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STUDY OF THE EFFICIENCY OF USING CRYOPROTECTORS ON THE RHEOLOGY OF THE TEST

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Abstract: One of the ways to improve the efficiency of the process of long-term storage of bakery products is the use of freezing of bakery semi-finished products and / or finished products . The aim of the study was to study the efficiency of using plant raw materials in the form of cryoprotects. The efficiency of using plant additives (persimmon powder, plantain powder, pectin), which are waste or by-products of the food industry in the form of cryoprotects to improve the rheological properties of dough and finished products is shown. The article presents the results of a study of the effect of pectin-containing persimmon powder and powder plantain which contains mucus as a cryoprotectant on the rheological properties of dough and physicochemical indicators of bread quality. The obtained data allow us to recommend pectin in the technology of bread from frozen semi-finished products.

Keywords: freezing, vegetable raw materials, flour, cryoprotectant , persimmon powder, plantain powder, pectin, mucus, dough semi-finished products, bread.

Introduction. In the last decade, rapid freezing has established itself as an industrial method for long-term preservation of frozen bakery semi-finished products and finished goods in economically developed countries. Freezing is the oldest and most effective method of preserving food products.

In Uzbekistan, new technologies based on freezing of semi-finished bakery products are being intensively developed; they are most quickly used in small businesses, retail chains and the HoReCa segment (hotels, restaurants, cafes), since these technologies are more flexible compared to traditional ones, which is very convenient for small-scale enterprises.

The sale of baked goods from frozen dough is carried out mainly through hot baking points: at metro stations, near educational institutions, in hypermarkets. The use of frozen bakery semi-finished products allows to expand the range and ensure high quality of finished products, which is the main task of the bakery industry [1, 2, 6].

The adoption of such a decision is due to the modern pace of life, in connection with which consumers of bakery products have a need for semi-finished products that can be prepared without much time expenditure [3, 4 , 5].

In economically developed countries, the use of such semi-finished products is becoming more widespread, as evidenced by the works of foreign scientists A. Basaran , E. A. Elhady , Pablo D. Ribotta , SM Van der Sluis [8, 9, 10, 11, 12].

The authors Jingjie Yang et al. studied the effects of freezing rate and frozen storage duration on the rheological properties and protein structure of unfermented dough. Samples were frozen at −40 (0.149 ° C /min), −30 (0.086 ° C /min), and −20 ° C (0.039 ° C /min) and stored at −18 ° C for 30 days. Freezing at −40 and −30 ° C resulted in minimal changes in the rheological properties of unfermented dough. In addition, freezing at −40 ° C resulted in higher maximum creep compliance (J_{max}) and lower zero-shear viscosity (η_0). Macropolymer content glutenin (GMP) gradually decreased throughout the storage period, while the content of free thiol groups (-SH) increased significantly, especially for samples frozen at −20 ° C. Fourier transform infrared (FTIR) spectroscopy showed that slower freezing rate and long storage resulted in a significant decrease in the proportion α - spirals and a noticeable increase in the share β - sheets and random spirals. The gluten network was severely damaged by slower freezing rates, but was relatively intact in frozen dough samples at −40 and −30 ° C [13].

Utah Fimolsiripol et al. investigated the effects of freezing and temperature variations during frozen storage on the quality of frozen dough and bread. Storage regimes were selected and designed to simulate good or bad practices likely to occur in the cold chain (±0.1 ^{0}C , ±1 ^{0}C , ±3 ^{0}C or ±5 ^{0}C). Quality changes and dough weight loss were measured for both constant and variable frozen storage conditions. Quality was assessed as CO2 production rate , yeast viability, bread specific volume and crumb hardness compared to fresh dough. Both the freezing process and subsequent frozen storage had a significant effect on all quality parameters. Dough weight loss and crumb hardness increased with increasing storage time. The rate of CO2 production decreased with increasing storage period, however constant storage conditions (−18 ± 0.1 ^{0}C) and good temperature control (−18 ± 1 ^{0}C) did not produce a significant difference in the rate of CO2 production . v for 112 days after freezing. Large temperature fluctuations during frozen storage (−18 ± 5 ^{0}C) and storage at higher temperatures (combination of −18 ^{0}C , −13 ^{0}C and −8 ^{0}C) resulted in significantly faster loss of dough and bread quality than storage at constant and/or lower temperatures.[14]

The production of frozen semi-finished products allows you to control the safety and quality of products, quickly respond to market changes, the costs of transporting finished products are significantly reduced, it is possible to increase the network of bakeries at the points of sale, due to the possibility of using a minimum amount of equipment.

However, there are a number of reasons that prevent the rapid introduction of new progressive technology into the industry. During the freezing of dough semi-finished products, denaturation and aggregation of proteins occurs, causing the loss of functional properties, yeast cells die due to the formation of ice crystals. It should also be noted that when freezing dough, dough, dough pieces, moisture is lost. Therefore, freezing of dough, dough, dough pieces in bread and bakery technology, in production is carried out with the addition of various cryoprotects.

The use of various cryoprotects is known , for example, enzyme preparations with glucoamylase (FP-GA) and hemicellulose (FP-GC) [3], enzyme-modified lecithin "Solek-K-EML" or the use of whipped frozen semi-finished products [5, 7].

Addition of cryoprotects during freezing allows to reduce or prevent protein denaturation. The mechanism of cryoprotection by low-molecular carbohydrates is confirmed by the studies of J. Park and T. C. Lanier . They proved that addition of sugars (lactose and glucose) to an aqueous solution of proteins led to an undesirable spontaneous change - stabilization of the solution in isolation from the surface of the hydrated protein. Among the substances with the property of water-retaining capacity, pectin is of interest, which is used in the food industry in confectionery production as a gelling agent . Considering the complex of positive properties of pectin, it was decided to use it for a new purpose, as a cryoprotection in the production of frozen semi-finished bakery products. Based on the above, the purpose of the work was formulated and the tasks of the study were determined.

The aim of our research was to develop scientific and practical recommendations on the technology of bread from frozen semi-finished products by studying the patterns of change in the rheological properties of dough, biochemical processes of semi-finished products, physicochemical indicators of the quality of finished products using plant materials as a cryoprotectant.

Let us dwell in more detail on the choice of the main raw materials and technological features of production, frozen at different stages of readiness of semi-finished products.

The most important component in the production of frozen semi-finished products for a bakery is the choice of flour. The baking properties of flour used in deep-freeze technology must be higher than those of flour suitable for traditional dough making methods : dry protein content of 9-11%, deformation energy W of at least 250, P/L = 1 (elasticity to extensibility ratio according to the alveograph), water absorption of 55-60%, dough stability of at least 10 min (according to the farinograph). The enzymatic activity of flour must be low (NP ≥ 300 sec according to Hagberg). The content of damaged starch must be low. For sugar- and fat-free products, it must not exceed 8% (according to the Odiid method).

During quick freezing, as well as during storage of frozen dough products, the gluten framework experiences a negative impact of cold on its rheological characteristics.

The key issue in the technology of deep freezing of dough is the problem of survival of yeast cells during freezing, storage at sub-zero temperatures and subsequent defrosting. Dry yeast should not be used if the shelf life of frozen semi-finished bakery products exceeds 4 weeks. For the production of frozen semi-finished dough products with a shelf life of more than 2 months, it is recommended to use only pressed yeast and in an increased dosage - 8% for frozen semi-finished products with a shelf life of up to 3 months and 10% - with a shelf life of 6 months. Do not forget that for the production of frozen products it is necessary to use the freshest yeast possible (no more than 2/3 of the shelf life declared by the manufacturer), which has not had time to use up its reserve sugars during storage.

Also, when mixing the dough, you need to take into account the main tasks such as:

- obtaining cold dough +16-20 °C (+12-16 °C – when cutting on automated lines) to slow down the start of fermentation (this is important for maintaining the viability of yeast after storing frozen semi-finished dough products);

- the dough should have a slightly denser consistency for better dimensional stability during defrosting.

To ensure the above parameters, the following measures must be taken:

- use of "liquid ice", ice water, partial (up to 80%) replacement of water with ice chips (depending on the temperature of the raw material and the environment);
- if possible, use chilled raw materials (some companies store flour at low temperatures specifically for this technology, and also use specialized equipment to cool the flour before feeding it for mixing);
- air conditioning in the workshop (+16-18 °C);
- increase the duration of kneading at the second speed by 2-4 minutes relative to kneading for the direct method of making products. This is due to the fact that the optimum swelling of proteins lies in higher limits than the temperature of the dough being kneaded, and to obtain a stable result, it is necessary to improve the gas-holding capacity of the gluten framework. In addition, when using crushed ice, more time is required to bind the ingredients.

If the mixed dough has a temperature higher than recommended, and the ambient temperature is +24 ^{0}C or more, then before cutting (and especially laminating) the dough must be placed in a cooling room or even in a shock freezing chamber until it reaches +10-12 ^{0}C. In the case of working with butter, the requirements become even more stringent: in the absence of an air conditioning system in the workshop and provided that the dough is "warm", it is advisable to pre-cool it to 0+4 ^{0}C.

Fermentation as such should be absent and represent only a relaxation of the dough before final shaping.

dough should be kept in a refrigerator.

If we are talking about puff yeast products, then it is not recommended to round the pieces of dough intended for layering. On the contrary, the dough must first be rolled out to a thickness of 5-7 cm and sent for resting at +4 ^{0}C. This will allow the dough to cool evenly throughout its thickness, as well as relieve tension from the gluten framework. Often, at enterprises, in the same refrigeration chamber, the pieces of dough are rested before layering and the already layered dough is cooled. With constant opening and closing of the doors of the common refrigeration chamber, the temperature conditions are violated. In this case, the dough awaiting layering is not cooled, but continues to ferment and heat up. Therefore, it is advisable to provide separate chambers for resting the kneaded and already layered dough. It is also worth considering the required number of shelves for cooling, so that portions of dough are not "stacked" on top of each other and, as a result, their uneven cooling.

Deep freezing is the main stage in the technology of manufacturing frozen semi-finished products from puff pastry and others. For the freezing process, shock freezing chambers of various types are used - depending on the volume of production: dead-end, tunnel or spiral. It is important that all the necessary parameters are met to ensure the quality of the final product.

The presence of air circulation in the shock chamber together with the optimally low temperature ensure the necessary kinetics of freezing of the dough piece. The duration of freezing of the dough semi-finished products should ensure a temperature in the center of -8-14 ^{0}C. The process will also depend on the semi-finished product itself, its shape and size. The larger the specific surface of the workpiece, the more optimal the freezing process is (it is recommended to make loaf-shaped workpieces weighing no more than 300 g, and roll out larger pieces of dough into a layer).

The freezing speed also depends on the product recipe. The presence of sugar reduces the crystallization temperature of water, i.e. its transition from a liquid to a solid state will occur much later compared to a dough piece made from simple dough. Rapid freezing with a freezing speed of 1 ^{0}C/min is the most optimal, which is ensured by air circulation in the chamber at a speed of 4 m/sec at a temperature of -35 ^{0}C.

Due to such freezing dynamics, the loss of yeast activity and gas-holding capacity of the dough due to microdamage to the gluten by ice crystals is minimized. For the freezing process, various types of shock freezing cabinets are used: dead-end, continuous tunnel or spiral - depending on the volume of production.

When choosing a shock freezer, you need to:

- in the technical specifications, indicate not only the weight of the frozen product, but also the weight of the inventory (sheets, carts);
- to clarify the system for defrosting the chamber when the ice layer builds up (automatic, cyclic, manual) to optimize the process of manufacturing frozen dough semi-finished products.

One of the factors that negatively affects the quality of finished products is dehydration. In cold air and low humidity conditions, products tend to lose moisture.

Therefore, the quality of packaging must meet a number of requirements related to certain functions.

Packaging materials must have the following properties:

- moisture and air impermeability;
- softness (not hardness) and cold resistance;
- ease of hermetic sealing;
- puncture and stretch resistance.

The materials most often used for storing frozen semi-finished dough products include:

- OPP (oriented polypropylene): more transparent, has a glossy surface, is less permeable to oxygen, is more resistant to heating; compared to low-density polyethylene (LDPE), it has almost double the tensile strength;
- LLDPE (linear LDPE): compared to LDPE, it has higher tensile and puncture strength (perforation resistance), higher abrasion resistance, which ensures the strength of the joints. However, it is less transparent and is somewhat more expensive;
- Coextruded films. For example, EVA (ethylene vinyl acetate and LLDPE) or LLDPE and HDPE (high-density polyethylene).

Frozen semi-finished bakery products are first packed in a polyethylene bag with a heat seal or plastic tie, then in corrugated boxes . It would be ideal to provide for a combination of a shock freezing chamber with a chamber for packing and storing frozen products, so as not to interrupt the cold chain.

Storage temperature –18-20 °C. As discussed above, the dough recipe includes substances such as salt and sugar, which reduce the crystallization temperature of water, i.e. water freezes not at –3-4 °C, but at –12-14 °C. Consequently, at a temperature of -18-20 °C in refrigerated chests, product stability will be ensured (provided that the packaging is optimally selected).

The shelf life of the products will depend on the quality of the raw materials, the recipe (it is not recommended to store dough semi-finished products, the recipe of which includes butter, for more than 3 months due to its tendency to transform taste and aroma), compliance with the standards of the production process and can range from several days to several months.

During transportation, the cold chain must not be interrupted under any circumstances. Due to the fragility of the products, there is a high risk of damage to the products, so the transport packaging must ensure the safety of the products.

Defrosting must be gentle, as the phenomenon of crystal "growth" may occur, which causes damage to the membranes of yeast cells. Currently, various defrosting methods are used.

The most common is defrosting in a final proofing cabinet. From the point of view of the quality of finished products, it is considered the worst, even at a relatively low temperature in the cabinet (up to +30 °C). The surface layer of the dough piece is " over-proofed ", which negatively affects the quality of the finished products.

The most modern and optimal method of defrosting frozen dough products involves the use of programmable final drying cabinets. proofing – programmable defrosting.

The first phase of defrosting is carried out at a temperature of 0 ^{0}C. In this case, the water gradually passes from a solid state to a liquid one, and until the moment of yeast activation (uniform proofing throughout the entire volume of the product), which reduces the effect of moisture condensation on the surface of the products. During the second phase of defrosting, the temperature slowly rises from 0 ^{0}C to +20 ^{0}C and above. With this method, it is important to ensure optimal humidity in the final product cabinet. proofing.

And finally, the third method, the most correct in the absence of specialized programmable chambers, is defrosting at room temperature followed by proofing in a final proofing cabinet. This method produces fewer defects compared to the first, but it is worth remembering the risk of weathering of the dough pieces during defrosting. Therefore, the recommended duration of defrosting in the workshop is 30-40 minutes.

Rotary or convection ovens are usually used for baking. The main feature of baking is a slightly shorter duration in order to limit the rapid darkening of the blanks due to the presence of a larger amount of fermentable sugars.

For dough subject to freezing, three fundamental factors are important: gas formation, gas retention , and rheological properties of the dough, since exposure to low temperatures results in a decrease in gas formation, a decrease in gas retention capacity, and a decrease in the rheological properties of the dough [15].

To correct and maintain optimal data of the listed factors, cryoprotectors are used - substances one of the properties of which is the ability to retain moisture, such as fructose, sorbitol, and so on.

Since pectin has water-retaining, water-binding capacity, we decided to use it in the technology of bread from frozen semi-finished products, as a cryoprotection and at the same time as an improver - surfactants (surface-active substances) of anionic action [3, 4]. It is also necessary to note such important properties as complex formation and radioprotective properties, which is very important in modern conditions. In this regard, the goal of the study was determined - to develop scientific and practical recommendations on the technology of bread from frozen semi-finished products by studying the patterns of change in the rheological properties of dough, biochemical processes of semi-finished products, physicochemical indicators of the quality of finished products using pectin as a cryoprotection.

Kenyaz N.V. studied the influence of various cry protectors on the rheology of the dough using cry protectors (pectin, sorbitol, fructose) on the physical properties of the dough [15].

In the work of Gerasimov A.A. the influence of the influence of betaine on the rheological properties of dough, quality indicators of finished products and activity of yeast cells at different storage periods of frozen dough pieces produced using betaine was investigated. It was established that the use of betaine increases the height of dough rise on the 1st, 7th, 14th and 30th days of storage and increases the amount of carbon dioxide retained in the dough without reducing the total amount of carbon dioxide released during fermentation relative to the control sample over the entire storage period. The use of betaine is recommended to improve the quality of finished products in technological chains designed for storage periods of frozen semi-finished products up to 30 days [16].

To achieve the goal set in the work at the initial stage of research, the effect of pectin on the rheological properties of the dough was studied in comparison with other substances used as a cryoprotectant , such as fructose and sorbitol.

Methodology & Empirical analysis. The rheological properties of dough with the use of cry protectors were studied on a Brabender farinograph. The physical properties of dough are important in the process of kneading, cutting and baking. In the experiment on the effect of cry protectors on the physical properties of dough, options were included with the introduction of cry protectors in dosages of 0.5; 1.0; 1.5; 2.0% of the flour weight. The sample without the addition of additives served as a control. Premium wheat flour was used in the studies. Data analysis showed that the use of pectin when kneading the dough leads to an increase in the WAC (water absorption capacity) of the dough in all experimental options compared to the control. It should be noted that the addition of pectin leads to an increase in the dough kneading time. The formation time and stability of the dough increased from 8.5 min in the control to 10 min when pectin was added to the dough at a dosage of 1.5%.

Results. The velocimetric assessment in all variants with pectin was higher in comparison with the control by 8 units. When adding sorbitol and fructose in the same dosages, the rheological properties of the dough were lower in comparison with the variant where pectin was added during dough kneading by 8 and 14 units, respectively. Analysis of the results obtained on the farinograph device allowed us to conclude that the WPS in variants with the addition of pectin increases due to the ability of the carboxyl groups of pectin to retain water, which is a positive factor when freezing dough pieces. Improvement of the structural and mechanical properties of the dough is associated with the strengthening of the gluten frameworks due to the interaction of hydroxyl and free carboxyl groups with the amino groups of gluten proteins, due to conformational changes in the protein molecule, leading to a more “dense packing”, and also due to the ability of methoxylated carboxyl groups to converge in an aqueous medium, with the formation of polymer chains of pectin, which is of considerable importance in the technology of frozen semi-finished products [15].

The main indicator of flour baking properties is the "flour strength" indicator, which was determined using an alveograph . The experiment used previously accepted dosages of cry protectors. The data obtained are presented in Table 1.

Table 1. Changes in rheological parameters of the test when adding cryoprotectants

Indicator	The value of test indicators when adding cryoprotectants in dosage, %				
	Control (0)	0.5	1.0	1.5	2.0
		Pectin			
The power of flour, e.a.	227	235	245	247	258
Maximum excess pressure, mm	71	70	83	95	103
The ratio of elasticity to extensibility (P/L)	0.70	0.7	1.01	1.40	1.56
		Persimmon powder			
The power of flour, e.a.	230	234	2 4 5	2 5 5	2 66
Maximum excess pressure, mm	71	69	80	9 3	100
The ratio of elasticity to extensibility (P/L)	0.70	0.6 8	0, 9 1	0, 9 7	1 ,53
		Plantain powder			
The power of flour, e.a.	232	236	247	253	268
Maximum excess pressure, mm	71	68	89	96	103
The ratio of elasticity to extensibility (P/L)	0.70	0.69	1.02	1.42	1.54

The conducted studies on the effectiveness of using plant raw materials as cry protectors show that they are superior to currently used cry protectors, such as pectin, in terms of dough formation time and stability. In the case of adding pectin-containing persimmon powder, dough liquefaction occurred, and when using plantain powder, which contains mucous substances, 1.3 minutes later compared to pectin in dosages of 1.0; 1.5%.

The flour strength index was also higher when adding plant raw materials as a cryoprotectant compared to pectin. Improvement of dough rheology when adding pectin-containing persimmon powder during kneading occurs because pectins and sugary substances, as well as polysaccharides, including mucus in the composition of plantain powder, form a strong framework due to the convergence of hydrophobic methoxy groups in an aqueous medium, and free carboxyl groups dissociate into ions that interact with –NH3+ groups on the surface of the protein, since pectins are surface-active compounds and thus improve the structural and mechanical properties of the dough.

Conclusions. One of the most promising proposals for technologies of delayed baking from frozen dough that retains enzymatic activity is the use of processed plant materials as a cryoprotectant. As a result of the conducted studies, it was established that the use of persimmon powder and plantain powder as an ingredient that protects yeast cells from various types of stress encountered in baking technologies can be implemented as the development of new technological solutions. Fundamentally, they are considered as a potential ingredient of wide functionality for various areas of the food industry.

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