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THE SUBSTANTIATION OF THE HEAT TREATMENT MODES OF THE COOKED SAUSAGE IN THE UNIVERSAL SMOKING-COOKING CHAMBER

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Abstract: *Heat treatment of sausages is one of the main stages of their complex and long production. The finished product quality, including its microbiological purity, directly depends on the conditions and regimes of its conduct. To ensure the quality sausages production with economical energy resources consumption, it is important to determine the operating modes of the smoking-cooking chambers taking into account the sausages geometric dimensions and the minced meat thermophysical properties.*

In the software FlowVision, the problem of conjugate heat exchange was solved, in which the heat transfer by convection (from a heated vapor-air medium to a sausage product) and heat conductivity (in the middle of a sausage) were considered. The process of heat treatment in a smoking-cooking chamber has been studied separately for the roasting and cooking stages (for roasting the temperatures of the vapor-air medium were considered to be 90 ... 110 °C, for cooking they were 75 ... 85 °C).

The temperature values in the center of the sausage product determine the culinary readiness and microbiological purity of the product. For cooked sausage with a diameter of 85 mm it is recommended to keep the temperature of the vapor-air medium at the roasting stage at 100 °C, which provides the required productivity at average energy costs. Cooking is recommended at the maximum of the temperatures which were considered – 85 °C, since a lower temperature significantly increases the duration of the process, as the driving force of the process becomes insignificant.

Keywords: *Cooked sausage, Heat treatment, Temperature, Roasting, Cooking.*

INTRODUCTION

Sausage products have a steadily high demand from consumers and each year they are becoming more and more important in the diet of the population. One of the main operations of their long and complex production is thermal treatment. The specificity of the heat treatment processes of sausages is that under the influence of heat, most of the vegetative forms of microorganisms are destroyed, enzymes are inactivated, a significant amount of moisture is removed from the product, the proteins denature and coagulate, the collagen of the connective tissue passes into gluten (Tornberg, E., 2005). When heat treatment takes place, the colour and smell of sausages are formed.

The heat treatment of sausages can consist in the following stages: preliminary drying, roasting, cooking, cooling, smoking, baking and drying. The need for this or that stage depends on the type of products that are manufactured.

The heat treatment of sausages is carried out by many ways: immersion in the liquid, irrigation, steam treatment, steam and water or vapor-air mediums, gas combustion products, electric heating, infrared radiation, ultrasound. However, the most practical application the method of heat treatment of sausages by steam or smoke air mixtures in universal smoking-cooking chambers obtained because of its relative simplicity, accessibility and efficiency.

The sequence, the specific processing modes and the medium composition are determined by the technology of the particular product. Smoking-cooking chambers are one of the types of equipment that consumes the most energy resources in the meat processing industry. There are many scientific publications that are devoted to the problems which are concerned with the organization of heat treatment of sausages, its influence on the quality and output of finished products, energy efficiency (Pavelko, V.I., Sokolenko, A.I., & Zaslavskyi, A.I. 2012; Soletska, D., 2014; Bondarenko, N.V., 2013; Bakalis, S., Cox P.W., & Fryer, P.J., 2001). To ensure the production of high quality sausages, it is important to co-ordinate their characteristics (geometric sizes and thermophysical properties of minced meat) with the operating modes of equipment. Especially relevant this problem is when cooked sausages of large diameter are produced, because it is necessary that heat treatment is occurred throughout the volume of the product, and the temperature in the center of the sausage reached the required values (68 – 72 °C) with the least possible energy costs. Even a small changing in temperature during the roasting and cooking of sausages significantly affect the output of finished products, its organoleptic and microbiological parameters.

EXPOSITION

The purpose of the article is substantiation of the ways of increasing the efficiency of heat treatment of cooked sausage in an universal smoking-cooking chamber, by determine the most appropriate modes of its work.

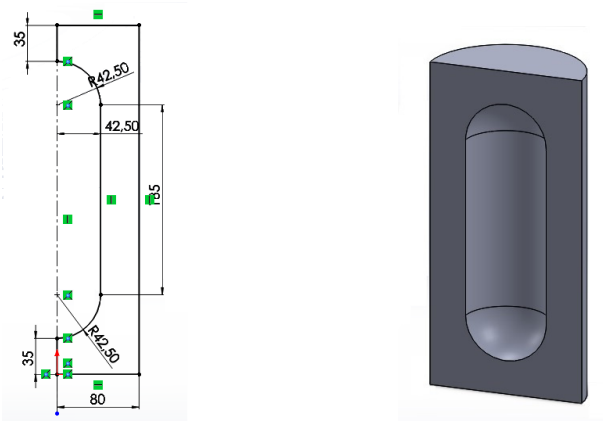
The object of research is the process of heat treatment of cooked high quality sausage in an universal smoking-cooking chamber. The subject of research is the modes of heat treatment by a steam-air mixture of sausage products with a diameter of 85 mm.

The heat treatment of cooked sausages is carried out in three stages: preliminary drying, roasting and cooking. For each stage, the various parameters of the working medium are characteristic. The task of heating the sausage was solved: the stages of roasting and cooking were considered, and the results of the completion of the roasting stage were the initial data for the study of the cooking stage.

Most often in the enterprises the modes of heat treatment are determined experimentally for a particular type of sausage products. However, performing the physical experiments it is enough complicated and costly method, therefore, in the work for analysis of the process of sausage heat treatment, computer simulation was performed in the FlowVision software system. The geometric model of the product and the medium surrounding it (Fig. 1) was created by the software SolidWorks.

The problem of conjugate heat exchange was solved, in which the heat transfer by convection (from a heated vapor-air medium to a sausage product) and heat conductivity (in the middle of a loaf) were considered.

In the subregion, where the steam-airflow around the sausages takes place, the model "Nonstick liquid" is chosen and the problem of the turbulent flow of the steam-air mixture is solved. In the Subregion of the sausage product the Solid-State model is chosen, the problem of heat transfer in the solid phase is solved.



а б

Fig. 1. The geometric model of the product and the medium surrounding it:
а – sketch; б – 3D model

The minced meat properties (density, specific heat and coefficient of thermal conductivity) of cooked sausage significantly depend on temperature. In order to take them into account during the simulation, the database of the FlowVision software system was complemented. In it the stuff "Minced meat" with the corresponding characteristics is supplemented.

To solve the problem of conjugate heat exchange between the working medium and the sausage, the boundary conditions are given (Fig. 2):

the boundary 1 – the input of the working medium at a normal speed υ=2 m/s and the corresponding temperature ("Input / Output" → "Normal input / output" → "Speed");

the boundary 2 – the symmetry ("Symmetry" → "Wall with a slip");

the boundary 3 – the conjugate («Conjugate» → «Speed» → «Wall, logarithmic law»);

the boundary 4 – the free output ("Free Outlet" → "Zero Pressure / Output").

After specifying boundary conditions, the boundary conditions of the "Conjugate" of the two subregions were bound.

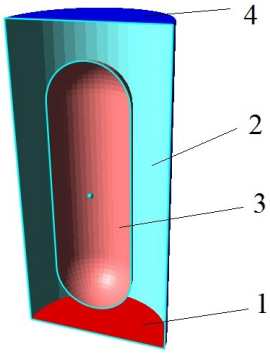


Fig. 2. The boundary conditions of the conjugate heat exchange between the working medium and sausage

The parameter that was varied during the simulation is the temperature of the working medium. It varied for the roasting process from 90 to 110 °C at an interval of 5 ° C, for the cooking stage – from 75 to 85 ° C at an interval of 2.5 °C (carried out on 5 computing experiments).

At the boundary condition 3, to increase the calculation accuracy, the calculated grid was thickened, for which adaptation was made on this boundary condition with the adaptation level 1. After the adaptation, the calculated grid has 25852 cells.

The solving of conjugate heat transfer problems, in which the flow of a liquid or gas and thermal conductivity in a solid body is simultaneously considered, encounters certain difficulties - the typical duration of processes in a gas (liquid) is significantly less than the characteristic duration of their in a solid. This leads to the fact that such problems have to be solved with a minimal integration step by time, which in turn determines a very long calculation time.

In the work, the own integration step by time was introduced in the subregion of a solid, it is equal to 2 seconds. In the subregion of the working medium, where the "Non-Dispersible Liquid" model is selected, a fixed step is given according to the time, based on the flight time, which is taken to be 0,017 seconds.

To visualize the results, 10 points were given in the cross section of the sausage from the center to the edge, in which the temperature values were recorded.

As a result of heat treatment, it is necessary to ensure the culinary readiness and guarantee the microbiological safety of the product. It is therefore important to reach the desired temperature in the center of the sausage, the magnitude of which is influenced by the treatment duration and the temperature of the working medium in the stages of roasting and cooking (Fig. 3 and Fig. 4, respectively).

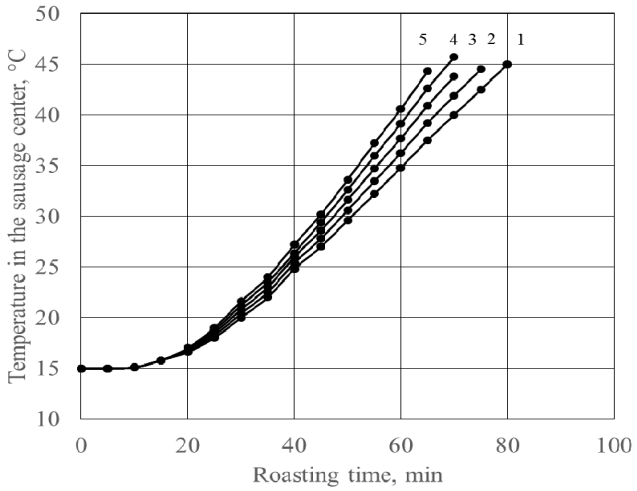


Fig. 3. Variation of temperature with time in the center of the sausage during the roasting process at working medium temperatures, °C:
1 – 90; 2 – 95; 3 – 100; 4 – 105; 5 – 110

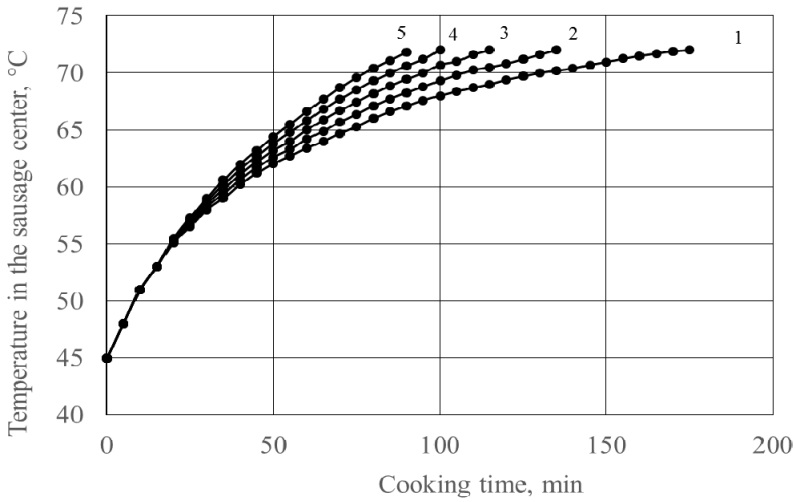


Fig. 4. Variation of temperature with time in the center of the sausage during the cooking process at working medium temperatures, °C:
1 – 75,0; 2 – 77,5; 3 – 80,0; 4 – 82,5; 5 – 85,0

It has been found that the increase of the working medium temperature from 90 to 110 ° C does not significantly affect the time during which the required temperature in the center of the product during the roasting is reached - 45 ° C. The stage of roasting in these conditions lasts from 67 to 81 minutes.

Instead, at the cooking stage (see Fig. 4), the change of the working medium temperature by 10 ° C – from 75 to 85 ° C – significantly affects the duration of the process, which ends when the temperature in the sausage center reaches the value of 72 ° C.

The difference for these two boundary values of temperatures is 83 minutes - from 91 minutes for a temperature of 85 ° C to 174 minutes for a temperature of the working medium of 75 ° C.

The temperature in the cross section of the sausage is significantly different for the peripheral and central areas at the end of the roasting processes (Fig. 5) and cooking (Fig. 6). Here the coordinate 0 m corresponds to the outer surface of the sausage; 0,0425 m is the center of the product.

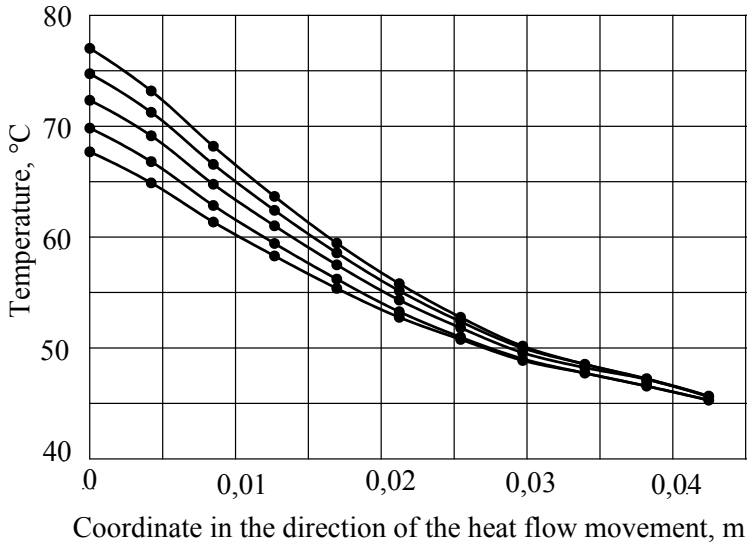


Fig. 5. Temperature distribution in the sausage cross section in the direction of the temperature front movement at the end of the roasting process
at working medium temperatures, °C: 1 – 90; 2 – 95; 3 – 100; 4 – 105; 5 – 110

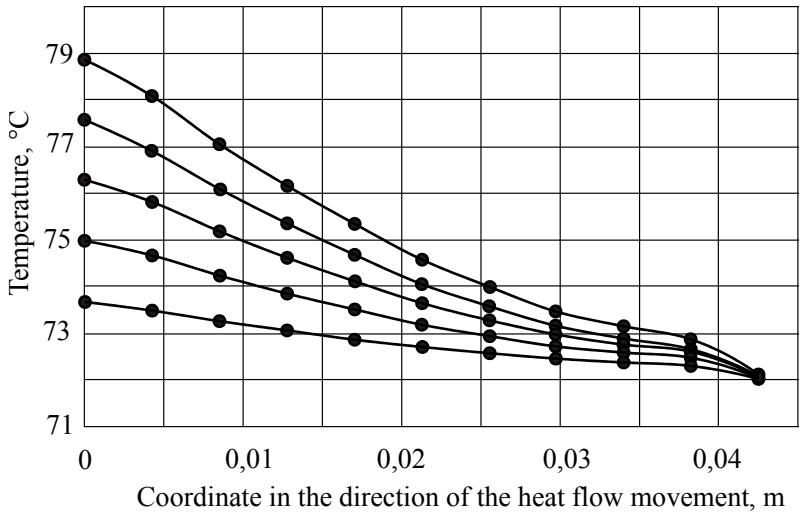


Fig. 6. Temperature distribution in the sausage cross section in the direction of the temperature front movement at the end of the cooking process
at working medium temperatures, °C: 1 – 75,0; 2 – 77,5; 3 – 80,0; 4 – 82,5; 5 – 85,0

The recommended values of the temperature of the working medium in the process of heat treatment of cooked sausage "Driskaya" at the stage of roasting is 100 ° C, as it provides the necessary heating time for relatively lower energy costs.

Increasing the temperature of the working medium from 75 to 85 ° C in the cooking stage will increase the heat loss to the environment by 17%. But the total heat consumption, if a longer process occurs at a cooking temperature of 75 ° C, will be by 89% higher. Therefore, taking into account the ratio of losses to the environment and the costs of heating the working medium, chamber and product, it is more appropriate to cooking at a temperature of the working medium of 85 ° C. Using a working medium whose temperature is lower than the specified value significantly increases the duration of the process, as the driving force of the process becomes insignificant.

CONCLUSION

As a result of heat treatment of cooked sausage it is necessary to achieve a pasteurization temperature of 72 °C in the center of the sausage to destroy vegetative forms of microorganisms and achieve culinary readiness.

The rational temperature of the working medium in the process of heat treatment of cooked sausage in the roasting stage is 100 ° C. It is recommended to cook the sausage at a temperature of 85 ° C, as the treatment at lower temperatures significantly increases the duration of the process, making the process driving force insignificant. The duration of the heat treatment, which consists of the roasting and cooking stages, for the proposed modes is 164 minutes.

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