Quality and safety monitoring production of boiled-smoked sausages

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Abstract. The main task of a food production enterprise is to obtain high quality, safe and competitive products. One of the effective ways to create guarantees for the production of high-quality and safe products is the development and implementation of a monitoring system for control points of technological processes of a food enterprise. The analysis of the technological process for the production of cooked-smoked sausages showed that the main controlled parameters of the process at various stages are air temperature and humidity. To monitor the technological process of the production of boiled-smoked sausages, a summary table has been compiled, which indicates the controlled parameters and their limit values. Considering that such a parameter as temperature has a tolerance of control boundaries of ±1 °C, the question arises about the accuracy of the measuring instruments used for control. An analysis of the means of control was carried out, and it was revealed that the measurement error should be within the range of no more than ±0.3 °C, and taking into account the aging of the measuring instrument, even less. To assess the compliance with the requirements for metrological assurance of control points, it is proposed to find a correspondence between the assigned limits and the ability of real measuring instruments to carry out reliable control. For the case of detecting inconsistencies in the quality management system of the process, the form of the matrix for the distribution of responsibilities and powers of personnel to perform corrective actions has been developed.

1. Introduction

The activity of food enterprises in modern conditions is based on a process approach to quality management [1]. The quality management system, acting in accordance with the requirements of the international standards of the ISO 9000 series [2], forms the requirements for quality [3].

Monitoring processes are a mandatory procedure for any management system, including a system based on the requirements of the ISO 9000 series. It is necessary to plan and organize the collection of these parameters at the checkpoints. The information received is subject to processing, after processing, the need for preventive action is assessed. When planning and organizing, it is necessary to define not only a set of procedures and processes, but also the appropriate resources for monitoring checkpoints. For the timely detection of critical limits of control values, the frequency of observations and measurements should be established and appropriate preventive or corrective actions (process adjustments) to be carried out. The monitoring frequency should be free from unacceptable risk violations of the quality and safety of the process.
An important stage in the development and implementation of a monitoring system is the determination of the limits of controlled parameters at control points and the choice of measuring instruments. The choice of measuring instruments for quality control is a rather complex technical problem requiring optimization, the solution of which depends on the tolerance of the controlled parameter and possible losses associated with the presence of a measurement error [4]. This is reflected in the structure of quality costs [5], especially in internal losses. Sometimes the tolerances assigned by the technologist are impracticable for quality control using standard and unified, that is, cheap measuring instruments that are saturated with technological equipment. Sometimes the tolerances assigned by the technologist are impracticable for quality control using standard and unified ones, i.e. cheap measuring instruments with which technological equipment is saturated. It is not clear how technologists justify such strict tolerance limits for a parameter, for example, for a drying temperature set as (11 ± 1) °C, it can be quite rational to assign (11 ± 2) °C. Beyond these seemingly unimportant limits, there are significant costs, in this case - the question of which resistance thermometer we will use – platinum or copper.

2. General methodology
One of the most difficult in food production from the point of view is the production of sausages [6]. At the initial stage of the study, an analysis of the technological process of cooked-smoked sausages [7], checked control points was carried out. The main prescriptions at all stages of the technological process for the production of cooked-smoked sausages are temperature and humidity [8]. Quality control of the technological process is carried out by employees of the quality service in accordance with the control scheme of the approved control points [9]. In this case, the dangerous factors are the violation of the quality of products, the environment, due to which the fact that these parameters go beyond the permissible limits leads to a deterioration in the quality of the technological process, and as a consequence - to a decrease in the quality of the finished product [10]. The appearance of significant external losses is possible. It also raises the issue of product safety, which has a deviation in the production process [11].

The object of the research is the process of production of cooked-smoked sausages from the point of view of ensuring quality and safety.

The subject of the research is quality control and safety of the production process of cooked-smoked sausages.

The purpose of the study is to identify control points of the production process, metrological analysis of the quality of control and the organization of preventive and corrective measures at each point.

Based on this goal, the research objectives:

- determination of control points of the technological process of the production of cooked-smoked sausages;
- development of corrective measures to ensure the quality and safety of products;
- development of recommendations for the organization and distribution of responsibility for corrective actions;
- development of recommendations for metrological support of critical control points.

3. Research results
Analysis of the production process of cooked-smoked sausages made it possible to identify control points. For each control point, the nominal values of the controlled parameters and their deviations are determined, which are taken from the technological maps. The information received is presented in summary table 1.
Table 1. Control points of the system for monitoring the technological process of the production of cooked-smoked sausages.

| Operation name                          | Number CP | Controlled parameter                        | Standard value          | Corrective act                                                                                     |
|----------------------------------------|-----------|---------------------------------------------|-------------------------|---------------------------------------------------------------------------------------------------|
| Preparation of raw materials           | CP 1      | Temperature in the thickness of raw meat:   | (2 ± 2) °C             | Accumulation of information on the actual causes of nonconformity, isolation of nonconforming raw materials |
|                                        |           | chilled                                      | (0 ± 1) °C             |                                                                                                   |
|                                        |           | defrosted                                    | (0 ± 1) °C             |                                                                                                   |
| Defrosting raw materials               | CP 2      | Room temperature                            | (20 ± 2) °C            | Arrangement and adjustment of cooling equipment                                                   |
|                                        |           | Relative humidity                            | (80–85) %              |                                                                                                   |
|                                        |           | Raw material temperature before boning       | < 10 °C                 |                                                                                                   |
| Cutting, deboning                      | CP 3      | Raw material temperature after trimming      | < 15 °C                 | Arrangement and adjustment of cooling equipment                                                   |
|                                        |           | Room temperature                            | (10–12) °C             |                                                                                                   |
|                                        |           | Relative humidity                            | (70–75) %              |                                                                                                   |
| Grinding, salting, minced meat and    | CP 4      | Temperature in the salting chamber           | (0–4) °C               | Development of a project for the installation of equipment that provides standard technological modes |
| filling in casings                     |           | Relative humidity                            | (80–85) %              |                                                                                                   |
|                                        |           | Minced meat temperature                      | (-2 ± 1) °C            |                                                                                                   |
|                                        |           | Relative humidity                            | (75–78) %              |                                                                                                   |
| Preparing for heat treatment           | CP 5      | Room temperature during molding              | (10–12) °C             | Arrangement and adjustment of cooling equipment                                                   |
|                                        |           | Room temperature during precipitation        | (6 ± 2) °C             |                                                                                                   |
|                                        |           | Raw material temperature at sediment:        |                         |                                                                                                   |
|                                        |           | 1 way                                        | (6 ± 2) °C             |                                                                                                   |
|                                        |           | 2 way                                        | (3 ± 1) °C             |                                                                                                   |
| Heat treatment (1 and 2 ways)          | CP 6      | Primary smoking temperature                   | (75 ± 5) °C            | Development of a project for the installation of equipment that provides standard thermal conditions, conduct repeated training with operators |
|                                        |           | Cooking temperature                           | (74 ± 1) °C            |                                                                                                   |
|                                        |           | Cooling temperature                           | < 20 °C                 |                                                                                                   |
|                                        |           | Secondary smoking temperature                | (42 ± 3) °C            |                                                                                                   |
| Drying                                 | CP 7      | Drying temperature                           | (11 ± 1) °C            | Arrangement and adjustment of cooling equipment                                                   |
|                                        |           | Relative humidity                            | (76 ± 2) %             |                                                                                                   |
| Storage                                | CP 8      | Room temperature                             | (12–15) °C             | Development of a project for the installation of equipment that provides standard thermal conditions |

Typical corrective actions have been developed, presented in the last column of table 1, which will make it possible to promptly and clearly respond to deviations in the parameters of raw materials during the production process, as well as to guarantee not only the safety of products in case of exceeding the
limit values of the controlled parameters, but also to ensure consumer properties - color, taste, smell, etc.

From the point of view of metrological assurance of control, such a parameter as temperature in this technological process has rather strict limits, for example, the temperature of the defrosted raw material should be \( t = (0 \pm 1) \degree C \). The tolerance of the controlled parameter is \( T = 2 \degree C \).

The classical condition for choosing measuring instruments is as follows [12]:

\[
\pm \Delta \text{lim} \leq \pm \delta,
\]

(1)

where \( \pm \text{lim} \) is the maximum error of the measuring instrument; \( \delta \) - permissible error of measurements.

It is necessary to designate such instruments for measuring technological parameters that would ensure the specified accuracy of tolerance control. The permissible measurement error \( \pm \delta \) from a metrological point of view should have a relation with the tolerance \( T \) in the form \( \pm \delta = \pm (0.1 \ldots 0.3) T \). For our example, \( \pm \delta = \pm (0.2 \ldots 0.6) \degree C \). Thus, the temperature measuring instrument must have a maximum error of no more than \( \pm \Delta \text{lim} \leq \pm 0.6 \degree C \). The limiting error of the measuring instrument includes the main and additional errors. The error described in the instrument passport is the basic error of the measuring instrument, which is determined for ideal measurement conditions. An additional error arises from the influence of influencing physical quantities – temperature, humidity, pressure, magnetic and electric fields, contamination of the working area, fluctuations in the voltage of the power source, etc. A priori, it is assumed that the additional error is equal to the main one, but it can be greater. Then the instrument for measuring the temperature in the thickness of the defrosted meat raw materials must have a measurement error of \( \pm \Delta \leq \pm 0.3 \degree C \). Otherwise, technological losses in product quality will begin due to incorrect acceptance or rejection of products. This condition will be satisfied by rather expensive and accurate means of measuring temperature of class A and AA, table 2. It is not recommended to take Class B due to the lack of a margin for the aging process – a natural increase in the error of the measuring instrument due to the oxidation of the material of the sensitive element. For the same reason, the use of a copper sensor is not recommended. Although it will cost less than platinum, copper will age faster and therefore will increase the cost of frequent calibration. For these reasons, the life of the copper sensor is much shorter. There is another component of the issue – the longer the stable readings of the device remain, the less it will harm production in the form of correctly rejected and incorrectly accepted products. To confirm the suitability of the selected means and methods of measurement, special techniques can be used [13], [14].

| Class admission | Tolerance (limit error), \( {^\circ}C \) | Measuring range, \( {^\circ}C \) |
|-----------------|------------------------------------------|---------------------------------|
|                 | Platinum thermal resistance, sensing element | Copper thermal resistance, sensing element | Nickel thermal resistance, sensing element |
|                 | wire | film | element | wire | film | element | wire | film | element |
| AA W 0.1        | ±(0.1±0.0017|\( t \)|) | From –50 to +250 | From –50 to +250 | – | – |
| F 0.1           | –   | –    | –       | –   | –    | –       |
| A W 0.15        | ±(0.15±0.002|\( t \)|) | From –100 to +450 | From –50 to +450 | From –50 to +120 | – |
| F 0.15          | –   | –    | –       | –   | –    | –       |
| B W 0.3         | ±(0.3±0.005|\( t \)|) | From –196 to +660 | From –50 to +600 | From –50 to +200 | – |
| F 0.3           | –   | –    | –       | –   | –    | –       |
| C W 0.6         | ±(0.6±0.01|\( t \)|) | From –196 to +660 | From –50 to +600 | From –180 to +200 | From –160 to +180 |
| F 0.6           | –   | –    | –       | –   | –    | –       |

\( |\( t \)| \) – absolute value of the controlled temperature, \( {^\circ}C \), without taking into account the sign.
On the other hand, technologists need to correctly assign the tolerances themselves, maybe here such accuracy of measurements would not be required, and it would not be necessary to use platinum resistance thermometers, the cost and verification of which are more expensive than copper ones.

For the implementation of corrective actions, persons who are responsible for the implementation of the necessary actions should be appointed. The consolidation of such responsibility of personnel in accordance with ISO 9000 series is carried out in the form of a matrix of distribution of responsibility and authority. The form of the matrix for the distribution of responsibility and authority of personnel for the implementation of corrective actions is developed and presented in table. 3. The duties of each official and responsibility are clearly stated here in order to quickly respond to non-compliance of products with established requirements when implementing control.

Table 3. Matrix of distribution of responsibility and authority corrective action personnel.

| Name of the implemented process                                      | Leader enterprise | Head Quality Services | Chief Technologist | Chief Engineer | Chief production | Chief Metrologist |
|---------------------------------------------------------------------|-------------------|-----------------------|--------------------|----------------|-----------------|------------------|
| Accumulation of information on the actual reasons for nonconformity, analysis of nonconforming raw materials | M                 | R                     | P                  | D             | C               | P                |
| Arrangement and adjustment of cooling and technological equipment   | M                 | Д                     | С                  | R             | P               | P                |
| Isolation of inappropriate raw materials and a conclusion on its further use | M                 | R                     | P                  | D             | С               | P                |
| Development of a project for the installation of equipment that provides standard thermal conditions | M                 | R                     | P                  | D             | С               | P                |
| Retraining with operators                                           | M                 | Д                     | С                  | Р             | С               | Р                |
| Metrological support of control operations in CP                    | М                 | Д                     | С                  | Р             | P               | Р                |

*M - management of the work of departments, officials in the process; R - responsible executor of work on the process; С - coexecutor, participation in the implementation of documented procedures; P - providing information on the process; D - development of documented procedures, organization of interaction between departments in the development and updating of procedures for an element.*

4. Conclusions
To build a quality and safety monitoring system, an analysis of the technological process for the production of cooked-smoked sausages was carried out. As a result of the analysis, there are nine control points for each stage of the technological process. For the identified control points, the limit values of the controlled parameters. Corrective actions have been developed if the controlled parameter is outside the tolerance range.

In order to develop a monitoring system, a summary table has been compiled, which indicates the controlled parameters and their limit values. The use of the developed table will increase the level of quality and safety in the production of cooked-smoked sausages.

For the organization of work on monitoring the production process of cooked-smoked sausages, the matrix of distribution of responsibility and authority.
It is recommended to choose the right measuring instruments in order to ensure the reliability of control and reduce the influence of measurement errors on the result. The results obtained can be used for further work on the determination of critical control points and the creation of HACCP worksheet.

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