related to the lower loaf volume and thus the poorer quality of the end product. Surfactants are usually compounds having water-binding properties and when used in the frozen dough systems help to bind the excessive moisture and thus prevent its availability to the fungus and other microflora, which are the major causes of deterioration and staling in bakery products. However, other factors such as the original quality of raw material, the processing methods and the packaging materials also play an important role. The review presented here is an effort to outline the role of certain surfactants and different ingredients that affect the quality and shelf-life of bakery products made from frozen dough.

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References

1. Scanlon MG, Sapirstein HD, Fahloul D. Mechanical properties of bread crumb prepared from flours of different dough strength. J Cereal Sci 32: 235-243, 2000.
2. Fik M, Macura R. Quality changes during frozen storage and thawing of mixed bread. Nahrung 45: 138-142, 2001.

3. Bloksma A, H. Dough structure, Dough rheology and baking quality. Cereal Foods World 35: 237-244, 1990.
4. Resanen J, Laurikainen T, Autio K. Fermentation stability and pore size distribution of frozen prefermented lean wheat doughs. Cereal Chem 74: 56-62, 1997.
5. Inoue Y, Bushuk W. Studies on frozen doughs. II. Flour quality requirements for bread production from frozen dough. Cereal Chem 69: 423-428, 1992.
6. Holmes J T, Hoseney RC. Freezing and thawing rates and the potential of using a combination of yeast and chemical leavening. Cereal Chem 64: 348-351, 1987.
7. Yousif AK. Concentration of acidic whey and its functionality in French type bread. Intl. J Dairy Tech 51: 72-76. 1998
8. Asghar A, Anjum FM, Ahmed A et al. W. Effect of polyols on quality and acceptability of frozen dough bread. Pak J Food Sci 15: 11-14, 2005.
9. Ribotta PD, Leon AE, Anon MC. Effect of freezing and frozen storage of doughs on bread quality. J Agri Food Chem 49: 913-918, 2001.
10. Yamauchi H, Nishio Z, Takata K et al. The quality of extra strong flour used in bread production with frozen dough. Food Sci Tech Research 7: 135-140, 2001.
11. Piazza L, Masi P. Moisture redistribution throughout the bread loaf during staling and its effect on mechanical properties. Cereal Chem 72: 320-325, 1995.
12. Berglund PT, Shelton DR, Freeman TP. Frozen bread dough ultra structure as affected by duration of frozen storage and freeze thaw cycles. Cereal Chem 68: 105-107, 1991.
13. Varriano ME, Hsu KH, Mahdi J. Rheological and structural changes in frozen dough. Baker's Digest. 54: 32, 1980.
14. Asghar A, Anjum FM, Butt MS et al. Effect of polyols on the rheological and storage study of frozen dough pizza, 16th All Pakistan Food Science Conference 25th January 2006.
15. Azizi M, Rao G. Effect of surfactant gels on dough rheological characteristics and quality of bread, Crit Rev Food Sci Nutr, 44: 545-522, 2004.
16. Bushuk W. Flour proteins: structure and functionality in dough and bread. Cereal Foods World 30: 447-551, 1985.
17. Addo A. Honey in frozen doughs. Food Chemistry 70: 137-144, 1995.
18. Asghar A, Anjum FM, Tariq MW et al. Effect of carboxy methyl cellulose and gum Arabic on the stability of frozen dough for the bakery products. Turk J Biol 29: 237-241, 2005.
19. Sharadanant R, Khan K. Effect of hydrophilic gums on frozen dough. Cereal Chem 80: 773-780, 2003.
20. Kamel B, Manji B. Effect of frozen storage on different pizza formulations. Cereal Foods World 31: 751-755, 1986.
21. Zwanenberg DV, White S, Jackson S et al. Progress for making pizza base. UK Patent Application GB 2275 171 1994.
22. Knock SD, Minnar A, Berry D et al. Leberosmittel-Wissenschaft und-technologie 28: 87-95, 1995.
23. Larsen DM, Setser CS, Faubion. JM. Effect of flour type and dough retardation time on the sensory characteristics of pizza crust. Cereal Chem 70: 647-650, 1993.
24. Dickson JS. Survival of selected indicator and pathogenic bacterial in refrigerated pizzas. J Food Protection 50: 859-861, 1987.
25. Bot A. Differential scanning calorimetric study on the effects of frozen storage on gluten and dough. Cereal Chem 80: 366-370, 2003.
26. Wolt MJ, D'Appolonia BL. Factors involved in the stability of frozen dough. I. The influence of yeast reducing compounds on frozen dough stability. Cereal Chem 61: 209-212, 1984.
27. Wolt MJ, D'Appolonia BL. Factors involved in the stability of frozen dough. II. The effects of yeast type, flour type, and dough additives on frozen-dough stability. Cereal Chem 61: 213-221, 1984.
28. Marston PE. Frozen doughs for bread making. Baker's Digest. 52: 18-20, 37. 1978.
29. Stauffer CE. Frozen dough production. In Advances in Baking Technology. Kamel BS and Stauffer CE. ed. Chapman & Hall. London, UK. 1993.
30. Wang ZJ, Ponte JG. Storage stability of gluten fortified frozen doughs. Cereal Foods World 38: 827-831, 1994.
31. Lu W, Grant LA. Role of flour fractions in bread making quality of frozen dough. Cereal Chem 76: 663-667, 1999.
32. Inou Y, Bushuk W. Studies on frozen doughs. 1. Effects of frozen storage and freeze thaw cycles on baking and rheological properties. Cereal Chem 68: 627-631, 1991.
33. Inoue Y, Sapirstein HD, Bushuk W. Studies on frozen doughs. IV. Effect of shortening systems on baking and rheological properties. Cereal Chem 72: 221-226, 1995.
34. Brown J. Other ingredients. In The Master Bakers' Book of Bread making, 2nd ed. Brown, J. (Ed.). Hastings Printing Co., Hertfordshire. p. 109-121, 1985.
35. Stear CA. Handbook of Bread Making Technology. Elsevier Applied Science, London, UK. 1990.
36. El-Hady El-Samahy E, Seibel W, Brummer JM. Changes in gas production and retention in non-prefermented frozen wheat doughs. Cereal Chem 73: 472-477, 1996.
37. Sultan WJ. Practical Baking, 5th ed. Van Nostrand Reinhold, New York, 1990.
38. Sideleau P. Freezing and thawing of unbaked products. Proc Am Soc Bakery Eng 89-95, 1987.
39. Box GEP, Hunter WG, Hunter JS. Statistics for Experiments. An Introduction to Design, Data Analysis, and Model Building. John Wiley & Sons, New York, 1978.
40. Stauffer CE. Emulsifiers and dough strengtheners. In Functional Additives for Bakery Foods. Van Nostrand Reinhold, New York, p. 69-124, 1990.

41. Hsu KH, Hoseney RC, Seib PA. Frozen dough. I. Factors affecting stability of yeasted doughs. Cereal Chem 56: 419-424, 1979.

42. Hsu KH, Hoseney RC, Seib PA. Frozen dough. II. Effect of Freezing and storing conditions on the stability of yeasted doughs. Cereal Chem 56: 424-426, 1979.

43. Davis EW. Shelf-life studies on frozen doughs. Baker's Digest 55: 12-14, 1981.

44. Hino A, Takano H, Tanaka Y. New freeze-tolerant yeast for frozen dough preparations. Cereal Chem 64: 269-275, 1987.

45. Drake E. Up-to-date review of freezing. Baker's Digest. 44: 65-66, 1970.

46. Lorenz K. Frozen dough. Present trend and future outlook. Baker's Digest. 48: 14-22, 30. 1974.

47. Inoue Y, Bushuk W. Effects of freezing and frozen storage, and thawing on dough and baked goods. Food Sci Technol 72: 367-400, 1996.

48. Lorenz K, Bechtel WC. Frozen dough variety breads: Effect of bromate level on white bread. Baker's Digest 39: 53-59, 1965.

49. Wood P. Compound dough conditioners. In The Master Bakers' Book of Bread Making, 2nd ed. Brown, J. (Ed.). Hastings Printing Co., Hertfordshire 78-108, 1985.