Determination of the factor space of the process of extrusion of sausage products

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Abstract

Introduction. The analytical researches were conducted for the purpose of scientific substantiation of the main factors and to determine the factor space of the process of sausage stuffing extrusion.

Materials and methods. Methods of research: theoretical – studying and generalization of a priori information on the conditions for the extrusion of sausages; qualimetric. An additive mathematical model as most widespread in a qualimetry is used for joining the quality rating into the generalized (complex) index.

Results and discussion. One of the main processes in the formation of sausage products, which guarantees the receipt of high-quality products is the filling (extrusion) of the shell by sausage mince.

The main factors of the process of sausage mince extrusion are ascertained: pressure of extrusion; mince temperature; vacuum evacuation. It is determined that the amount of pressure of extrusion depends on the type of membrane, type of product, its composition, physical-mechanical and rheological properties, which is 0,30–2,00 MPa. The minced meat temperature affects the stability of the emulsion, therefore, when extruded in the sausage shell should be in the range from +8 to +18 ºC. Vacuuming has a positive effect on: reducing the volume of air void; color; texture; maturation of the product; the terms of its storage; reduction of oxidative processes in adipose tissue, as well as bacterial insemination; improvement of the rheological characteristics of the product; water-holding capacity (WHC); improving the density of the long loaf. The evacuation measure for individual types of mince is individual and can have pressure up to –0,09 MPa.

The coefficient of regression and the value of confidence interval are calculated Δb_i=0,004 (α=0,2; f=8). The coefficients of regression are checked for significance with a confidence intervals: b_0=0,654>±0,004; b_1=0,041>±0,004; b_2=0,06>±0,004; b_3=-0,021>±0,004l; b_{12}=-0,008>±0,004, b_{13}=0,006>±0,004, b_{23}=0,018>±0,004, b_{123}=-0,051>±0,004. It has been established that all variables influence the complex quality index statistically significant.

Conclusion. Generalization of literary facts has been carried out, which allows to establish the main factors in the process of extruding sausage mince, which depend on the type of shell, the type of product, its composition, physical-mechanical and rheological properties. In order to increase the complex quality index, it is necessary: to increase the pressure of product (x_1) to 2,25 МПа; maximize residual pressure (x_2) to –0,8 МПа; reduce the temperature to (x_3) to 275 K.

Introduction

Today, the Ukrainian meat and sausage products market is experiencing both negative and positive changes. According to the technical report, among to the negative one can be distinguished: depressed state of the meat market; large-scale using of cheap imported raw materials as an alternative to more expensive domestic; increase in energy prices and the main components of the sausage production; constant fluctuation (increase) prices of finished products; reduction of qualitative and taste indicators in pursuit of a mass consumer with low solvency; monopolization of the market – crowding out of the network of small and medium-sized producers; the export of domestic sausage products remains in perspective.

The positive changes concern with: renovation of production facilities; the desire of produce in the manufacturing of competitive products from high quality raw materials; the activation of brand products and the expansion of assortment presence in the middle and low-end segments; an increase in the volume of production of fine-packed products, as well as smoked and dried sausages in branded packaging; the introduction of new national standards for meat and meat products that allow the release of new names of sausage products.

All these positive/negative trends strongly affect the industry. For producing of high-quality products manufacture should use all possible measures(Kuzmin O. et al, 2016, 2017; Pasichnyi V.M. et al, 2015) [21, 18, 19, 20]. One of such measures is to improve the quality of the production of the most widespread group of sausage products – boiled sausages, which, due to its range and high taste and consumer properties has high demand among the population. The consumption of boiled sausages, sausages and small sausages in the total amount is almost 60%, while semi-smoked and boiled-smoked sausages, respectively, 30 and 10 %.

Materials and methods

Methods of research: theoretical – studying and generalization of a priori information on the conditions for the extrusion of sausages; qualimetric. An additive mathematical model as most widespread in a qualimetry is used for joining the quality rating into the generalized (complex) index.

Results and discussions

The group of sausages includes meat products made from sausage mince in the shell, or without it, subjected to heat treatment or fermentation and ready to be consumed.

General classification of sausages:

– by type of meat: beef; pork; horses; from poultry meat etc.;

– on the composition of raw materials: meat; by-product; bloody;

– in the form of a shell: in natural; artificial; without shell;

– on the pattern minced meat in the cut: with a homogeneous structure; with the inclusion of tongue or shredded meat;

– by appointment: for general use; delicacies; for dietary, for baby food.

– according to the production technology: boiled; semi-smoked; smoked (boiled, smoked and dried); stuffed; sausages and small sausages; liver sausages; blood sausages; meat loaves; paste; gulls and studs.

By food value, sausage products have no equivalent, because the variety of recipes include foods of different nutritional values: protein content – 10 to 30 %, fat content – 10

to 50 %, moisture content – from 20 % (smoked and dried) to 80 % (gipsies). Therefore, the energy value of these products varies from 800 kJ in boiled sausages to 2400 kJ in smoked.

The group of boiled items includes: boiled sausages; sausages; small sausages; meat loaves. A distinctive feature of the production of this group is the careful grinding of raw materials, which, as a result, acquires certain properties: it actively binds water and fat; forms a secondary structure; exhibits stickiness and viscosity. In turn, all these properties depend on the quality of raw materials and technological aspects (the method of salting, the level and type of mince, the temperature of mince, parameters of extrusion, precipitation, heat treatment, etc.).

The process of making sausage products includes the following main operations: collapse – separation of meat from bones; venation – branch of veins, cartilage, blood vessels; cutting the prepared meat on the weight pieces; salinization in metal containers and endurance in brine; grinding on a wolf or a whistler; stuffing and mixing in a stuffing mixer; formation of the sausage at the following stages: preparation of sausage shell; serving sausage stuffing for filling; minced shell extrusion; distortion of the loaves; clipping; shaving; a pile of sausage loaves on a stick and a frame. Further sedimentation and compaction of mince; roasting, cooking, smoking in thermocouples; cooling and delivery of the finished product to the warehouse (Huazi Wang et al, 2017; Yi-Chen Lee et al, 2012) [1, 2].

One of the processes that guarantees the receipt of high-quality products is the process of forming sausage products, which includes (table 1): preparation of the shell; handing of the mince; dosage and filling (extruding) of the shell by mince; distortion of loaves, bundles, clipping, shaving; A swath of sausage loaves on a stick and frame.

Sausage shell is a technological capacity that gives the product certain characteristics (Zonin V.G., 2006) [3]: keeps a form that is convenient in storage, protects against external factors, excess weight loss, microbiological and oxidative damage, due to its own strength, density, elasticity, and moisture resistance, a certain level of water, steam and gas permeability.

For each type of sausage according to the technological instruction picked up shell of a certain type, diameter and length is selected. Shells are divided into four groups (Essien E., 2003) [5]: natural (natural, intestinal); protein (collagen), artificial; artificial viscose and cellulose; synthetic (polymeric).

The extrusion (Grazyna Budryn et al, 2016) [4] – is the process of forced filling of the membranes, which is carried out by squeezing the minced meat from the syringe through the tongue, or its dosage with subsequent sealing in a certain form.

After extruding sausage loaves or clips with aluminum brackets on clipsators (Zonin V.G., 2006; Marianthi Sidira et al, 2015; Feiner G., 2006) [3, 6, 10, 8], or twisted on special semiautomatic machines, or tie with twine. After that, the natural shells of raw sausages are stamped (Rogov I.A., et al, 2000) [7] to remove air, the artificial shells do not dent, because their mechanical strength is reduced. In the upper part of the twine baton do a loop for hanging them on sticks and placing on mobile frames.

Consider the main factors that, in our opinion, are weighty in the process of extruding sausage minced: the pressure of extrusion; minced meat temperature; vacuum evacuation.

The pressure at which the minced meat is displaced in the shell (the pressure of the extrusion) is an important factor characterizing the degree of filling of the shell with minced meat (Grazyna Budryn et al, 2016) [4] and affects the compressibility of the structure, the density of stuffing mince (Gorbatov A.V., 1982) [12], the presence of the gas phase (Marianthi Sidira et al, 2015) [6, 10] and change in offset characteristics (Gorbatov A.V., 1982) [12]. With increasing of the pressure, the value of all structural and mechanical characteristics increase (Gorbatov A.V., 1982) [12], except for the plastic viscosity, which

does not depend on pressure (Essien E., 2003) [5]. Under the influence of pressure, the reorientation of particles in the structure of sausage minced is carried out, which leads to a more compact packaging with simultaneous volumetric deformation (Gorbatov A.V., 1982) [12]. The number and volume of air cavities are reduced, the rest are deformed (Yi-Chen Lee et al, 2016) [9], and the change in the size of the particles of the shells of hydrates (Gorbatov A.V., 1982) [12] and the redistribution of the liquid between the particles and the disperse medium (Gorbatov A.V., 1982) [12], or its slight separation from the structure (Grazyna Budryn et al, 2016) [4] due to the reduction of WHC (Essien E., 2003) [5]. Such a mechanism of action of pressure leads to a strengthening of bonds between particles, that why the strength of the structure increases and for the destruction of the system required more intense external actions (Orawan Winther-Jensen et al, 2014) [11].

The magnitude of the pressure of the extrusion is regulated by a change in the ratio of the velocity of leakage of minced meat from the tufts and movement of the shell (Grazyna Budryn et al, 2016, J.-P.G. Piette et al, 1998) [4, 13]. If the extrusion pressure is too weak, the emulsion gives additional shrinkage, if the packing is too dense, the product may burst during heat treatment.

The process of extrusion is characterized by a pressure that depends on the type of membrane, type of product, composition, physical-mechanical and rheological properties (viscosity, plasticity).

So, boiled sausages are syringe with a small density on pneumatic syringes under pressure from 0,4 to 0,6 MPa (0,4–0,5 MPa (Rogov I.A., et al, 2000) [7], 0,49–0,59 MPa (Zonin V.G., 2006) [3], 0,5–0,6 MPa), on hydraulic ones – in the range 0,8–2,5 MPa (0,8–1,0 MPa (Rogov I.A., et al, 2000) [7], not more than 2,5 MPa), in order to prevent the extension of minced meat and further breaking of the shell (Rogov I.A., et al, 2000) [7].

The mince of sausages and small sausages are syringe under pressure 0,3–0,8 MPa (0,3–0,4 MPa (Yordanov D., Dinkov K., 2000) [14], 0,39–0,49 MPa (Zonin V.G., 2006) [3], 0,4–0,5 MPa (Rogov I.A., et al, 2000) [7], 0,4–0,6 MPa, 0,4–0,8 MPa).

Stuffing of semi-smoked sausages is sucked densely than boiled sausages, as the volume of loaves is greatly reduced with drying (Rogov I.A., et al, 2000) [7]. The pressure value for pneumatic syringes is 0,5–1,2 MPa (0,5–1,2 MPa (Rogov I.A., et al, 2000) [7], 0,59–0,78 MPa (Zonin V.G., 2006) [3], 0,6–0,8 MPa), for hydraulic – 1,0–1,2 MPa.

The mince of boiled-smoked sausages is also densely syringed using hydraulic piston syringes at a pressure of 0,5–2,0 MPa (0,5–1,2 MPa, up to 0,7–0,8 MPa, up to 1,2 MPa (Zonin V.G., 2006) [3], 1,3 MPa (Rogov I.A., et al, 2000) [7], up to 2,0 MPa).

The mince of smoked sausages is syringed the most densely (Rogov I.A., et al, 2000) [7] using hydraulic piston syringes at a pressure of 0,8–2,0 MPa (0,8–0,9 MPa (Yordanov D., Dinkov K., 2000) [14], 1,3 MPa (Rogov I.A., et al, 2000) [7], 1,3–1,5 MPa, up to 2,0 MPa).

During extrusion, the meat emulsion is subjected to mechanical effects: compression, friction and pressure, which causes an increase in its temperature. Exceeding the level of +18 ºC on the syringe can lead to a change in the physical and chemical parameters of minced meat: a decrease in rheological characteristics (Gorbatov A.V., 1982) [12] – (the decrease of emulsifying and WHC, the appearance of fatigue, bouillon and fatty edema in the finished product), in addition to the rate of destruction of the protein structure (Gorbatov A.V., 1982) [12] due to denaturation; increase in the rates of oxidation of fatty acids (Warriss P.D., 2000) [15]. In the complex with liquid and gas phases, an increase in the level +18 ºC (James S.J., James C., 2002) [16] leads to the growth of pathogenic microorganisms (James S.J., James C., 2002) [16], which affects further product damage (Sams A.R., 2001) [17].

Table 1

List of technological operations in the formation of sausage products

№	**The name of the operation** (Zonin V.G., 2006; Rogov I.A., et al, 2000; Feiner G., 2006) [3, 7, 8]	**Technological parameters and additional information of the operation**	**Technical facilities**
1.	Preparation of sausage shell	Saline natural shells are liberated from salt, washed in cold running water. Dry bladders soak in warm water for 10-15 minutes. After, the shell is washed, blown with compressed air, calibrated, sorted and cut into segments of a certain length.	– a bath for a sausage casket; – a binding table; – calibration device
2.	Submission of sausage mince to fill the shell	Transportation of minced meat in technological carts, feeding and loading of a syringe with the help of lift-loader. The temperature of mince is 12 ... 16 °C, and for semi-smoked sausages and boil-smoked sausages 12 ° C.	– carts technological; – lift-loader
3.	Dosage and filling (extrusion) of the shell by the mince	Dosage is carried out on the length of the loop or by the method of volume dosage. The crumb in the melting process is degassed.	– a syringe for filling the sausage membrane; – the dispenser of the mince; – an alternating set of threads
4.	Distortion of loops or viscous, clips (imposing metal clips at the end of the loaves), trimming	Strapping with special stitched straps. In the upper part of the loins of twine do a loop for hanging them on a stick.	– disturber; – clipsator; – a table for knitting sausage loaves
5.	Winging of sausage loaves on a stick and frame	Loaves hang on a stick and placed on the frames so that there is a gap between them to prevent clogging. The rate of placing sausages on one frame is 100-250 kg, depending on the type of sausages.	– mobile frames; – sticks

However, an excessive decrease in temperature also leads to changes in physical and chemical parameters: the reduction of oxidation rates of fatty acids (Warriss P.D., 2000; Kuzmin O. et al, 2017), [15, 18]; reduction of the degree of dispersion of fat, which negatively affects the fat holding capacity (FHC), slows down the development of the process of color formation and microbiological parameters: the decrease of the growth of pathogenic microorganisms (James S.J., James C., 2002; Sams A.R., 2001) [16, 17]. With a sufficient density of loaves, lowering the temperature can increase the content and break the shell of the sausage during cooking.

In addition, one of the important factors is the oxidations-reduktions potential consideration of fat in the main raw materials of the formulations and the antioxidants and food additives used in the manufacturing process that regulate the rheological and functional-technological characteristics of the mince (Pasichnyi V.M. et al, 2015) [20].

The mince temperature is an important and too critical factor, which in the process of making sausage minced meat affects the stability of its emulsion (Gorbatov A.V., 1982) [12]. According to a priori information, the temperature of the minced meat can vary from +2 °C to + 20 °C (Gorbatov A.V., 1982) [12], and when extruded in the sausage shell should be in the range from +8 to +18 ºC.

The presence in the pores and capillaries of the meat raw material of the gas phase (air) (Essien E., 2003) [5], which may be in a free state – with the formation of individual blistering and voids, or dissolved state – in the entire volume of the product, negatively affects (Sams A.R., 2001) [17]: color (red → green → gray); taste; consistency; stability of the lipid fraction; oxidation; fermentation; microbial contamination; expiration date.

Evaporation – deaeration (Warriss P.D., 2000) [15] is used to remove/reduce the gas phase in the raw materials and finished products, which positively affects: reduction of the volume of air void; color; texture; maturation of the product; the terms of its storage; reduction of oxidative processes in adipose tissue, as well as bacterial insemination; improvement of the rheological characteristics of the product; WHC; improving the density of the loaf.

The main stages of evaporation of minced meat result in processes (Marianthi Sidira et al, 2015) [6, 10]: milling; mixing; rubbing; extrusion. Evaporation during syringing is carried out with the aim of removing air, which gets into mince at previous stages of making minced meat. The evacuation measure for individual types of mince is individual, vacuuming is carried out at a pressure up to «–» 0,09 MPa.

The main operations that affect the concentration of the gas phase in mince: the crushing of raw materials on the dormouse (growth from 3,00 to 4,61 % vol.); mixing of the components of the formulation (growth from 4,75 to 5,80 % of volume); fine grinding on a whistle (growth at rubbing to 8,62 % vol. reduction after vacuum rubbing to 1,82 % vol.); extrusion in the mode of vacuuming and without it (vacuum extrusion removes up to 53,7 % than without it).

The amount of minerals in the process of extrusion is controlled by the rate of flow of mince from the flint, the linear velocity of the shell (Essien E., 2003) [5] and the diameter of the shell. The tension of the membrane during irradiation is not the same, therefore, the degree of stuffing is not the same. In addition, the individual segments of the shell have a different mass, since the shell itself has an uneven diameter along its entire length.

Vibration. The effect of vibration on the displacement characteristics of minced meat is investigated both during mixing and with the settling of stuffed mince in the shell. Treated in different variants, yielded 1,5–2,5% higher with a quality improvement of 0,3–0,4 points (with a five–point system) compared with the control. The voltage of the cut of the studied finished products was 38–43 kPa, compared with the control – 32 kPa (Gorbatov A.V.,

1982) [12]. The studied minced meat batches had higher values of the marginal strain of displacement compared with the control (Gorbatov A.V., 1982) [12]. In our view, vibration can be used in the process of extrusion as an additional factor that will help to remove the residual air from the stuff.

Our research (Pasichnyi V.M. et al, 2015) [20] and the priori information that was obtained allow us to determine the region of the factor space of variables (x_1, x_2, x_3) taking into account the actual conditions of the production process (Table 2). The criteria for optimizing the process of extrusion are determined by the characteristics of sausage mince: y_1 – tasting score (points); y_2 – moisture content of mince (%); y_3 – WHC of the mince (%); y_4 – fat–retaining capacity mince (%); y_5 – the effective viscosity (Pa·s); y_6 – effective shear stress (Pa); y_7 – volumetric deformation (%); y_8 – mass fraction of protein (%); y_9 – mass fraction of moisture (%); y_{10} – the number of mesophilic aerobic and facultative anaerobic microorganisms (number/cm^3); y_{11} – number of bacteria in the group of intestinal sticks (number/cm^3); y_{12} – yield of finished products to the mass of raw materials (%).

$x_1(+1) = 1,35 + 0,9 = 2,25;$ $x_1(-1) = 1,35 - 0,9 = 0,45;$

$x_2(+1) = -0,64 + (-0,16) = -0,8;$ $x_2(-1) = -0,64 - (-0,16) = -0,48;$

$x_3(+1) = 280 + 5 = 285;$ $x_3(-1) = 280 - 5 = 275.$

Table 2

The scope of the experimental space of the experiment

Factor		Name of the factor	Level of factors			
			Upper	Lower	Null	Step
			+1	–1	0	–
$P_{p.e.}$	x_1	Pressure of extrusion, MPa	2,25	0,45	1,35	0,90
$P_{v.p.}$	x_2	Vacuum pressure, MPa	–0,80	–0,48	–0,64	–0,16
T	x_3	Mince temperature, K	285	275	280	5

The coefficient of regression and the value of confidence interval are calculated Δb_i=0,004 (α=0,2; f=8). The coefficients of regression are checked for significance with a confidence intervals: b_0=0,654>±0,004; b_1=0,041>±0,004; b_2=0,06>±0,004; b_3=-0,021>±0,004; b_{12}=-0,008>±0,004, b_{13}=0,006>±0,004, b_{23}=0,018>±0,004, b_{123}=-0,051>±0,004. It has been established that all variables influence the complex quality index statistically significant.

According to the obtained data, all variables influence the integrated quality index. We will write down the equation obtained:

$$y_к = 0,654 + 0,041x_1 + 0,006x_2 - 0,021x_3 - 0,008x_1x_2 + \\ +0,006x_1x_3 + 0,018x_2x_3 - 0,051x_1x_2x_3$$

The given experimental data allow us to conclude, that in order to increase the complex quality index, it is necessary: to increase the pressure of product (x_1) to 2,25 МПа; maximize residual pressure (x_2) to –0,8 МПа; reduce the temperature to (x_3) to 275 К.

Conclusions

Generalization of literary facts has been carried out, which allows to establish the main factors in the process of extruding sausage mince, which depend on the type of shell, the type of product, its composition, physical-mechanical and rheological properties. Found rational ranges of values that affect to the physico-chemical, microbiological and organoleptic characteristics of the finished product.

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