Quality of bakery products using flax seeds

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Abstract. The article presents the semi-finished product recipe for bakery products, the feature of which is the introduction of white flax seeds and wheat grains in their native form. The technology provides for the processing of plant materials in the form of whole seeds (grains) to increase nutritional value by improving the fatty-acid and amino-acid composition, as well as enriching the finished product with plant fiber and biologically active substances of plant origin. Using the principle of hydromechanical dispersion as the basis for technological processing of raw materials will allow preserving the native properties of raw materials and prolonging the expiration date of bakery products obtained on the basis of the semi-finished product, and reducing the process of moisture loss during storage. A mechanical-acoustic apparatus is used as technical and hardware equipment, which allows reducing microbial contamination and improving the safety of the semi-finished product during further storage and baking of finished bakery products. Statistical processing of organoleptic assessment data is presented taking into account weighting factors in comparison with a control sample. The energy value of the experimental samples of bakery products was calculated, indicating an increase in the calorific value of the samples with an increase in the content of white flax seeds in the recipe. A methodology for constructing a cause and effect diagram for the example of the production quality analysis of bakery products is considered. The root causes of possible risks of quality deterioration in the production of bakery products are identified.

1. Introduction
Nowadays, the production of food products requires an analysis of quality indicators and the causes of the defective product appearance. As an object of research, the technology for obtaining a semi-finished product for bakery products was determined, which is characterized by a uniform distribution of the recipe components in the form of a homogeneous mixture, while during the kneading process, the microbial contamination of the product is reduced due to mechanical-acoustic effects. Bakery products made from semi-finished products are distinguished by the crumb structure and improved organoleptic characteristics.

2. Materials and methods
A feature of the semi-finished product recipe is the introduction of white flax seeds and wheat grains in their native form. When using wheat grains and white (yellow) flax seeds in their original whole form, it will increase nutritional value [1–4] and enrich the product with plant fiber, improve fatty-acid and amino-acid composition, and also prolong the expiration date of bakery products while reducing the hardening process. The grinding of seeds and the homogeneous mixture creation of the semi-
The processing technology consists in grinding and homogenizing wheat grain and white (yellow) flax seeds in the presence of water in a mechano-acoustic apparatus with the recipe ratio shown in Figure 1.

As a result of gentle heat treatment and mechanical-acoustic effects on plant raw materials, they receive a semi-finished product for bakery products with improved organoleptic indicators when baking finished products.

At the “packing” stage, the semi-finished product is subjected to packaging in a polymer packaging approved for use for food purposes in accordance with the current regulatory documentation and is subjected to shock freezing at temperatures up to minus 18 °C for use in catering enterprises or a retail network.

The production process consists in a combination of various equipment – mechano-acoustic homogenizer, in which semi-finished product is obtained, proofing (proofer), baking (oven), packaging (packaging apparatus), so when organizing work it is important to determine the relationship of product quality indicators with all possible reasons and identify the influence of causes at all levels of the technological process, identify the most significant and carry out a level search for the root causes.

The object of analysis is the quality of bakery products obtained by baking from a semi-finished product.

The aim of the study was to assess the energy value of finished bakery products obtained from semi-finished products, its organoleptic assessment and identification of the main groups of reasons that contribute to the implementation of dangerous factors while reducing the quality of bakery product production.
Calculation of energy value was carried out by the standard calculation method: 1 g of digestible carbohydrates - 3.75 kcal or 15.7 kJ; 1 g of fat - 9.0 kcal or 37.7 kJ; 1 g of protein - 4.0 kcal or 16.7 kJ.

For organoleptic evaluation, the samples are transferred to a clean dry white plate for each taster in an amount of 20-30 g.

The tasting was carried out in the following sequence: appearance → color → texture → smell → taste (taste of a baked product). The number of points was set in the following order: 5 - full compliance with the requirements; 4 - single minor discrepancies; 3 - numerous minor discrepancies; 2 - significant discrepancies; 1 - gross discrepancies; 0 - not subject to evaluation.

Quality indicators are determined in the following sequence:

a) appearance, color - visually, by means of external examination, while the samples are laid out in a white container;

b) texture - visually, use a glass rod by pressing or rubbing the mass;

c) smell - olfactory, establish the typical odor for this category of product, evaluate the quality of individual characteristics of the smell, if provided, and also determine the presence of extraneous odors;

d) taste - tactile, after baking the product, determine the taste of the crumb at a temperature of 20 ± 3°C, determine the presence of specific characteristics, as well as extraneous flavors.

The assessment was carried out on a 5-point scale, taking into account the weight coefficient of organoleptic indicators. The weighting coefficients depending on the organoleptic indicator establish the following [5,6]:

- for appearance - k = 0.1;
- colors - k = 0.1;
- for texture - k = 0.3;
- for odor - k = 0.2;
- for taste - k = 0.3.

If there are no discrepancies during the tasting assessment (B=5), the weight coefficient is multiplied by 5. In the case of a discrepancy, the weight coefficient is multiplied by the lowest (worst) score (B_min) if there are several discrepancies. An assessment of the quality level, taking into account the weight coefficient (quality) of each organoleptic indicator in points, is calculated by the formula:

$$Q_{\text{quality}} = \sum (k \times B_{\text{min}})$$

where k is the weight coefficient of each organoleptic indicator; B - assessment of each indicator, score.

The overall assessment of the quality level was calculated as the arithmetic mean of the all taster ratings, accurate to the first decimal place. To improve the accuracy of the final result, widely differing estimates should be excluded, considering them to be misses. From the remaining number of ratings, the arithmetic mean is recalculated, which is the final scoring of the analyzed sample.

At the same time, a category of product quality has been established:

- “excellent” - from 4.1 to 5.0;
- “good” - from 3.1 to 4.0;
- “satisfactory” - from 2.1 to 3.0;
- “unsatisfactory” - from 1.0 to 2.0;
- “not appropriate (not possible to evaluate)” - less than 0.9.

Analysis of tasting data with an organoleptic assessment of the proposed point scale, taking into account weighting factors, includes ranking by quality levels: “standard” (quality category “excellent”, “good”, “satisfactory”) and “non-standard products, cannot be sold” (quality category “unsatisfactory” and “non-conforming”).

When evaluating a sample of less than 2.0 points at 50% of experts, the sample is removed from the tasting.

As a graphical representation of the analysis of the process under study, a causal diagram or Ishikawa diagram (“fish skeleton”) is chosen - a popular analytical tool, the basis of which is the
search for causes of discrepancy with the expected result, called the “Ridge” of the diagram. The diagram is built on the principle of searching for a sequence of events leading to the appearance of an undesirable result. The basis of the root cause was “bones”, which corresponded to categories of impact on the sequence of events [5-9]. The primary risk factors are selected the production processes - “control factors”, “input process parameters”, “factors affecting the process”, “output process parameters”.

The “fish skeleton” diagram was used as a tool for structured brainstorming [10].

The construction of the diagram is as follows (Figure 2):
1. We chose a problem to solve - a straight horizontal arrow ("Ridge" of the diagram), in our case it was the quality of bakery products.
2. We used the “brainstorming” method, protocols (researching of safety indicators, physico-chemical indicators, tasting assessments), while identifying the most significant factors and conditions affecting the problem (first-order reasons) - inclined large arrows - choosing a list of quality indicators (inconsistencies, defects), for which it is necessary to carry out an analysis (the “skeleton” of the diagram), while the subordination and interdependence of factors should be ensured; the identified factors were systematized and grouped into causal blocks.

![Figure 2. The sequence of actions when using the Ishikawa diagram [10].](image)

3. A set of reasons was revealed that influenced significant factors and conditions (causes of the second, third and subsequent orders) - inclined small arrows, “bones” of the diagram. Factors are distributed and schematically indicated by the degree of their significance, since not all individually identified factors must be included in the diagram, therefore, it is necessary to determine the significance of each factor on the object of analysis.

3. Research results
The study of the technical characteristics of the semi-finished product for bakery products was carried out after bringing the product to culinary readiness. The assessment included a study of energy value and organoleptic indicators.

Studies of the energy value of finished products from semi-finished products were carried out in accordance with the established methodology for calculating data and are shown in table 1.
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by stratification according to individual factors. If a noticeable difference in the spread between the production of semi-finished bakery products was carried out, a complex causal diagram is analyzed by a layered texture, a weak flavor (smell and taste). For the "color" indicator, all samples received the physicochemical, organoleptic, structural and mechanical processes - processing of raw materials on the selected equipment, to prevent additional error was within the normal range. The addition of flax seeds affects the indicators "texture", "appearance" and "taste". At the same time, an increase in flax seeds leads to a deterioration of the decrease in scores is due to reduced foaming of the mass, graininess of the texture and the acidic taste of the crumb. Rigid texture, lumpy, dense, without air bubbles, mass is caused by insufficient water in the dough, and the receipt of intermolecular bonds with starch molecules and protein fractions.

In sample No.3, the decrease in scores is due to the presence of unbound water during the formation of the bakery semi-finished product while kneading. Visually, the sample is characterized by a layered texture, a weak flavor (smell and taste). For the "color" indicator, all samples received the maximum number of scores - 5. The highest number of scores in indicators of "appearance" and "texture" was achieved by sample No.2, the texture is relatively viscous, the product is uniform in weight, homogeneous, with a pleasant flavor.

Using the Ishikawa diagram, a causal analysis of the implementation of hazardous factors in the production of semi-finished bakery products was carried out. A complex causal diagram is analyzed by stratification according to individual factors. If a noticeable difference in the spread between the "layers" is detected, measures are taken to liquidation this difference and eliminate the cause of its occurrence. For example, in the processing of plant raw materials, attention should be paid to processes - processing of raw materials on the selected equipment, to prevent additional microbiological contamination, as well as changing the technical properties of the product, primarily physicochemical, organoleptic, structural and mechanical.

When analyzing the root cause, "control factors" are second-order reasons - research methods (which should have the status of state or interstate), legislative acts (development strategy decisions, etc.), risks (related to the seasonality of the raw material supply, product requests on the market, import and export of products), processing technology of raw materials (traditional or having design features while giving products unique technical characteristics), recipes (traditional or developed with the requirements of the root causes of "market research") as shown in Figure 3.

| Sample No. | Ratio wheat grain/flax seeds | Energy value kcal | Energy value kJ |
|------------|-----------------------------|------------------|----------------|
| Control*   | 100*/0                      | 242.00           | 1011.56        |
| 1          | 50/30                       | 292.33           | 1223.38        |
| 2          | 60/20                       | 272.25           | 1139.36        |
| 3          | 70/10                       | 252.18           | 1055.34        |

Note * wheat bread; ** in the form of baking wheat flour

According to table 1, the increase in energy value is proportional to the increase in the content of flax seeds, due to the characteristics of the chemical composition of the raw materials used.

Statistical processing of organoleptic evaluation data of samples is presented in table 2.

| Name of indicator | Characterization of bakery products |
|-------------------|------------------------------------|
|                   | No. 1  | No. 2  | No. 3  | Control |
| Appearance        | 0.20±0.05 | 0.40±0.03 | 0.20±0.03 | 0.20±0.02 |
| Color             | 0.50±0.03 | 0.50±0.02 | 0.50±0.03 | 0.50±0.03 |
| Texture           | 0.60±0.14 | 1.50±0.02 | 0.60±0.15 | 0.80±0.04 |
| Odor              | 0.40±0.10 | 0.60±0.10 | 0.40±0.10 | 0.30±0.03 |
| Taste             | 0.60±0.14 | 0.90±0.15 | 0.60±0.11 | 0.60±0.05 |
| TOTAL             | 2.30±0.09 | 3.90±0.06 | 2.30±0.08 | 2.40±0.02 |

According to the results of averaged ratings, sample No.2 gained the highest score, the measurement error was within the normal range. The addition of flax seeds affects the indicators “texture”, “appearance” and “taste”. At the same time, an increase in flax seeds leads to a deterioration of indicators characterizing the samples by the formation of stickiness and crumb density both when assessing visual indicators and when chewing while determining taste (sample No.1). In sample No.1, the decrease in scores is due to reduced foaming of the mass, graininess of the texture and the acidic taste of the crumb. Rigid texture, lumpy, dense, without air bubbles, mass is caused by insufficient water in the dough, and the receipt of intermolecular bonds with starch molecules and protein fractions.

In sample No.3, the decrease in scores is due to the presence of unbound water during the formation of the bakery semi-finished product while kneading. Visually, the sample is characterized by a layered texture, a weak flavor (smell and taste). For the “color” indicator, all samples received the maximum number of scores - 5. The highest number of scores in indicators of “appearance” and “texture” was achieved by sample No.2, the texture is relatively viscous, the product is uniform in weight, homogeneous, with a pleasant flavor.

Using the Ishikawa diagram, a causal analysis of the implementation of hazardous factors in the production of semi-finished bakery products was carried out. A complex causal diagram is analyzed by stratification according to individual factors. If a noticeable difference in the spread between the "layers" is detected, measures are taken to liquidation this difference and eliminate the cause of its occurrence. For example, in the processing of plant raw materials, attention should be paid to processes - processing of raw materials on the selected equipment, to prevent additional microbiological contamination, as well as changing the technical properties of the product, primarily physicochemical, organoleptic, structural and mechanical.

When analyzing the root cause, “control factors” are second-order reasons - research methods (which should have the status of state or interstate), legislative acts (development strategy decisions, etc.), risks (related to the seasonality of the raw material supply, product requests on the market, import and export of products), processing technology of raw materials (traditional or having design features while giving products unique technical characteristics), recipes (traditional or developed with the requirements of the root causes of "market research") as shown in Figure 3.
When analyzing the root cause, the “input process parameters” include market research (including research on the competitive environment for product sales, development of logistics, as well as the development of this segment of the product on the market and its demand from consumers and manufacturers), initial technical characteristics of raw materials (chemical composition, microbiological and safety indicators).

The root causes of “factors influencing the process” include the complexity (information support and design properties) and metrological support (verification or periodic calibration) of the equipment, and there is a need of analysis the effectiveness or analysis of the defectiveness of the finished product, since it is necessary to take into account not only the technological equipment on which the product is directly produced, but also additional equipment (scales, packaging equipment, thermometers, etc.), and also includes food value, indicators of safety and chemical composition of raw materials, technological properties (these reasons indicate the influence of obtaining a high-quality finished product, changes in the processing of raw materials of the main technical characteristics under the influence of not only heat treatment, but also the presence of yeast cells and mold, organic acids of sugars, proteins, etc.).

“Output process parameters” are already presented to the finished product as the retention of properties during packaging, storage (storage conditions, temperature, humidity, illumination both in production and in the distribution network) and transportation in compliance with the requirements ensuring the quality of the product during the whole expiration date. At the same time, critical control points must be established during production and production inlet. Monitoring in determining of the critical control points is carried out to comply with the established periods - the measurement of the specified parameters, the persons responsible for maintaining records, as well as analysis to determine corrective and preventive measures. At the same time, it is possible to ensure the functioning of the control system for incoming raw materials, recipes, performers, tooling, the condition of equipment and the quality of measuring and control instruments, the technological process (production, packaging, labeling, transportation and sales), regulatory documentation.

“Human resources” in any production have high risks of defect occurrence at all stages of production, therefore, they can be included both as a component of the root cause and as a component of the root cause of “influence factors”.
4. Conclusions

An assessment of the energy value of the finished bakery products using white flax seeds was presented, an increase in the energy value was proportional to the increase in the content of flax seeds due to the chemical composition of the raw materials used. According to the results of organoleptic evaluation, sample No.2 had the highest score, the measurement error is within normal limits. The addition of flax seeds affects the indicators “texture”, “appearance” and “taste”. The main thing in the analysis of product quality is to identify the causes that contribute the emergence of hazardous factors that reduce the product quality. The result of the process depends on numerous factors, between which there are relationships of the cause-result type. The structure or nature of these multifactorial relationships can be determined through “brainstorming” methods or systematic observations.

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