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The study of the intensification of technological parameters of the sausage production process

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ABSTRACT

One of the sources of sodium are meat products. Increased consumption of meat products and sodium intake leads to serious health problems. The task of reducing the dosage of sodium chloride in minced meat needs to be addressed. The partial replacement of table salt with sea salt will reduce the sodium concentration in products to 20%. It is established that this modification increases the moisture-binding properties of minced meat and lowers the dosage of salt in the mass of raw meat, which will reduce the level of harm to the body due to excessive consumption of sausages. It is proposed to introduce a bacterial preparation based on the strain *Staphylococcus carnosus*, which will reduce the amount of sodium nitrite in the finished products. Technology has been developed to regulate the composition of microelements in meat products by enriching them with a kelp extract. It was found that changes in the composition of minced meat can adversely affect the taste and physicochemical properties of the product, which is confirmed by expert studies. As a result of laboratory studies, it was found that a partial change of salt in the sea helps to improve the stability and physicochemical quality of minced meat (active acidity, water activity, moisture retention, and shear stress). According to the research results, the recipe of sausages recommended for implementation at the enterprises of the meat processing industry of Ukraine has been developed.

Keywords: sodium, concentration, sausage meat, kitchen salt, sea salt.

INTRODUCTION

Sodium is one of the elements critically essential for supporting the normal state of an organism, and the most source of its income is the table salt (sodium chloride, NaCl). The man's organism contains about 0.3 kg of this salt, and its most significant part is dissolved in blood and plasma **[1]**. Consumption of table salt assists in the system's normal functioning and oppresses the germination of putrescent microorganisms **[2]**.

The average sample of the table salt contains 94 – 99% of sodium chloride and small quantities of copper, iron, fluorine, magnesium, manganese, and potassium **[3]**. The positive functions of sodium ions that enter the organism with this salt in foods consist of normalising kidneys' functioning and activating absorption of amino acids and glucose in bowels. The presence of sodium is also retained in organism water, which assists in regulating water-salt metabolism and activation of state of albumen of angiotensin II, which normalises the level of arterial pressure **[4]**. The normal sodium concentration in plasma is 12 – 17 mEq/m^3, and its deflection of physiological norms leads to a severe increase in levels of morbidity and mortality **[5]**. The presence of sodium in normal concentrations assists in the normal functioning of the nervous system thanks to supporting the potential of nerve cells at the proper level. After they have received the signal, the electrochemical impulse perceived by the neighbouring cells is generated. Taking these facts into consideration and studying the effects of various doses of consumed sodium on the metabolism processes, the Linus Pauling Institute of the Oregon State University, USA, recommends the daily norm of consumption of sodium on the level of about 1500 mg of (0.0038 kg of table salt) **[6]**.

However, the factual level of sodium consumption is much bigger and composes 0.0082 – 0.0094 kg in the USA, 0.0094 kg in the UK, and 0.012 in the East-Asia countries. The excessive consumption of salt leads to worsening of the state of health, which appears in accumulation of water in the organism, spraining of muscular ligaments and deterioration of capability of muscles to contract, arising of inflammations in kidneys, nephropathy,

renal failures, and neutrality, impairment of transmission of impulses in the brain, dotting of blood and increasing of risks of insult, overactivity and excessive excitability **[7]**. It is recommended to abandon or decrease the consumption of spicy flavouring, canned foods, and sausages to decrease the organism's salt concentration; the prevalence of sodium in this kind of food leads, among others, to the appearance of neoplasms. For instance, the Japanese are often affected by stomach cancer because of excess salted and pickled products **[8]**.

At the same time, the significant part of the rations of Europeans consists of meat products. The typical structure of consumption of sodium with foods is as follows (Figure 1): cereals – 35%, meat and meat products – 26%, vegetables – 11%, dairy products 8%, other products – 20%.

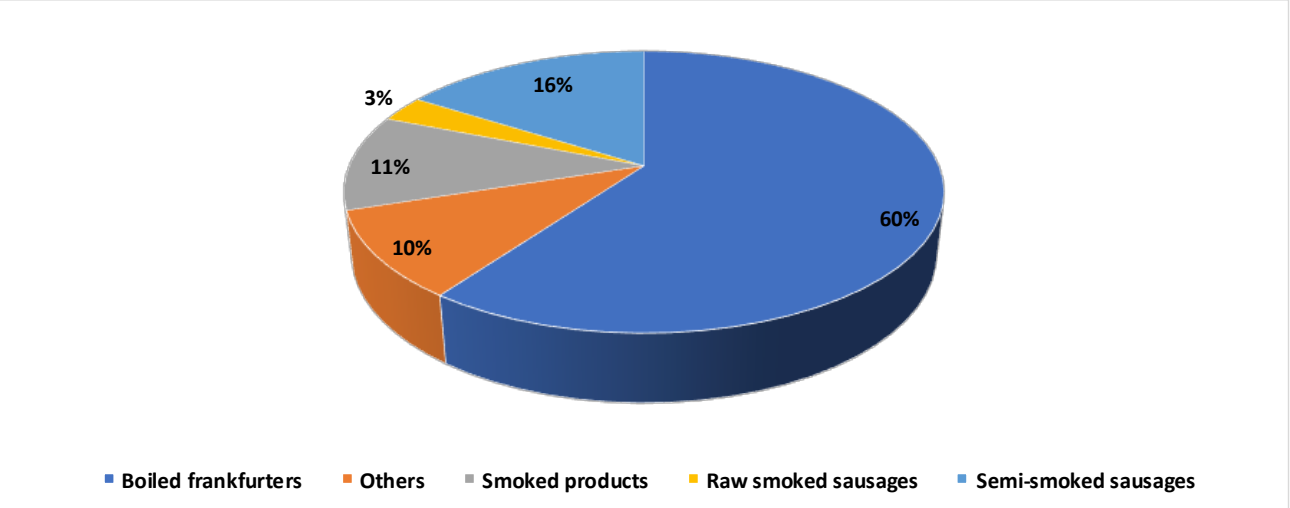


Figure 1 Structure of the market of meat products in Ukraine in 2020.

So, meat products, mainly sausages (60% of a full proposal of meat products on the market), are one of the organism's principal sources of sodium intake **[9]**.

Scientific hypothesis

The fabrication technology of frankfurters may be optimised in limiting sodium consumption. To reach this goal, we propose to replace the table salt used in the meat products formulations traditionally for the sea one and add to the minced meat mass the *Staphylococcus carnosus* bacterial culture. Such replacements should decrease the quantity of consumed sodium by a factor of 20 – 30% and cut the time of ripening of the mix. The iodine deficit in the ration may be solved if an additive of laminaria seaweed enriches the sea salt.

MATERIAL AND METHODOLOGY

Samples

The study was carried out using two samples, which composition is shown in Table 1. The design of basic ingredients of the control mix conformed to this one of frankfurters of "Liubytel'ski" produced by the standard of DSTU 4436:2005 **[10]**, which composition was modified by additives recommended for use to give the mix some medicinal properties.

The composition of the experimental meat mix was modified by replacing in traditional frankfurters formulation of kitchen salt for the sea one and enriching the basic formulation by *Staphylococcus* bacterial culture and extracts of rosemary and *laminaria* (Table 1).

Table 1 The basic ingredients of minced meat

Ingredient	Control mix	Experimental mix
Basic raw materials		
Beef	33	30
Semi-fatty pork	33	26
Fatty pork	34	34
Blood albumen	-	1.0
Water to hydrate the blood albumen	-	2.0
Cellular tissue (orange dietary fibers Citri-Fi 100)	-	0.5
Water to hydrate cellular tissues	-	6.5
In total	100	100
Spices and materials		
Kitchen salt	2.2	-
Sea salt with *laminaria*	-	2.1
Sugar	0.16	0.16
Sodium nitrite	0.0075	0.005
Bacterial preparation (Iprovit LRR)	-	0.05
Rosemary extract	-	0.015
Water	35.0	30.0

Chemicals

The components of the minced meat mixes, which masses were detected in this work, were as follows:

Petroleum ether (excise, AR grade, Khimlaborreaktyv LLC, Ukraine).

Nitric acid (A brand, CP, Khimlaborreaktyv LLC, Ukraine).

Potassium dichromate (AR grade, Khimlaborreaktyv LLC, Ukraine).

Hydrochloric acid (A brand, AR grade, Khimlaborreaktyv LLC, Ukraine).

Sodium hydroxide (A brand, AR grade, Khimlaborreaktyv LLC, Ukraine).

Sodium tripolyphosphate (technical, p 85%, Khimlaborreaktyv LLC, Ukraine).

Sulfuric acid (A brand, CP, Khimlaborreaktyv LLC, Ukraine).

Animals and Biological Material

The biological materials used in this work were beef muscle meat, semi-fatty pork muscle meat, blood albumen, and *Staphylococcus carnosus* bacterial culture.

Instruments

Drying oven (DC-300, producer (Inter-Synthesis) Limited Liability Company, Ukraine).

Muffle furnace (SNOL, producer (Inter-Synthesis) Limited Liability Company, Ukraine).

Laboratory press (Velp Scientifica, producer (Inter-Synthesis) Limited Liability Company, Ukraine).

Mettler Toledo analytical balances (producer (Inter-Synthesis) Limited Liability Company, Ukraine).

The analyser of fat (SOX 406, producer (Inter-Synthesis) Limited Liability Company, Ukraine).

Instrument of (Combo) for measuring the oxidative potential (producer (Inter-Synthesis) Limited Liability Company, Ukraine).

Penetrometer (Ulab 3-31, producer (Inter-Synthesis) Limited Liability Company, Ukraine).

Laboratory centrifuge (producer (Inter-Synthesis) Limited Liability Company, Ukraine).

Chemical cups (CC-100, CC-150, CC-200, CC-250, CC-500, producer (Laboratory equipment) Limited Liability Company, Ukraine).

Petri dish (producer (Inter-Synthesis) Limited Liability Company, Ukraine).

Measuring flasks (MF-100, MF-150, MF-200, MF -250, MF-500, producer (Laboratory equipment) Limited Liability Company, Ukraine).

Muffle furnace (SNOL 8,2/1100, producer (Laboratory equipment) Limited Liability Company, Ukraine).

Measuring pipettes (MP-0,001, MP-0,002, MP-0,005, MP-0,01, MP-0,015, producer (Inter-Synthesis) Limited Liability Company, Ukraine).

Conical flask (CF-100, CF-150, CF-200, CF-250, CF -500, producer (Laboratory equipment) Limited Liability Company, Ukraine).

Burette for titration (producer (Laboratory equipment) Limited Liability Company, Ukraine).

Filters (producer (Laboratory equipment) Limited Liability Company, Ukraine).

Gas chromatograph (Kupol_55, Shimadzu Corporation, Japan).

Amino acid analyser (LC-2000, Biotronik, Khimlaborreaktyv LLC, Ukraine).

Laboratory Methods

Characterising of the chemical composition has been carried out according to the following methods: the mass fraction of moisture by drying the product sample down to a fixed weight at a temperature of 100 – 105°C according to DSTU 8029:2015 **[11], [12]**; the mass fraction of ash by weight method, after mineralisation of the product's sample weight in a muffle furnace at a temperature of 500 – 600°C according to DSTU 8718:2017 **[13]**; the mass fraction of lipids by Soxhlet method, which consists in the fact that fat is weighed after its extraction with a solvent from the dry sample weight in the Soxhlet apparatus, based on determining the change in the sample's weight after fat extraction with a solvent by DSTU 8718:2017 **[14]**; the mass fraction of protein by determining the total nitrogen by the Kjeldahl method. Cinefaction of samples was performed on Velp Scientifica DK6 series (Italy) with a vacuum pump (JP). Distillation was made on a steam distillation device Velp Scientifica UDK 129 (Italy), DSTU 8030:2015 **[15]**.

Determination of the fiber's mass fraction was carried out by removing acid-alkaline-soluble substances from the product and determining the residue weight, conventionally fiber by DSTU 8844:2019 **[15]**.

Determination of the fatty acid content was carried out by chromatographic method on the Kupol 55 chromatograph (Russia) GOST ISO 17764-1:2015 **[16]**.

The mineral composition (the content of potassium, calcium, magnesium, phosphorus, manganese, and so on) was determined by atomic emission spectrometry with inductive plasma, and the content of heavy metals (lead, cadmium, arsenic, mercury, copper, and zinc) was determined by atomic absorption spectrometry according to DSTU EN ISO 11885:2019 **[17]**.

Description of the Experiment

Sample preparation: The purpose stated in the experiment was the comparative determining of technological and functional properties of control and experimental mincemeat systems carried out after determining the composition of tested masses. The properties to control were as follows: active acidity, the activity of water, water holding capacity, and limiting shifting tension. The masses to control were prepared by the thorough mixing of ingredients in a special mixing vessel and storing of the mixed mass overnight before the experiment. Each property was determined threefold.

Number of samples analyzed: Four types of sausages with different moisture content and shelf life were used in the study of samples.

Number of repeated analyses: Each study was carried out five times, with the number of samples being four, which amounted to twenty repeated analyses.

Number of experiment replication: The study was repeated five times, with the experimental data processed using mathematical statistics methods.

Design of the experiment: The active acidity and oxidative potential of mixes were determined by measuring the difference of potential of glassy and reference electrodes poured in the mix by the method normalized by the standard of DSTU ISO 2917:2001 **[18]**. The water activities were determined in the indication of a moment of appearance of dew on the surface of the cooled indicator. The water-holding capacities and plasticity of tested samples were measured in the threefold pressing of the sample of 0.0003 kg mass by a strain of 1 kg and measuring of gain of mass of filtering paper and area of water spots on it. The limiting efforts of the shift were measured in measuring of depth of insertion of the measuring head of the penetrometer into the minced meat mass. The emulsifying capacity of homogenized mince meats was determined by adding a rated quantity of sunflower oil, centrifugation of the mix, and determining the volume of oil-free of weighed solid particles. The mass stability was determined by warming during 30 minutes of the sample prepared in the previous experiment to 80°C, cooling it for 15 minutes by flowing water, centrifugation for 5 minutes at 500 pm, and measuring the volume of emulsified oil. To obtain each property's real value, determining all properties was repeated in the same conditions once more.

The studied meat products are characterized by a relatively big sodium chloride content, which concentration varies in the diapason of 1.2 – 6%, even reaching in some cases 12% **[19]**. For instance, the content of NaCl in sausages is 1.3 – 3.5% (0.006 – 0.014 kg of sodium in one kilogram of the product) **[20]**. For instance, the content of sodium in 0.1 kg of the product in 10 types of sausages the most popular in Europe (the numbers in parentheses show its ratio to its recommended daily allowance – RDA) is as follows **[21]**:

Sausage, Polish, beef with chicken, hot: 1540 mg (96% RDA).

1. Sausage, summer, pork and beef, sticks, with cheddar cheese: 1483 mg (93% RDA).
2. Sausage, Berliner, pork, beef: 1297 mg (81% RDA).
3. Sausage, Italian, pork, cooked: 1207 mg (75% RDA).

4. Sausage, turkey, hot, smoked: 1196 mg (75% RDA).
5. Sausage, chicken, beef, pork, skinless, smoked: 1034 mg (65% RDA).
6. Sausage, chicken, and beef smoked: 1020 mg (64% RDA).
7. Sausage, Italian, turkey, smoked: 928 mg (58% RDA).
8. Sausage, smoked link sausage, pork, and beef: 911 mg (57% RDA).
9. Sausage, meatless: 888 mg (56% RDA).

Therefore, decreasing the quantity of sodium in sausages is one of the actual problems of the modern meat-processing industry **[21]**.

The existing fabrication methods of products, which contain lesser quantities of sodium, may be realized in different ways, including decreasing portions of added table salt, partial replacement of sodium chloride in it by other salts, etc. **[22]**. The components proposed to replace some sodium are chlorides of calcium and potassium. By information to WHO, the use of potassium chloride is the most efficient factor in decreasing the income of sodium in the organism, which assists in the normalization of blood pressure, normalization of the content of glucose in the blood, and decreasing the risk of the progress of cardiovascular diseases. Such a method is especially actual for Ukraine, where its level is the highest in Europe **[23]**. One more action in the betterment of the composition of consumed salt is its enrichment by iodine **[24]**.

Statistical Analysis

Experimental data were processed using mathematical statistics methods in the STATISTICA Microsoft Excel editor. The accuracy of the obtained experimental data was determined using the Student's t-test with confidence coefficient ≤ 0.05 with many parallel definitions of at least 5 (confidence probability $p = 0.95$). Linear programming problems were solved using the MS Excel table processor's 'Search for a solution' setting (Excel Solver).

RESULTS AND DISCUSSION

The principal purpose of our investigation was a development of a formulation of sausage meat that would contain a decreased quantity of sodium. Similar scientific studies are described in the following scientific papers **[25], [26], [27], [28]**. Still, the authors of the above scientific papers used a different composition of raw meat and increased concentrations of sodium chloride. The assigned task was solved using a composition that contained a mix of table and sea salt. The basic indices of quality of both salts are cited in Table 2.

Table 2 Content of minerals of dry sea and table salts (%).

Mineral	Sea salt*	Kitchen salt of extra grade**
Sodium	30.6	38.7
Chloride	55.0	59.7
Calcium	1.2	0.024
Potassium	1.1	0.008
Magnesium	3.7	0.001
Iron	no data	0.005
Sulfate	7.7	0.16
Hydrocarbonate	0.45	no data
Iodine**	5×10^{-6}	-

Note: *(Wikipedia, 2020) ** (DSTU 3585:2015).

So, the partial replacement of table salt by sea one in salting of meat would permit to decrease sufficiently the content of sodium in it **[29] (WHO, 2007)**. Considering this fact, we exercised the compositions of sausage meats salted by usual and sea salts to find the level of acquiring by these of over-salted taste. There were used the solutions that contain 0.5 – 2.4 % of salts are as follows ***a)*** pure kitchen salt and ***b)*** pure sea salt. Scientific works **[30], [31], [32], [33]** describe studies using 3% table salt, which in our opinion may adversely affect the physicochemical composition of finished products. The expert method controlled the taste of salted meats, which results showed the practically identical feeling of salinity (Figure 2).

The experts found that the moderated taste of salinity of salted meat after its cooking is about 2%, whether it was the pure kitchen salt or the mix of kitchen and sea ones. Therefore, such concentration was recommended for the fabrication of sausage meat mixes. Scientific works **[34], [35], [36], [37]** describe studies using different concentrations of the table and sea salts in the range from 0.5 – 1.5%; as a result of similar studies, it was found that such concentrations hurt the organoleptic properties of the finished product. The one more recommendation

was to enrich them with iodine, preferably by the extract of *laminaria* to compensate its deficit, what technique is the best recommended for use **[38], [39], [40], [41]**.

One more source of income for the organism of cation of sodium with meat products is sodium nitrite $NaNO_2$ added to give them the stable red coloration. However, dietitians recommend limiting using of this salt because of its decomposition with forming of nitrogen oxide, NO, in acid environments, for instance, in the man's stomach, which leads to forming of mutagenic nitrosomioglobine in its interaction with the meat myoglobin **[42]**, **[43]**, **[44], [45]**. However, the result of preserving the red color of boiled sausages may also be reached in adding into the sausage meat of special cultures of microorganisms, which permits reducing the dosing of nitrite-ion.

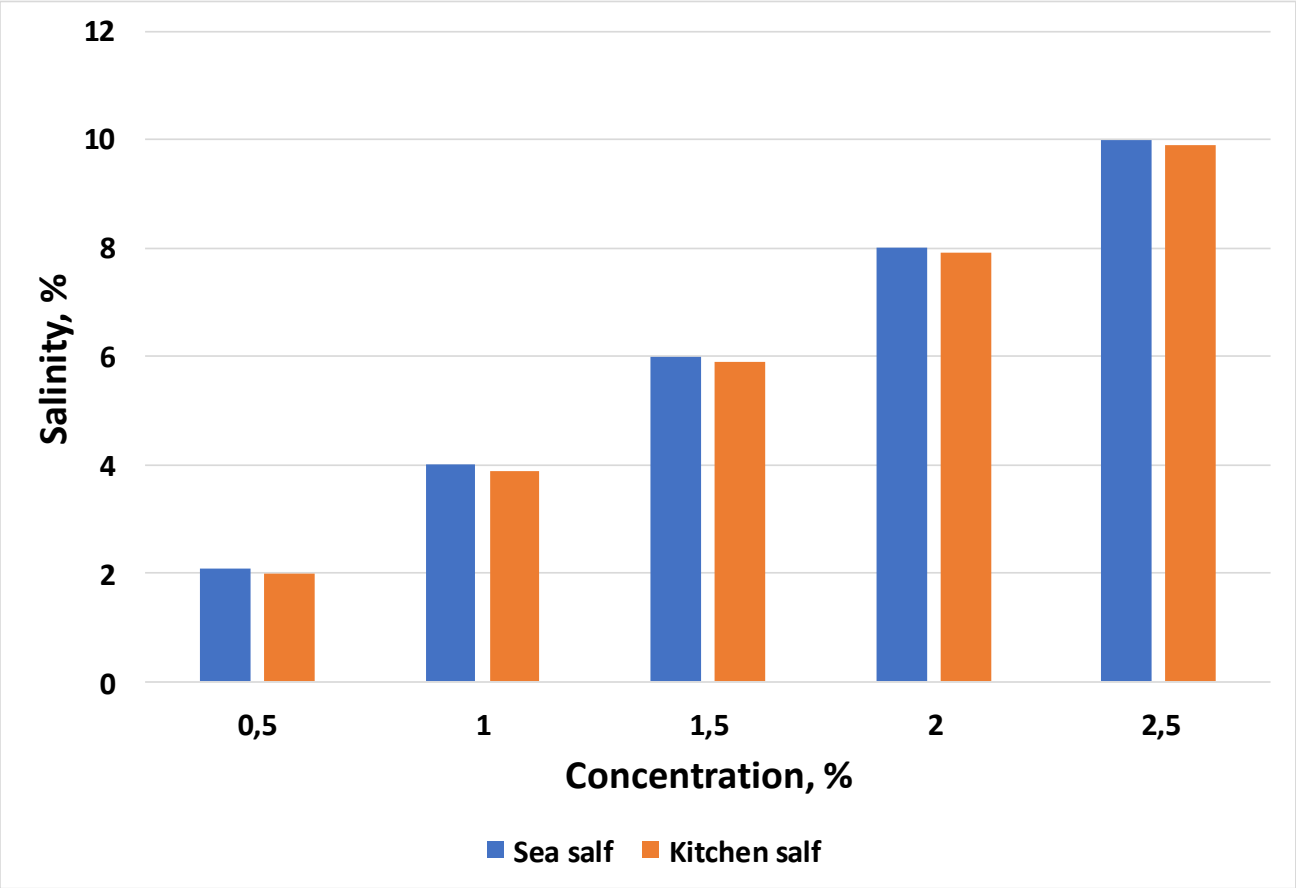


Figure 2 Results of organoleptic evaluation of salinity of meat systems.

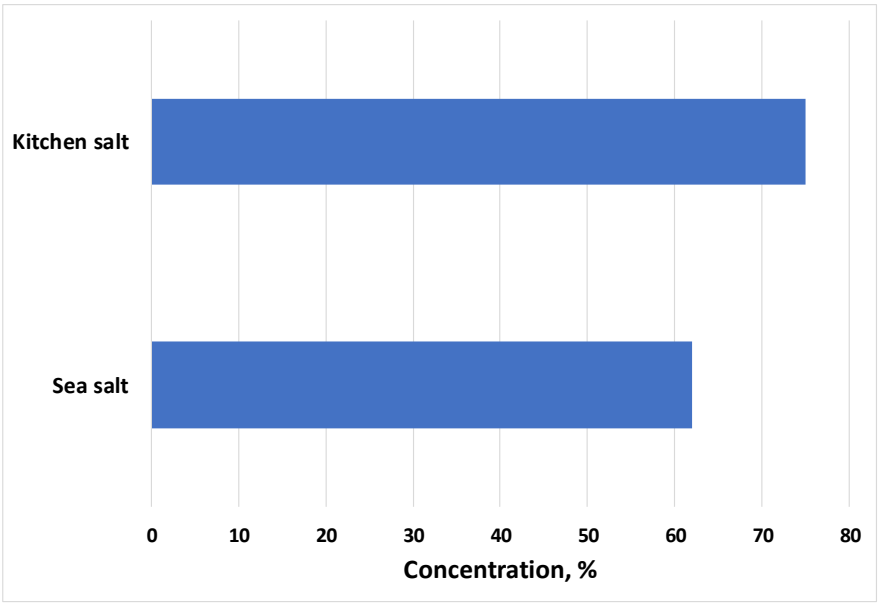
According to the research of leading scientists in meat production, it was proved that microflora reduces the residual amount of nitrites and preserves the basic physicochemical and organoleptic properties of meat products **[46], [47]**. To reach such goal, producers use the most often the specific culture of *Staphylococcus carnosus* **[48], [49]**. The special analysis of the kinetics of reduction of nitrate ion by this culture showed its completeness in boiled sausages **[50]**.

The results of studying of one of the principal functional properties to hold water by meats salted at +4°C during 24 hours in dosage of 0.0024 kg of pure kitchen and sea salts per 0.1 kg of meat showed that the use of sea salt permits to increase the quantity of retained water dramatically in use of sea salt instead of the kitchen one (Figure 3).

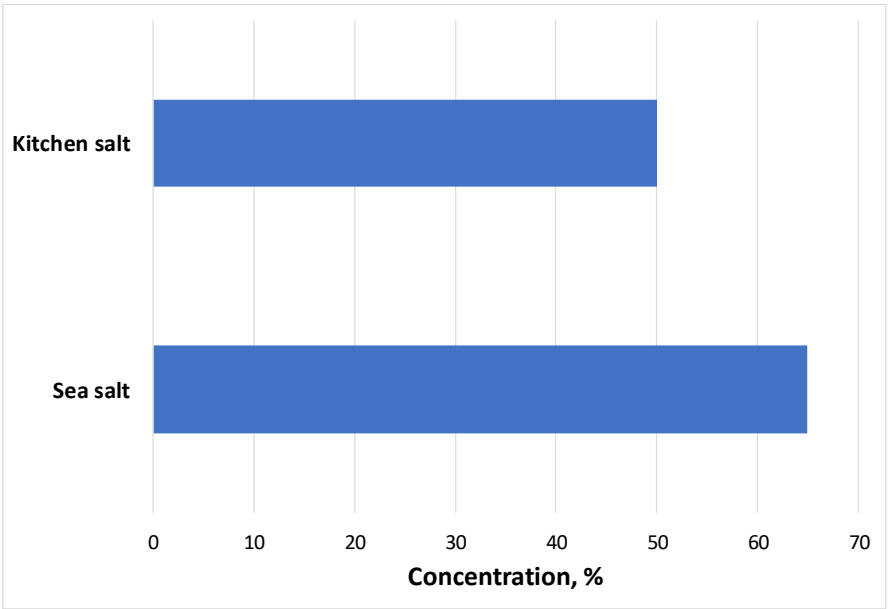
Because each ingredient of the mix influences on organoleptic and physicochemical properties of sausage meats, we studied the potential influence on such properties of mixes enriched by potassium chloride and preparation of "Vepro 75 PSC". There were studied the properties of control sausage meat, which composition conforms to the national standard of DSTU 3583:2015 **[51]**. "Kitchen salt. Specifications" and the experimental meat mixes salted by 20% solutions of kitchen salt (control sample) and by the mix of kitchen and sea salts enriched by extract of *laminaria*. The compositions of samples used in the experiment after their salting are shown in Table 3.

Table 3 Chemical composition of control and experimental samples of sausage meat, %.

Component	Designation of the sample	
	Control	Experimental
Albumen	12.3 ± 0.8	15.0 ± 0.7
Fat	9.4 ± 1.2	12.4 ± 1.0
Water	66.7 ± 0.7	70.1 ± 1.3
Sodium chloride	1.55 ± 0.1	1.2 ± 0.09
Sodium nitrite	0.0044 ± 0.0002	0.0012 ± 0.0002
Ash	0.97 ± 0.01	2.20 ± 0.01



a)



b)

Figure 3 Capability of salted meat to hold water: a) beef, b) pork.

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Sodium nitrite	0.0044 ± 0.0002	0.0012 ± 0.0002
Ash	0.97 ± 0.01	2.20 ± 0.01

The organoleptic valuation of taste and physicochemical properties of tested products showed that all tested parameters of quality of the experimental product surpassed the ones of the control one (Figure 4).

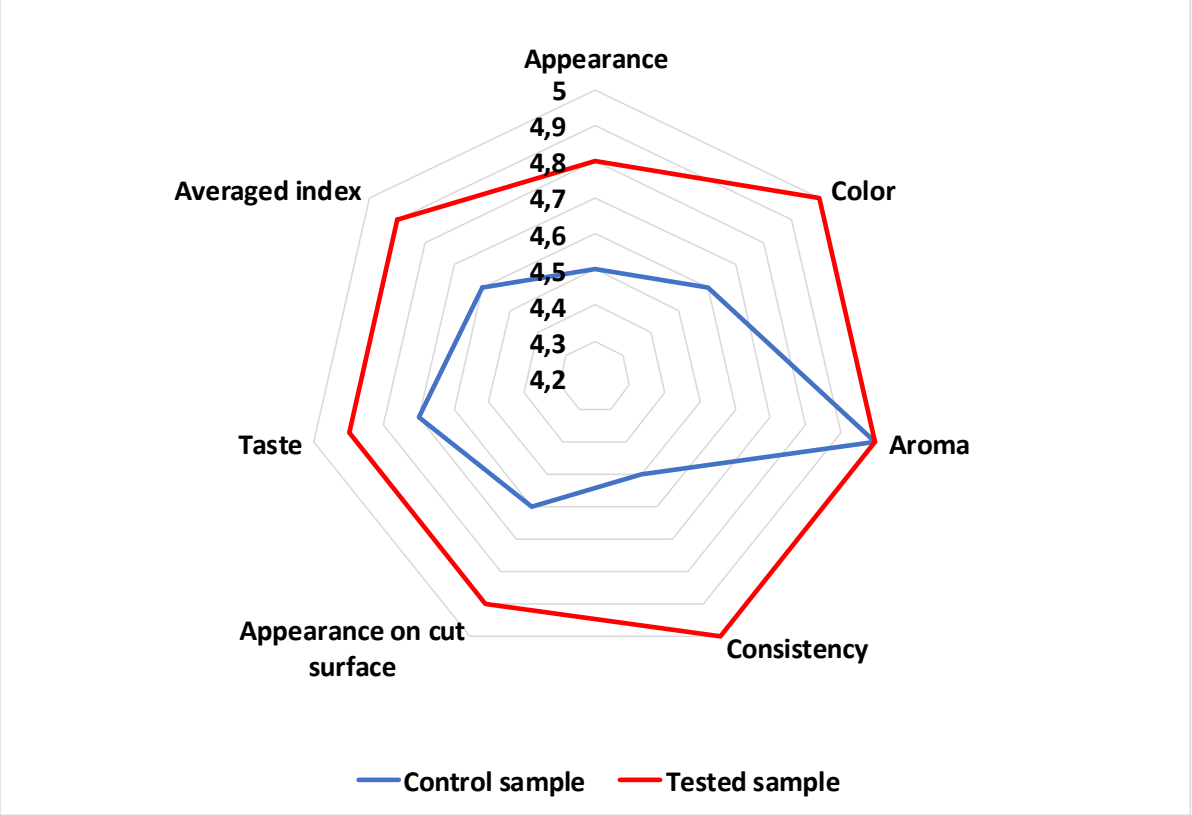

Figure 4 Results of organoleptic valuation of control quality and experimental mincemeat samples.

The physicochemical properties of sausage meats were controlled by indices of their active acidity, the activity of water, capability to hold water, and limiting shift effort (Table 4).

Table 4 Physicochemical properties of minces salted by kitchen salt and the mix of salts.

Index	Sample	
	Control	Experimental
Active acidity, pH	5.8 ± 0.1	5.5 ± 0.1
Activity of water, A_w	0.95 ± 0.05	0.96 ± 0.05
Limiting shift effort, Pa	605 ± 30	805 ± 39

It is clear from these data that replacing the usual salt for the mix of salts enriched by hydrophilic chlorides of magnesium and potassium permits an increase in the content of moisture in the mix and a decrease in the laying of meat in the mix.

Variation of the capability of the mincemeat in salting it by the sea salt shows Figures 5 and 6.

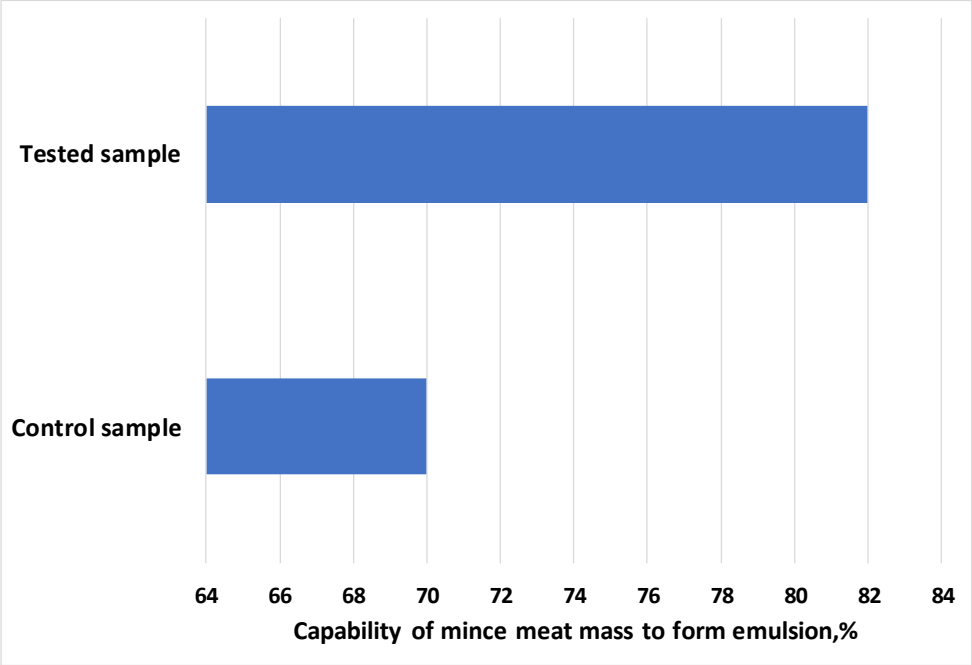

Figure 5 Capability of sausage meat systems to hold water.

Considering the results of this work, the formulation of the frankfurters character was developed by medicinal properties because of the decreased quantity of sodium in the mass.

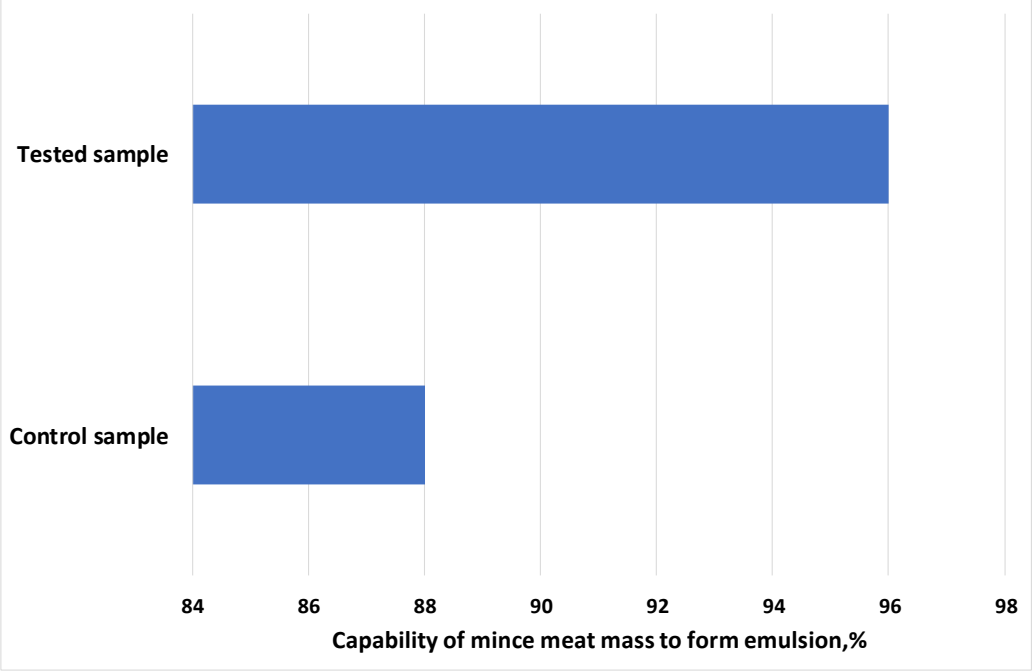

Figure 6 Stability of sausage meat systems.

Taking into account the results of experimental research, a recipe for sausages with health properties was developed sausages “Ozdorovchi” (Figure 7) by TU U 10.1-00493706-064:2019, which principal ingredients are milled beef and pork, bacterial preparation of “Iprovit-LRR”; preparation of porcine plasma blood of Vepro 75 PSC, sea salt of (Salty), citric fibers of Citri-Fi 100 and sugar.

The health properties of the product are related to several factors:

1) the product is characterized by an extended shelf-life;
2) the product is characterized by a reduced sodium content due to the use of sea salt.

Figure 7 Sausages “Ozdorovchi” by TU U 10.1-00493706-064:2019.

CONCLUSION

Based on a systematic analysis of domestic and foreign literature sources, as well as patent search, the problem of the limited range of food products enriched with digestible sodium compounds was revealed, which allowed justifying the prospects and relevance of use protein-bound forms of sodium to improve the quality of meat products.

Conducted market research, as well as consumer motivations and preferences when choosing meat products indicate expediency of launching new products with improved consumer characteristics and justify the choice of sausages for enrichment with sodium compounds.

Experimental studies have shown that replacing table salt with seaweed, which was enriched with kelp extract, can reduce the amount of sodium cation by 30%, enrich the mineral composition, maintain a feeling of sufficient salinity and enhance the health effects of the product.

It is proved that the addition of minced kelp extract can reduce the level of peroxide in the fat and meat mixture during storage for 10 days and makes it possible to slow down the growth rate of fatty acids present in the stuffing.

Therefore, there was realized the strategy of decreasing of consumption of excess sodium ions and giving the product of medicinal properties, which permits to recommend its introduction in serial production.

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