Rheological properties of bakery products in freezing processes

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Abstract. The study studies the rheological properties of bakery products, which depend on technological and technical properties, but pay special attention to the grain composition. The process of creating bakery products and its further use makes it possible to identify the grain composition and its characteristics. The study analyzes in detail the rheological properties of bakery products and proposes mechanisms to improve its quality characteristics.

1. Introduction
A fairly promising direction in our country in the production of bakery products in the form of freezing dough pieces, both fermented and without fermentation, necessitates a qualitative rethinking in the field of application of modern equipment and advanced technologies, taking into account the quality of the input raw material and the presence of specially designed improvers. All this together is designed to provide a consistently high quality parameter of finished bakery products. At the same time, particular importance is attached to strict observance of the production characteristics of the ongoing technological process at such stages of the production of bakery products as: dough kneading, fermentation, dough separation, molding, proofing, cutting, freezing, storage. When applying the technology of freezing bakery products, attention should be paid to the need to stabilize the structure of the dough piece. This stage is necessary in order to form a good volume and prevent the appearance of a wrinkled crust or its peeling after baking a baked product. To avoid negative consequences, specially designed improvers should be used, which also help to retain moisture in baked goods, which will prevent the finished product from drying out. In addition, during freezing, large loads act on dough pieces of bakery products, which contributes to the appearance of defects that need to be eliminated [1-3].

2. Materials and methods
The aim of the study is to identify the distinctive subtleties in the technology of freezing dough, which are relevant for the modern production of bakery products. To achieve this goal, the following tasks were set and solved: to identify the fundamental defects of bakery products that affect the quality of finished bakery products, to analyze the causes of these defects and to suggest possible ways to eliminate them when freezing bakery products.

During the study, materials of normative and technical documentation, open information from the Internet were used [4-6].
The study used the methods of monographic, abstract-logical and system analysis, which allowed the authors to successfully solve the tasks.

3. Research results

As a result of freezing, dough blanks experience enormous loads both inside and on the surface of the dough product, which leads to the formation and appearance of certain shortcomings (table 1), therefore, the correct combination of specially designed improvers and strict adherence to technological parameters can mitigate the negative effect of shock temperatures [7-9].

Table 1. The main ways to eliminate defects when freezing bakery products.

| Defect                                | Cause                          | Elimination                                      |
|---------------------------------------|--------------------------------|--------------------------------------------------|
| Bubble wrap on baked goods            | - increased dynamism of        | - selection of a specially designed               |
|                                       | enzymatic substances           | improver                                         |
|                                       | - excessively wet surface of   | - regulation of steam supply                      |
|                                       | the dough piece                | - reduction of the temperature regime of baking   |
| Airing of semi-finished products      | - storage of semi-finished     | - regulation of air humidity and storage time     |
|                                       | products without packaging     |                                                  |
|                                       | low air humidity               | - storage of semi-finished products in packaging  |
|                                       | - too long storage             |                                                  |
| small volume                          | - lack of a special improver   | - adjusting the proofing time and baking         |
|                                       | - overproofing                 | time                                             |
|                                       | - excessively high baking      |                                                  |
| temperature                           | Contamination, mechanical     | - the use of airtight packaging that protects,    |
|                                       | damage to the surface of frozen| eliminates the loss of moisture and aromatics    |
|                                       | semi-finished products         |                                                  |
| Storage of different types of frozen  | - lack of space in freezers    | - storage of frozen products separately          |
|                                       | semi-finished products         | - storage of frozen products in accordance with  |
| under the same conditions             |                              | the requirements for each type of product        |
| Icy humidifier                        | - condensate from dough pieces | - periodic defrosting of the unit                |
|                                       | and freezing of moisture       |                                                  |
| Chaos in the refrigerator plant       | - lack of a clear system in    | - clear organization of staff work               |
|                                       | work: frequent opening of the  |                                                  |
|                                       | door when looking for something| - numbering of racks - keeping a journal          |

For conventional dough, especially for deep-frozen dough pieces, three groups of factors are the most important and necessary: gas formation, gas retention and rheological properties of the dough. Under the influence of shock temperatures, there is a reduction in gas formation, a decrease in gas-holding capacity and a transformation in the rheological properties of the dough. The composition of specially designed improvers used in shock freezing allows you to adjust and optimize this set of factors.

The fundamental components of improvers used in baking are sugar, enzymatic substances, emulsifiers, stabilizers, ascorbic acid. Moreover, sugars are an important element for gas formation, but there are not enough own sugars in flour for this process. With the help of an improver, it is possible to achieve the required amount of fermentable sugars in the dough. At the same time, one should take into account the fact that, due to the difference in the methods of preparing the dough, it is necessary to constantly maintain the fermentation activity in optimal parameters, which can only be
obtained by using certain enzymatic substances. The activity of the amylolytic group of enzymes, which to a certain extent depend on changing temperature regimes, should be combined with the activity of yeast components in the fermentation process, which also depend on temperature values.

The structural features of each enzyme complex in improvers that are used in the freezing of bakery products are mainly related to the freezing methods, both for pre-fermented dough pieces and for unfermented dough pieces.

As an emulsifier, lecithin, diacetyl ester of tartaric acid, monoglycerides, diglycerides or a complex combination is usually used in the most frequent cases. The presence of emulsifier elements in the dough contributes to starch grains and gluten proteins with water, that is, it shows it in a bound state, while there is an improvement in the ratios in the test piece of free and bound moisture. The membrane shell of gluten becomes thinner, but at the same time they become more elastic, so the dough is easily stretched and does not tear. In addition, emulsifier elements affect the freezing of water in dough pieces, namely, they demonstrate the ability to redistribute free moisture in the workpiece, resulting in a decrease in the formation of crystalline ice of large fractions that violate the gluten structure. In the absence of emulsifiers, coarse ice crystals are one of the main factors in the appearance of irreparable defects in bakery products. In order to represent this process, let us imagine the mechanism of formation of ice crystals in a dough piece.

The appearance of ice in the dough piece does not appear during the freezing process, but during the formation of crystallization centers, around which the activation of ice crystals occurs in the future. Crystal assets in dough pieces are represented by water molecules in a certain quantitative ratio, which form a characteristic ice structure. In this case, the dependence of the random formation of a crystallization center and the rate of crystal formation on temperature changes is of particular importance (figure 1).

When the temperature regime changes upwards, the rate of crystal formation has a definitely constant maximum value. With dynamically increasing freezing, the crystallization rate approaches zero. In this situation, the liquid acquires an amorphous state, which contributes to the formation of ice. The formation of a crystal lattice with small ice crystals is associated with a quantitative characteristic of the crystallization assets and the speed parameter of the appearance of crystals in the dough piece. Moreover, the greater their ratio, the smaller the ice crystals will be, since with rapid freezing, multiple ice crystals of small fractions are formed, and with slow freezing, everything happens exactly the opposite, a much smaller number of ice crystals are formed, but at the same time with a larger faction.

When storing frozen bakery products, it is necessary to maintain a regular temperature at all times. An increase in temperature will certainly lead to recrystallization, that is, the process of formation and

![Figure 1. Relationship between freezing time and temperature factor in the central part of the dough piece.](image)
growth of some crystals at the expense of others, which corresponds to an increase in large fractions due to small ones. It becomes obvious that the presence of large ice crystals is extremely undesirable. On the one hand, the increase in large ice crystals provokes an increase in internal pressure, that is, ice crystals grow in size, which necessitates the release of more space. On the other hand, the ever-increasing pressure creates such a tension that causes the appearance of gaps in the structure of baked goods. As a result of the negative influence of factors after the completion of the baking process, the finished product has insufficient volume and an unevenly porous crumb. On this basis, in order to reduce ice crystals of large fractions, it is necessary to use shock freezing for bakery products, while applying significant air circulation.

An innovative alternative to shock freezing of bakery products is the equipment of vacuum cooling systems, since air cooling is an important component of the technological process for the production of bakery products. To prevent the appearance of condensate on the packaging materials, it is imperative to ensure the removal of heat from the finished product, and the heat removal must be carried out up to temperature parameters not higher than the ambient temperature. The cooling process can be considered complete only when the temperature inside the bakery product can decrease to the temperature conditions of its storage.

In the process of baking bakery products, for their further baking at the points of sale, the use of this type of equipment provides the ability to reduce the duration of the technological process in rotary ovens by almost half (on average by 48%). Next, the trolley with hot bakery products is sent to a special chamber, where it is cooled under vacuum to +15°C for 2-4 minutes. Then the cooled bakery products are transferred to storage at a temperature not higher than +5-8°C and stored for at least 12 days. The considered technology is an alternative to the freezing process, for the reason that it allows to obtain an economic effect due to the optimal temperature storage conditions.

Significantly positive aspects from the use of vacuum cooling in the production of bakery products, which have been practically tested, are the following provisions:

- Cost savings associated with heating rotary ovens, while increasing the productivity of the bakery, can occur on average by 26%;
- Reduction of costs for air cooling of already finished bakery products against the background of a simultaneous reduction in the duration of the cooling process can be an average of 9 times;
- Improving the organoleptic and microbiological characteristics of bakery products, taking into account the increase in their shelf life while reducing technological costs and increasing the yield of the finished product;
- Reduction of energy costs for cooling, freezing, warehousing and logistic movement of bakery products

Using vacuum cooling in the production of bakery products, an increase in the volume of finished products, the uniformity of the porous structure of the dough, which will help eliminate the appearance of microcracks on the crust, were noted. At the same time, neither the taste nor the aromatic characteristics of the bakery product deteriorate. The longer shelf life of bakery products is due to the fact that during vacuum cooling there is a rapid decrease in the temperature parameter. It is known that mold fungi and other microorganisms freely develop in the temperature range of 25...65°C. With traditional cooling of bakery products, they are in this temperature environment for quite a long time with an interval of one to six hours. With vacuum cooling, the ontogeny of microorganisms is minimized and the cooked bakery products remain fresh for quite a long time. Using an innovative vacuum cooling system, a bakery solves several urgent problems, the main ones being improving the quality and increasing the shelf life of finished bakery products and real energy savings.
4. Conclusion

The quality of bakery products obtained from frozen semi-finished products is influenced by three groups of factors: gas formation, gas retention and rheological properties of the dough, namely the deformation and stress of the dough in the form of several properties: extensibility, compression, torsion, transverse force. Having information about the description of the state and behavior of the dough, both during kneading and during the entire technological process of dough preparation, one can judge the characteristics and quality of the finished bakery product. Ultimately, unresolved defects will necessarily lead to a deterioration in the quality of bakery products. The implementation of the fundamental principles of the implementation of the technological process will contribute to the output of bakery products with guaranteed high quality: strict adherence to all technological aspects at the successive stages of dough preparation, the undoubted use of a specially developed dough improver, quick freezing of bakery products using shock freezing, preventing changes in temperature conditions in the process of storing frozen bakery products, equipment for a vacuum cooling system for finished bakery products.

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