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DEVISING TECHNIQUES FOR REINFORCING GLUED SAUSAGE CASINGS BY USING DIFFERENT PHYSICAL METHODS

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This paper has substantiated the development and rationalization of techniques to manufacture sausage casings from natural raw materials with predefined functional and technological properties. It is noted that the issue related to the rational utilization of intestinal raw materials and the improvement of the production economic profitability could be resolved by implementing effective technologies of glued intestinal sausage casings.

The strength has been investigated of the reinforcing seam between the layers of intestinal membranes obtained by such techniques as the local tanning, local thermal coagulation resulting from passing an electric current through wet raw materials, local thermal coagulation due to the arc discharge through dried raw materials.

The rational concentration of tannin in tanning solution has been determined, at which it is recommended to make a reinforcing seam on glued intestinal casings by means of local tanning. A value of the breaking load for the reinforcing seam made by using local electric currents has been derived, which is 14 N/m. A 4.7-time increase in the breaking load has been established to occur, compared to the control sample. A value of the breaking load for the reinforcing seam obtained by applying an arc discharge has been found, which is 18 N/m. It was noted that the breaking load had increased compared to the control sample.

Working bodies for an installation were designed aimed at reinforcing glued sausage casings by such techniques as local tanning; local thermal coagulation resulting from passing an electric current through wet raw materials; local thermal coagulation as a result of arc discharge through dried raw materials. It is noted that the advantages of techniques for the reinforcement of glued sausage casings are the high breaking load and the effective utilization of raw materials

Keywords: glued sausage casings made of natural raw materials, reinforcement, tanning, breaking load

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1. Introduction

Global trends in the development of the sausage casing market testify to a steady increase in their output and use. Thus, the average annual volume of the global market of sausage casings is about EUR 4 billion. Its growth rate fluctuates at 3.0–3.5 % per year. This is a consequence of increased demand for both finished sausage products and semi-finished products in casings [1, 2].

Despite the rapid development of innovations in the technology of artificial casings, intestinal sausage casings remain the priority factors for ensuring the quality of sausage products and their demand. This is due to the versatility of their utilization from a technological point of view, as well as consumer preferences associated mostly with the naturalness of the raw materials used [3–5].

At the same time, the life-related and manufacturing defects in the treatment of intestines lead to the formation of a significant amount of waste in the intestinal production (up to 20 %) [6]. As a result, valuable animal raw materials are not used for their primary purpose but irrationally. Thus, intestinal waste is used for the manufacture of animal feed, as well as in the technology of making protein collagen masses for different purposes [7–10]. However, up to now, the manufacture of sausage casings from the intestines of farm animals has remained the most justified. The issue related to the rational utilization of intestinal raw materials and the improvement of the production economic profitability could be resolved by implementing effective technologies of glued intestinal sausage casings.

The technology of glued intestinal sausage casings exploits the ability of the intestines to form a stable adhesion between the bands and segments of films by drying them. However, the use of such casings is limited because the process of gluing-layering them in a humid environment and under the influence of the internal pressure of minced meat is an inverse phenomenon. As a result, the strength of such casings is insufficient for their use in moist minced meats [11]. Thus, it is a relevant task to investigate and devise techniques to improve the strength of glued intestinal sausage casings.

2. Literature review and problem statement

Paper [12] reports the results of a study into the manufacture of glued intestinal casings from pork bellies intended to produce sausage and other products. It is shown that the technical result achieved is the utilization of non-conforming raw materials, reducing the cost of processing intestinal raw materials, diversifying the shapes and sizes of sausage casings, products, improving the strength of casings. At the same time, to enhance the strength of glued intestinal sausage casings, the paper proposed increasing the number and cross-location of layers of intestinal bands. However, the task of reducing the reversibility character of the process of gluing-stratification of glued intestines remained unresolved. In addition, the disadvantage of this technique is the increase in the amount of raw materials used and the thickness of the casing.

Close solutions to resolving the task of ensuring a stable adhesion between the layers of glued intestinal casings could be techniques for connecting natural casings using a laser [13] and a high-frequency current [14]. The applied physical methods make it possible to achieve the strength of adhesion between the segments of the intestinal products. At the same time, the implementation of the proposed solutions involves only the sleeve segments of intestinal products in wet conditions. The above allows us to assert the expediency of investigating the techniques for reinforcing glued intestinal casings by different physical methods.

The ways to constraint the reversibility of the process of gluing-stratifying glued intestinal sausage casings are associated with their physical and chemical properties and food purpose [15]. These properties are determined by interaction with water, thermal coagulation, and tanning of the main proteins of the connective tissue of the submucosal layer of the intestines. In this case, the acquisition of irreversible properties at the thermal coagulation and tanning of collagen [16, 17] is a decisive factor, since its share is largely dominating compared to reticulin and elastin [4–6, 11]. At the same time, the conditions that form the thermal-coagulating and tannin influence, which can improve the strength of the reinforcing seam of glued intestinal casings, remain undefined.

Thus, the development and rationalization of techniques of electrophysical reinforcement of glued intestinal casings, through tanning, is an important issue, resolving which could improve the strength, increase the resource and energy efficiency of the technology of glued intestinal sausage casings.

3. The aim and objectives of the study

The aim of this study is to improve the strength of adhesion between the layers of glued intestinal casings by rationalizing the techniques of their reinforcement, which would contribute to improving the resource and energy efficiency of the technology for manufacturing glued sausage casings from natural raw materials.

To achieve the set aim, the following tasks have been solved:

– to examine the strength of the seam between the samples of intestinal casings made by locally tanning them with a solution of tannin of different concentrations and at different duration;

– to examine the strength of the seam between the samples of intestinal casings made by passing local electrical currents through the processed moisture raw materials;

– to examine the strength of the seam between the samples of intestinal casings made as a result of thermal coagulation of the raw materials around the points of an arc discharge.

4. Materials and methods to study the strength of seam between intestinal casings

4. 1. Materials and equipment to study the strength of seam between the intestinal casings

The raw material examined in the course of our research were the products of pork bellies, processed and prepared in accordance with acting manufacturing instructions. That is, the raw material was the separated pork bellies, which were cleaned in advance from serous, muscle, and mucous membranes, washed, sorted by quality, salted, and stored in the form of salted products. The raw materials were desalted, washed, and aged in water.

The wet raw materials after washing were used before reinforcing with the help of local thermal coagulation resulting from passing an electric current.

Before reinforcing with the help of tanning and when using an arc discharge, the raw materials were cut, the resulting strips were placed in a mold in the form of a cylinder, and dried at a temperature of 35...39 °C to the moisture content not exceeding 10 %.

The installation shown in Fig. 1 was used to establish the strength of the seam between the samples of the intestinal casings made by reinforcing them.

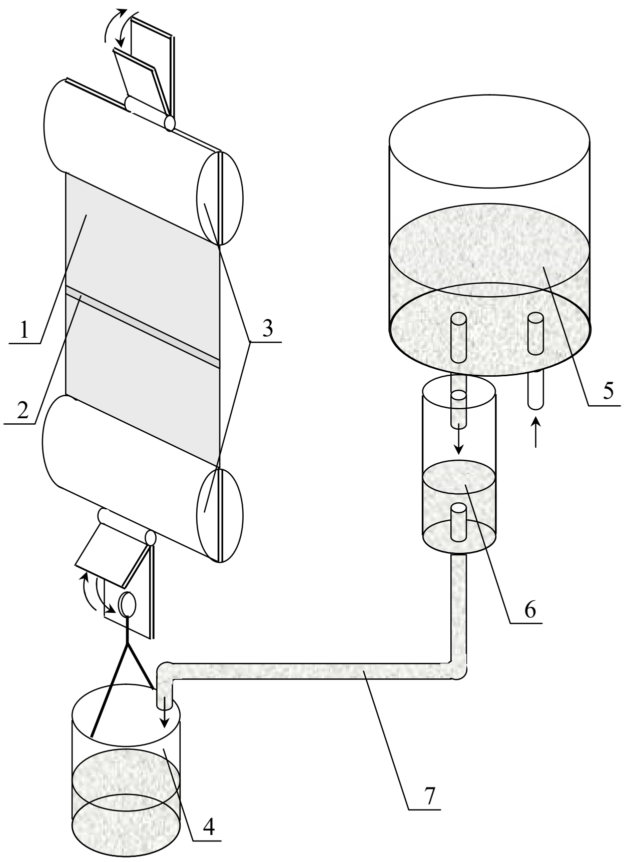


Fig. 1. Experimental installation to examine the strength of seam made by reinforcing the studied samples: 1 – sample of the studied raw materials; 2 – reinforcing seam; 3 – clamp holder; 4 – load; 5 – container with water; 6 – dropper; 7 – capillary

4. 2. The research methodology used in the study of the strength of a seam between intestinal casings

The methodology for determining the strength of the reinforcing seam, made by any of the applied techniques, implies the following. The samples consisting of two layers of the intestinal casing sewn with a reinforcing seam were wetted for 3 minutes in water before our examination. The layers were separated to the resulting seam. Each layer was fixed in clamp holders (3). A container (4) was connected to the lower clamp holder to serve as a variable load. Next, by using a system consisting of a container of water (5), a dropper (6), and a capillary (7), we increased the loading by slowly adding water to capacity 4. The loading was increased until the moment when the seam between the layers of the intestinal casings breaks. Then the load was weighed; we calculated the gravity force it creates.

The load value at which the seam between the layers of the intestinal casings broke was considered a breaking load (P). The breaking load was normalized for the length of the seam:

$$P=\frac{F}{l}, \tag{1}$$

where F is the force generated by the load, N; l is the seam length, m.

The breaking load for the seams of the samples studied was compared with a sample made of two layers of the intestinal membrane without any reinforcement. This sample was considered a control. The breaking load for the control sample is 3 N/m.

5. Results of studying the strength of the reinforcing seam made in various ways

5. 1. Results of studying the strength of the reinforcing seam made locally tanning the raw materials with a tanning solution

The raw materials, which were reinforced with a tanning solution, represented two layers of the intestinal membrane. In a wet state, the layers were stacked and dried. Samples in the form of a rectangle with the characteristic dimensions: width h=50 mm, length l=100 mm, were cut from the resulting raw materials. Such a sample of the raw materials from the intestinal casings was placed between parallelepipeds made from a capillary-porous material (Fig. 2).

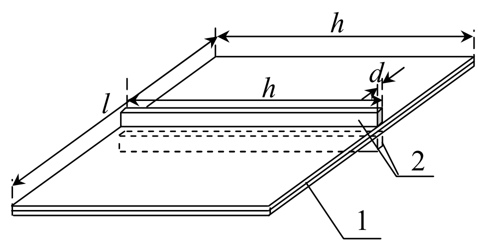


Fig. 2. The technique to make a reinforcing seam by locally tanning the raw materials with a tannin solution: 1 – sample of raw materials from two layers of intestinal membrane; 2 – parallelepipeds made from a capillary-porous material

The characteristic dimensions of the plane along which the parallelepipeds made from a capillary-porous material join the samples of the raw materials are, respectively, h=50 mm, d=3 mm.

The capillary-porous material, from which the parallelepipeds are made, was moistened with a tanning solution of the predefined concentration. The capillary-porous material was selected in such a way (that is, with the most likely radius of capillaries and pores) so that the solution is evenly distributed under the influence of capillary forces across the volume of the parallelepiped. During the experiment, the content of the tanning solution in the parallelepipeds was maintained constant.

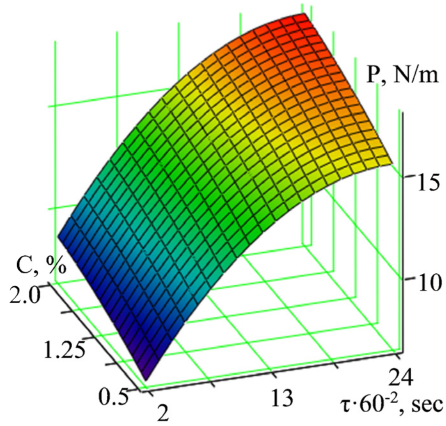
Local tanning was carried out by using a solution of tannin whose concentration changed discretely in the range from 0.2 % to 2.0 %. In this case, the duration of exposure also varied discretely in the range from 2 hours to 24 hours.

Fig. 3 shows the surface that illustrates the strength value of the reinforcing seam (P, N/m) depending on the tannin concentration (C, %) in the tanning solution and the duration of local tanning ($\tau\cdot 60^{-2}$, sec). Breaking load P was determined at the installation shown in Fig. 1 according to the procedure described in section 4. 2.

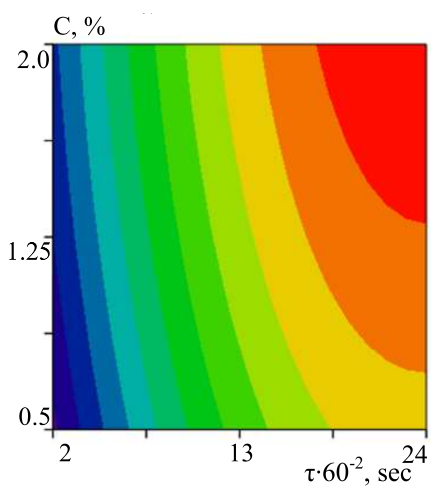
The source data for building the surface, which illustrates the strength of the reinforcing seam between the layers of intestinal casings, were the results from an experiment with two factors that varied discretely. Accordingly, one factor is the duration of tanning, the second – the concentration of tannin in the tanning solution. The response from such a two-factor experiment was a breaking load of the seam between the layers of the intestinal casings. The error of measuring the breaking load did not exceed 5...7 %. For simplicity and visualization, building the surface was limited to a plan of type 3^2. That is, we selected from an array of experimental data only those for a two-factor experiment with three levels for each factor. The regression equation for such an experiment takes the following form:

$$f(x,y) = c_0 + c_1 \cdot x + c_2 \cdot y + c_3 \cdot x^2 + c_4 \cdot y^2 + c_5 \cdot x \cdot y, \qquad (2)$$

where c_0, c_1, c_2, c_3, c_4, c_5 are the regression coefficients.



a



b

Fig. 3. Dependence of the strength value of the reinforcing seam between the intestinal casings on the concentration of tannin in the tanning solution and the duration of local tanning: *a* — the surface of the breaking load values; *b* — tomogram of the surface of breaking load values

The adequacy of the resulting model was tested by finding a correlation coefficient between the approximation functions for experimental data and the surface's secants with corresponding parameter values. In this case, the correlation coefficient did not leave the range from 0.93 to 0.97.

The surface of the breaking load values demonstrates a bend relative to the $O\tau \times OC$ coordinate plane. That is, there is an increase in the breaking load at increasing both the concentration of tannin in the tanning solution and at prolonging the duration of local tanning.

Fig. 2 shows the secants of the resulting surface parallel to the $O\tau \times OP$ coordinate plane, which represent a change in the breaking load depending on the duration of tanning at the following concentrations of tannin in the tanning solution, %: 0.5; 1.25; 2.0. Experimental data in these dependences were approximated by the polynomial function of the following form:

$$f(x) = a_0 + \sum_n a_n \cdot x^n, \qquad (3)$$

where a is the approximation coefficient; n is the degree of a polynomial.

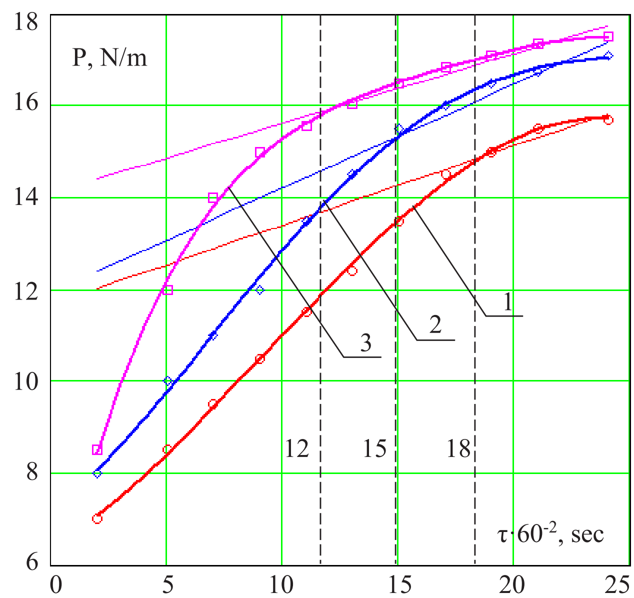


Fig. 4. Change in the breaking load of reinforcing seam depending on the duration of local tanning at the following concentrations of tannin in the tanning solution, %: 1 — 0.5; 2 — 1.25; 3 — 2.0

The breaking load of the reinforcing seam monotonously increases as the duration of local tanning increases. After the predefined duration of local tanning, the dependence of the breaking load starts approaching the asymptote parallel to the $O\tau$ axis. That is, there is a rational value for the duration of exposure of raw materials to the solution of tannin. Increasing the duration of tanning relative to these values is irrational since it entails an increase in the time for gluing the intestinal casings in this way and, as a result, reducing the productivity of making them at a non-significant increase in the breaking load of the reinforcing seam. The gain of the breaking load at this section does not exceed 10 %.

The rational values of the duration of local tanning with a solution of tannin of defined concentrations were determined through the linear approximation of the acquired experimental data. The function of the following form was used:

$$f(x) = b_o + b_1 \cdot x, \qquad (4)$$

where b_0, b_1 are the approximation coefficients.

The range of experimental data for the linear approximation was chosen in such a way that the last point of the array corresponded to the maximum duration of local tanning, that is, 24 hours. The first point was chosen based on the correlation coefficient between the resulting linear approximation function (3) and the polynomial approximation function (2). The starting condition was that the correlation coefficient should not have exceeded 0.95. It is important that in the linear section for which the approximation was carried out the increase in breaking load should not exceed 10 %.

The rational values of duration were considered those that were at the point where there was a difference between the linear and polynomial functions (dotted lines in Fig. 4). The rational value of duration, defined in this way, at the local tanning with a tannin solution with a concentration of 0.5 % is 18 hours; with the solution with a concentration of 1.25 % – 15 hours; with the solution with a concentration of 2.0 % – 12 hours.

The concentration of tannin in the tanning solution also has a rational value. It can be determined by the same procedure based on the secants of the surface shown in Fig. 3. In a given case (Fig. 5), the secants are parallel to the $OC \times OP$ coordinate plane and represent a change in the breaking load of the reinforcing seam depending on the concentration of tannin in the tanning solution at the different duration of local tanning, h: 2; 13; 24.

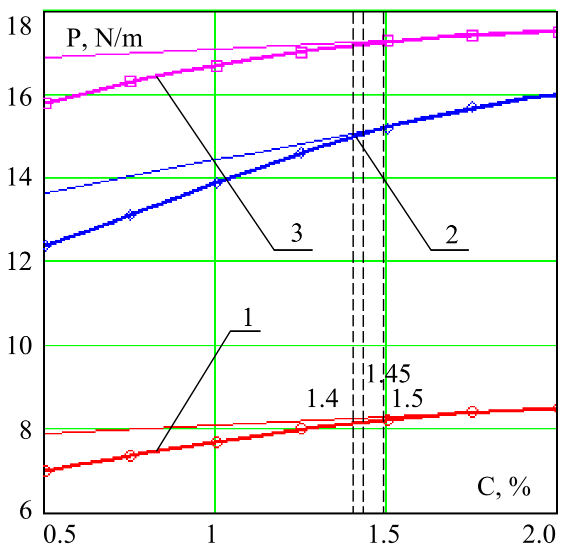


Fig. 5. Change in the breaking load of the reinforcing seam depending on the concentration of tannin in the tanning solution at the different duration of local tanning, h: 1 – 2; 2 – 13; 3 – 24

The rational value, defined in such a way, of tannin concentration in the tanning solution during local tanning over 2 hours is 1.5 %; over 13 hours – 1.45 %; over 24 hours – 1.4 %. Thus, the rational value of tannin in the tanning solution during local tanning should be selected from the range of concentrations from 1.4 % to 1.5 %.

To calculate the range of the rational duration of local tanning for the range of the rational concentration of tannin in the tanning solution, it is necessary to build the secants of planes for the upper and lower boundaries of the range of rational concentrations (Fig. 6). The secants are parallel to the $O\tau \times OP$ coordinate plane and represent a change in breaking load depending on the duration of tanning at the concentrations of tannin in the tanning solution of 1.4 % and 1.5 %.

Fig. 6 shows that the rational duration of local tanning at the concentration of tannin in the tanning solution is 1.4 % is 15 hours; at the concentration of 1.5 % – 13 hours. Based on this, the rational concentration of tannin in the tanning solution, at which it is recommended to make a reinforcing seam on glued intestinal casings by means of local tanning, should be chosen from the range of concentrations from 1.4 % to 1.5 %. At the same time, the rational duration of tanning lies in the range from 13 to 15 hours.

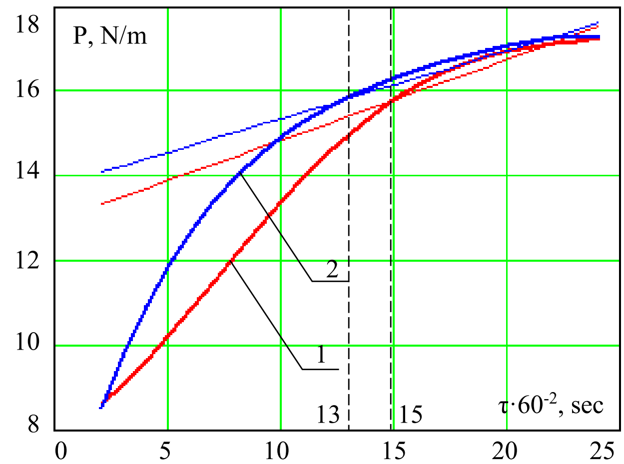


Fig. 6. Change in the breaking load of the reinforcing seam depending on the duration of local tanning at the following concentrations of tannin in the tanning solution, %: 1 – 1.4; 2 – 1.5

However, it should be noted that it is possible to choose any concentration of tannin in the tanning solution from the studied range, that is, in the range of concentrations from 0.5 % to 2.0 %, if required by manufacturing conditions. The duration should be determined in accordance with the surface, which represents a change in the breaking load for the reinforcing seam between the layers of intestinal casings made by local tanning using a tanning solution, depending on the concentration of tannin and the duration of tanning since any concentration from the studied range of concentrations produces the value of the breaking load of 15 N/m. This value is 5 times greater than the control sample, that is, a sample of two layers of the intestinal casing without any reinforcement (3 N/m).

5. 2. Results of studying the strength of the reinforcing seam made by using local electrical currents

The raw materials through which the electric current was passed represented two layers of the intestinal casing. In a wet condition, the layers were stacked. Of these, samples were cut in the form of a rectangle with the following characteristic dimensions: width, h=50 mm; length l=100 mm. The samples were placed between copper electrodes. One of the electrodes was a plate, the other was a cylinder with a pointed end (Fig. 7).

The electrodes are connected to the DC source. Next, the power source is switched on to pass DC through the wet raw material over a certain time. Moisture raw materials are stored in NaCl solution in accordance with acting technological instructions, so it is a conductor with the predefined resistance. When the electric current passes, the raw material is locally heated and coagulated.

Next, the power supply is disconnected and the electrode is moved 3...5 mm along the specified straight line (bar-dotted line in Fig. 7). The power source is enabled to pass an electric current through the raw materials at the next point within a specified time. The operation is repeated along the entire length of the planned straight line, which then acquires the properties of the reinforcing seam.

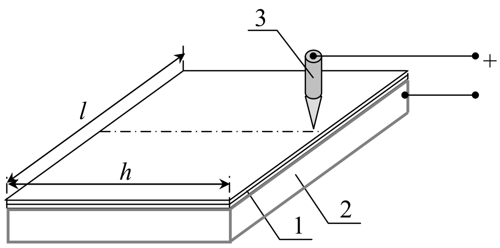


Fig. 7. The technique for making a reinforcing seam between two layers of intestinal casings by passing local electrical currents through raw materials: 1 — sample of raw materials from two layers of intestinal membrane; 2 — electrode in the form of a plate; 3 — electrode in the form of a cylinder with a pointed end

The value of the breaking load for the reinforcing seam derived in this way, and determined at the installation in Fig. 1, is 14 N/m. In this case, in formula (1), the length of the seam *l* was considered the length of the line along which the operation was carried out to pass the local electric current through the wet raw materials. As one can see from the result, there was an increase in breaking load compared to the control sample (3 N/m), by 4.7 times. At the same time, it is possible to reduce or increase the strength of the reinforcing seam by increasing or reducing the distance between the points through which the electric current is passing.

5. 3. Results of studying the strength of the reinforcing seam made by using an arc discharge

The raw materials, which were reinforced using an arc discharge, represented two layers of the intestinal membrane. In a wet state, the layers were stacked and dried. Samples in the form of a rectangle with characteristic dimensions were cut from the resulting raw materials: width, h=50 mm; length l=100 mm. The resulting sample was placed between electrodes, as shown in Fig. 7. One of the electrodes was a plate, the other was a cylinder with a pointed end. However, unlike electrodes in the previous experiment, they are made not of copper but graphite.

The electrodes are connected to the power supply; it is turned on. The difference in the potential between the electrodes is increased to a certain value before the arc discharge occurs between them. Between the electrodes, there is a dried sample consisting of two layers of the intestinal casing and represents a dielectric layer. As a result of the arc discharge through the dielectric layer, it forms a hole with a size less than 1 mm with molten edges.

Next, the power supply is disconnected and the electrode is moved 3...5 mm along the specified straight line (bar-dotted line in Fig. 7). The power supply is then turned on again to enable the arc discharge at the next point and form a hole in it with melted edges. The operation is repeated along the entire length of the planned straight line, which, as in the previous experiment, then acquires the properties of the reinforcing seam.

The value of the breaking load for the reinforcing seam made by using an arc discharge, and determined at the installation shown in Fig. 1, is 18 N/m. In this case, in formula (1), the length of the seam *l* was considered the length of the line along which the operation was carried out to enable the arc discharge through dried raw materials. In this case, there was a 6-fold increase in breaking load compared to the control sample (3 N/m). It should be noted that it is possible to reduce or increase the strength of the reinforcing seam by increasing or reducing the distance between the points at which the arc discharge occurs.

5. 4. Design of the working bodies to an installation for reinforcing glued sausage casings

Our study of the strength of reinforcing seams, made by various techniques, allows us to formulate requirements for the working conditions and structural features of the working bodies of installations for reinforcing glued sausage casings.

When reinforcing glued sausage casings by local tanning, the requirements are as follows:

– only a certain part of the surface of the raw material (two layers of the intestinal membrane), the one that is subject to reinforcement, should be in direct contact with a tanning solution;

– direct contact between the tanning solution and the part of the surface of the raw material to be reinforced should last within a certain time;

– the rational concentration of tannin in the tanning solution should be chosen from the range of concentrations from 1.4 % to 1.5 % while the rational duration of tanning lies in the range of 13 to 15 hours.

Based on the above requirements, we designed working bodies for the installation (Fig. 8) to reinforce glued sausage casings by means of local tanning.

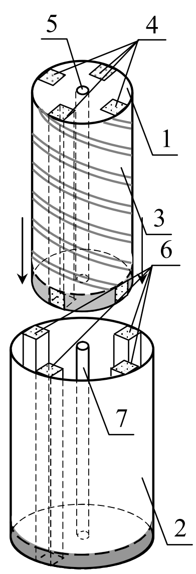


Fig. 8. Working bodies of the installation for reinforcing glued sausage casings by means of local tanning: 1 — solid cylinder; 2 — hollow cylinder; 3 — intestinal casings wound in a spiral; 4 — cuts in the cylinder filled with capillary-porous material; 5 — hole for a guide; 6 — parallelepipeds made of capillary-porous material; 7 – guide

The technique of local tanning involving the designed working bodies is implemented as follows. Wet raw materials, which are intestinal casings, are wound on solid cylinder 1, covered with an anti-adhesion coating (for example, Teflon), spiraled one on one. The raw materials on the cylinder are dried to the moisture content not exceeding 10 %.

Next, a solid cylinder, along guide 7, through hole 5, is inserted into hollow cylinder 2. Cylinder 1 has cuts filled with capillary-porous material; cylinder 2 hosts parallelepipeds, on the inner walls, made of the same material. The solid cylinder is inserted into the hollow one in such a way that the cuts with capillary-porous material in a solid cylinder are opposite to the parallelepipeds of capillary-porous material on the inner walls of the hollow cylinder. The diameters of the cylinders are such that the capillary-porous material contacts the raw material both on the inside and on the outside.

The hollow cylinder is filled to a mark shown in Fig. 8 with gray color with a tanning solution with the appropriate concentration of tannin (or any other tanning substance). Capillary-porous material is selected so that its capillaries and pores under the influence of surface tension are filled with a tanning solution along the entire length of the cylinders. In this state, the raw material is kept over a certain time, which corresponds to the concentration of tannin in the tanning solution. During this time, we control the level of the tanning solution in the hollow cylinder. At the end of the tanning, the raw materials on the cylinder are dried and removed from the cylinder.

Our study into the strength of the reinforcing seams made by using local electrical currents and applying an arc discharge has made it possible to design the working bodies of the installation for reinforcing glued sausage casings employing these techniques (Fig. 9).

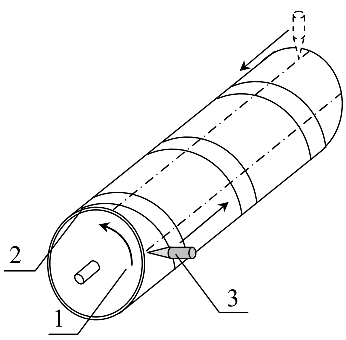


Fig. 9. Working bodies of the installation for reinforcing glued sausage casings made by using local electrical currents and by applying an arc discharge: 1 – electrode in the form of a cylinder; 2 – intestinal casings wound in a spiral; 3 – cylindrical electrode with a pointed end

The technique for making glued reinforced sausage casings using local electric currents is as follows. Wet raw materials (3), which are intestinal casings, are wound on a cylindrical electrode in a spiral one on one. The electrode surface is made of metal with low specific resistance (for example, stainless steel).

Using electrode 3, an electric current is passed through wet raw materials. As a result of current passing through the raw material over a certain time, the raw material is locally heated and coagulated. The duration of passing a local electric current is determined by the power supply capacity. Then the power is switched off, a drive mechanism shifts the electrode along the cylindrical electrode at a distance of 3...5 mm depending on the requirements for the functional and manufacturing properties of glued reinforced sausage casings. The operation is repeated along the entire length of the cylinder.

Next, the cylindrical electrode, by a drive mechanism, is rotated at a certain angle, and the operation to pass a local electric current is repeated in the opposite direction.

After rotating the cylindrical electrode at 360°, the resulting reinforced casing is removed and dried. In this case, the reinforcement of the cylindrical casing with a length of 300 mm and a diameter of 20 mm takes no more than 20 minutes.

The technique for making glued reinforced sausage casings applying an arc discharge is implemented similarly. However, electrodes, in this case, are made of graphite while the raw material represents dried intestinal casings wound in a spiral one on one on a cylindrical electrode.

Thus, based on the current study, we designed working bodies for the installation for reinforcing glued sausage casings using the local tanning; local electric current; arc discharge.

6. Discussion of results of studying the strength of the reinforcing seam made by various techniques

Our study of the strength of the reinforcing seams made by various techniques has shown that the reinforced glued intestinal casings demonstrate significantly higher values of breaking load compared to control. For the reinforcing seams made by tanning (Fig. 4, 5), the breaking load increases by 4...5 times. For the reinforcing seams made by applying local electrical currents, a given value increased by 4.7 times; for the seams made by applying an arc discharge, it increased by 6 times.

It should be noted that the processing applies to only that part of the raw materials whose area is negligibly small compared to the total surface area of the raw materials. That is, only a negligibly small part of the intestinal casing changes its functional and manufacturing properties relative to the starting one. However, there are no data on equipment for manufacturing reinforced glued sausage casings. Given this, based on the current study, we designed working bodies for the installation for reinforcing glued sausage casings using the local tanning, local electric current, arc discharge.

The advantages of applying the technique of local tanning of intestinal casings (Fig. 8) and its technical solution are that we reinforce the glued intestinal casings only, rather than continuous tanning. It should be noted that at the continuous tanning of glued intestinal casings [16, 17], the resulting raw materials become hard and require additional operations to plasticize it, and, consequently, additional material and energy costs. Another advantage is that a given technique produces a glued reinforced sausage casing, which consists of only two layers of the intestinal casing. At the same time, at least three layers of intestinal casings are used in the most common technology for making glued sausage casings, which is more resource-consuming.

The advantages of techniques for reinforcing glued sausage casings, made by using local electric currents and by applying an arc discharge (Fig. 9), are as follows. Firstly, the reinforcing process has a low duration – no more than 20 minutes. Secondly, the reinforcing seam has a high breaking load – not less than 14 N/m. Thirdly, the efficiency of the utilization of raw materials improves: no more than two layers of intestinal casings are used.

The main limitation of our research is that the designed technical solutions, except for the installation for local tanning, are conceptual and thus require further development. This is the prospect of further research. The technical solution for reinforcing glued sausage casings by means of local tanning is ready for implementation.

7. Conclusions

1. We have established the rational concentration of tannin in a tanning solution at which it is recommended to make a reinforcing seam on glued intestinal casings by means of local tanning. It should be chosen from a range of concentrations from 1.4 % to 1.5 % while the rational duration of tanning lies in the range of 13 to 15 hours.

2. A value of the breaking load for the reinforcing seam made by using local electric currents has been derived, which is 14 N/m. It was determined that there was an increase in breaking load compared to the control sample (3 N/m), by 4.7 times. It is noted that it is possible to reduce or increase the strength of the reinforcing seam by increasing or reducing the distance between the points through which the electric current is passed.

3. A breaking load value has been derived for the reinforcing seam made by applying an arc discharge, which is 18 N/m. It is noted that there was a 6-fold increase in breaking load compared to the control sample (3 N/m). It is noted that it is possible to reduce or increase the strength of the reinforcing seam by increasing or reducing the distance between the points at which the arc discharge is enabled.

4. We have designed working bodies for the installation for reinforcing glued sausage casings in the following ways: by local tanning; by local thermal coagulation resulting from passing an electric current through wet raw materials; by local thermal coagulation as a result of an arc discharge through dried raw materials. It is noted that the advantages of techniques for reinforcing glued sausage casings are the high breaking load (not less than 14 N/m); the effective utilization of raw materials (no more than two layers of intestinal casings are used).

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