Food product quality and safety control based on HACCP principles

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Abstract. The quality and safety of the resulting food product depend on many factors, including action coordination at all stages of the production process. A high level of control makes it possible to ensure it. In this sense, the HACCP system is the most suitable quality control system. The paper considers the possibility of the HACCP principles’ application to the technological process of bakery product production from wheat flour in the conditions of the Kemerovo Bread Factory. Then the authors present the possible risk analysis, identify critical points of the technological process, establish critical limits for each of the points, and define a monitoring system.

1. Introduction

In today’s context, the successful operation of an enterprise depends on many factors, but the main one is still the product safety and high quality, therefore, it is necessary to control these parameters at all stages of the product life cycle. To ensure the high quality of the product, it is necessary to apply a systematic approach, in which a set of coordinated measures is established. A large number of quality and safety systems are used at Russian enterprises: GMP - good manufacturing practice; GHP - Good Hygiene Practice; HACCP - Hazard Analysis and Critical Control Points; quality management systems according to ISO 9000 series; ISO 14000 - Environmental Management Systems; ISO 18000 - Occupational Safety and Health Management; ISO 17000 - Laboratory Certification; Safety Management System in accordance with the requirements of the international standard ISO 22000, the main component of which is the HACCP plan; PCP - Production Control Program [1, 2].

Today, HACCP (Hazard Analysis and Critical Control Points) is the most suitable quality control system for the food industry [3, 4]. This system focuses on the technological process of a specific product (product group) and considers the presence of specific risks arising in the product production chain and these risks are significant from the point of view of the external consumer safety ensuring [5, 6, 7]. The Technical Regulations of the Customs Union "On Food Safety", approved on December 9, 2011 (amended on August 8, 2019) set requirements for all food manufacturers to develop and implement procedures based on HACCP principles [3, 8].

The aim of the work was to adapt the HACCP principles in the technological process of the bakery products’ production from wheat flour in the conditions of the Kemerovo Bread Factory. To achieve this goal, the following tasks have been set: to analyze possible risks, to identify critical points of the technological process, to establish critical limits for each of the points and to define a monitoring system. According to the principles of the HACCP system, in order to ensure the high quality of the product, it is necessary to anticipate risks and eliminate the possibility of their occurrence in advance.
2. Materials and methods
The research material was the technological process of the bakery product production from wheat flour in the conditions of the Kemerovo Bread Factory. The process was studied through monitoring and analysis of registration and accounting documents and an internal audit of the quality control system.

3. Results
In order to identify the conditions that can allow potentially dangerous risks appearing, at the first stage of the research, potentially dangerous factors were identified as follows: microbiological, chemical and physical.

Thus, it was found out that the main physical potentially dangerous factors at enterprises for the production of bakery products from wheat flour can be: glass fragments, metal impurities and elements of technical equipment, small pieces of equipment (for example, nuts, screws, pieces of conveyor belt, etc.), wooden fragments and plastic, soot deposits from sheet cake pans and baking forms, various insects and their waste products. All of the above can get into the product with raw materials or through equipment and tools. In addition, sources of physical danger are packaging materials (for example, fragments of cellophane, threads, cardboard, etc.), as well as the personnel themselves if personal hygiene and sanitary requirements of production are disrupted (nails, hair, personal items such as earrings, buttons, etc.). In addition, the water used can be a source of undesirable taste and odor.

The main source of chemical hazard is also raw materials, the introduction of which can contaminate the product with toxic elements (Pb, As, Cd, Hg), mycotoxins, pesticides, allergens, radionuclides (Strontium-90, Cesium-137), insecticides and rodenticides (used to control insects and rodents). Packaging is of no small importance, as its poor quality can lead to product contamination with toxic elements and other contaminants. Lubricating oils, detergents and disinfectants can enter the product from the equipment. Food additives are chemically dangerous if the technology and production recipes are not followed, as well as products of secondary oxidation of fats resulting from the deviation of the production process from the technology.

An indicator of high microbiological contamination and the likely presence of pathogenic microflora is a high content of colony-forming units (CFU) of mesophilic-aerobic and facultative-anaerobic microorganisms (QMAFAAnM) entering the product through raw materials, the environment and packaging material. Dangerous microbiological factors include the following: the presence of bacteria of the E. coli group, yeast and mold in excess of the norm of Sanitary Rules and Regulations, as well as the presence of other regulated microorganisms in the product (Staphylococcus aureus, Proteus and Bacillus subtilis).

Then we estimated the likelihood of a hazard occurrence by using the algorithm shown in Figure 1.

The next step was the analysis of potentially dangerous factors and assessment of the consequence severity using a risk analysis diagram for each stage of the production cycle. We considered the need to take into account each of the above hazards.

Initially, the acceptance processes for raw materials and components were identified. It was found that the most likely physical hazards are: the presence of metal impurities and wood fragments in the raw material, as well as possible contamination by rodents and birds and infection with grain pests (for example, ticks or insects), in addition, there is a high probability of accidental ingestion of personal items of workers. These factors need to be prevented by implementation of incoming control of raw materials, materials, as well as personnel training. Despite the fact that the probability of chemical hazard realization is not high; all of the hazardous chemical factors (toxic elements, mycotoxins, pesticides and radionuclides) must be controlled at the stage of raw material supply. Incoming control should also be carried out to avoid the growth of unwanted micro flora. Most likely, there is the presence of bacteria of the genus Bacillus subtilis; however, there determines the presence of all microorganisms, including bacteria of the genus Salmonella, due to the severe consequences of its effect on the body.
Figure 1. Algorithm of the likelihood of a hazardous factor (the numbers indicate the severity of the consequences of the dangerous factor implementation: 1 - mild - there is a slight malaise; 2 - medium – possibility of the disease diagnose and treating within several days; 3 - severe - entails hospitalization and loss ability to work for a long time, and there is a likelihood of disability; 4 - critical - death or first-degree disability.

At the stage of raw material storage, the situation is somewhat different. There is a high probability of grain pests and waste products of birds and rodents entering the raw materials, therefore, it is necessary to monitor compliance with the requirements for production facilities. In order to avoid the formation of allergens, strict adherence to the commodity neighborhood is required. Products such as milk and its processed products, nuts, wheat, rye and oat flour, sesame seeds, eggs and egg products should be stored separately. This also needs to be taken into account. It should be noted that if the temperature and humidity storage conditions are not observed, the formation of secondary oxidation products and the multiplication of unwanted microflora are likely to appear, therefore, these factors should also be controlled.

At the stages of preparing and dosing of raw materials, the most likely manifestation may be the ingress of foreign objects into the product with the raw material, such as: elements of technological equipment, wood, paper, cardboard, cellophane and other fragments of packaging materials and personal items of workers, as well as various grain pests, rodents, birds and their waste products, metal impurities are often found. The presence of glass, although not considered a frequent occurrence, nevertheless, due to the severe consequences when it enters the body, must be controlled. In view of all of the above, the conclusion follows that it is necessary to maintain the integrity of the packages, tools and containers; the most important thing at this stage is sifting and filtering all raw materials. Chemical risks are also important, that is, the introduction of allergens with raw materials, excessive amounts of food additives, as well as various toxic chemicals, for example, insecticides, so these factors are also controlled. In
addition to all of the above, one should not forget about the possible seeding of raw materials by microorganisms.

When kneading the dough, it is necessary to control the presence of all kinds of foreign objects (glass, wooden objects, elements of technological equipment, personal items of workers and products of their vital activity, the presence of birds, rodents and their waste), as well as the growth of QMAFAnM and coliforms, which may get into a future product as a result of non-compliance with the rules of industrial sanitation and personal hygiene of personnel. It should be noted that the possibility of dough contamination with lubricating oils and disinfectants and detergents that are used for equipment treatment and sanitation must be added to the chemical hazards indicated at the previous stage of the production process.

If the personnel do not follow the rules of personal hygiene and instructions for using the equipment (no covers on the bowls or improper equipment lubrication with special materials) during the fermentation process, it is possible that rodents, birds and their waste products, as well as insecticides, detergents, lubricating oils and personal items of personnel, may enter the dough. In case of deviations from technological parameters, such as maintaining a certain temperature, fermentation duration and regulation of the dough acidity, the development of bacteria of the genus *Bacillus subtilis* is likely to happen. All of the above risk factors must be controlled.

During the molding process, all risks of physical hazardous factors of the fermentation stage remain, contamination with elements of detergents and disinfectants is also possible, biological risk factors do not need to be taken into account.

At the stage of proofing, the main preventive actions are the observance of the rules of personal hygiene of personnel and the firing of forms, sheet cake pans (to prevent soot and personal items of personnel and products of their vital activity from getting into the workpiece).

The physical factors taken into account in the process of finishing the product include: the presence of technological equipment elements, metal impurities, wood, paper, cardboard, cellophane and other fragments of packaging materials, stones, waste products of personnel and their personal items, birds, rodents, and their waste, cockroaches, impurities, pest infestation of grain stocks. Lack of incoming control of raw materials or poor-quality reception at this stage can lead to contamination with toxic elements, mycotoxins, pesticides, radionuclides, allergens and secondary oxidation products.

In the baking process, perhaps the most important preventive action is to maintain hygiene standards to prevent entering of workers’ personal items into the product. If the schedule for firing forms and sheet cake pans is not followed, there is a possibility of soot formation on them and, as a result, the latter getting into the bakery product.

At the "cooling" technological operation, it is also necessary to observe the rules of personal hygiene of personnel, control over inventory, items made of wood, in addition, untimely repair of the premises may lead to the fact that fragments of building materials get into the product.

The process of packaging and labeling is accompanied, in addition to the "dangers" indicated in the previous stages, also by the likelihood of various chemicals transfer from packaging materials to the product and as a result any allergic reactions can develop among consumers. Failure to comply with the processing of tools and equipment, personal hygiene rules for staff, poor-quality control over packaging can lead to the development of pathogenic and opportunistic microorganisms, in addition, untimely packaging (packaging in a warm form) - to contamination with bacteria of the genus *Bacillus subtilis*.

At the stage of product acceptance control, attention should be paid to the presence of fragments of building materials, personal hygiene of personnel, the presence of birds, rodents and cockroaches in production. To avoid the ingress of chemical residues from the packaging materials, only certified packaging materials must be used.

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During storage of bakery products, in addition to the hazards indicated in the previous stage, the number of microorganisms must be carefully controlled. Storage conditions must be observed. Further, critical control points were identified during the production of bakery products. According to the data obtained, it has been established that all physical potentially hazardous factors must be taken into account in the manufacture of products at all technological stages. At the stage of preparation, screening and dosing of raw materials, actions are taken to identify and eliminate the risk (to an acceptable level) of some physical hazards. The increasing risks of physical danger occur at the stages of kneading, fermentation, dough cutting and shaping, as well as packaging of the finished product.

The identification of critical points for potential chemical hazards has shown that they are largely not taken into account in the manufacture of products in such operations as dough fermentation and product cooling. During the kneading, proofing, baking and packaging phases of the finished product, the risk of chemical hazards is likely to increase. In the process of storage, preparation and dosing of raw materials, cutting and molding of the product, various chemical hazards can be detected and actions can be taken to eliminate risks to an acceptable level, which contributes to the development of a higher quality product.

Potential biological hazards should be considered at all stages of the production of bakery products, special attention from this point of view should be given to the stages of fermentation of the dough and packaging of the finished product. "Correction" of biological "dysfunction" can occur at the baking stages, and in the process of cooling the product, at the stage of storage and transportation, the risks of microbiological hazards can be identified and eliminated.

The analysis identified 15 critical control points. For each of them, critical limits are determined. The checkpoint at the stage of preparation, sieving and dosing of raw materials does not allow the presence of glass, metal impurities, wood fragments, as well as toxic chemicals such as insecticides and rodenticides. During kneading, fermentation, cutting and shaping of the dough, the absence of pathogens of parasitic diseases on the working surfaces (coliforms, \( S. aureus \), etc.) and elements of detergents is monitored. At the stage of packaging, the presence of pathogens of parasitic diseases is also not allowed and the growth of the number of coliforms is controlled, toxic elements are not allowed. At the stage of storage of raw materials, a critical control point is the determination of contamination and pest infestation of grain stocks (the established critical limit is "not allowed"). After baking, the growth of QMAFAnM should not exceed 25,000 CFU/mg. During the cooling of the product, it is not allowed to get on it with detergents and disinfectants. The development of mold fungi during storage and transportation should be no more than 50 grams.

In the course of the work, the need for monitoring was identified; for this it is necessary:
- to carry out an analysis to determine the presence of glass, metal impurities, wood fragments;
- to take samples from the surface of the container for diluting the starter culture and carrying out microbiological analysis for the presence of pathogens of parasitic diseases on the working surfaces (coliforms, \( S. aureus \) and others);
- to carry out a microbiological analysis of the container surface for diluting calcium chloride to detect coliforms and other dangerous microorganisms on the working surface;
- to carry out a microbiological analysis of the working surface for contamination and pest infestation of grain stocks;
- to carry out a chemical analysis to identify toxic chemicals (insecticides, rodenticides), toxic elements, insoluble calcium and magnesium soaps and other elements of detergents and disinfectants;
- to carry out a microbiological analysis to control the growth of QMAFAnM and coliforms, as well as the development of molds.

4. Conclusion
The identified monitoring procedures allow monitoring critical control points and providing information for the development of corrective actions.

Thus, a program of mandatory preventive measures was developed and work was carried out to implement the principles of HACCP in the production of bakery products from wheat flour in the
conditions of the Kemerovo Bread Factory. Potentially dangerous factors were identified and an analysis of the likelihood of these factors was carried out. Preventive actions have been developed for each factor threatening the safety of manufactured products; established critical control points and defined critical limits for each of them. A monitoring system for critical control points has been developed.

The research results were tested at the Kemerovo Bread Factory. It has been proven that a control system based on the HACCP principles helps to reduce manufacturing defects, improve the quality and safety of products and, consequently, increase the degree of consumer confidence in them. Fulfillment of the above procedures at a food enterprise allows increasing the competitiveness of products and expanding sales markets.

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