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Biotechnological aspects of the modification of secondary collagen-containing raw materials – tripe for the production of cost-effective functional meat products

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Abstract

The paper presents the scientific justification for the creation of a food product, that can satisfy the physiological needs of a person in the necessary energy, as well as the functional nature, created taking into account the nutritional value of food. The authors have chosen a method of limiting chemotaxis – the process of directing bacteria to the attractants, thereby preventing the development of microorganisms. The selected source of structural collagen protein – tripe, was cleaned and ground in a meat grinder, treated with diocide (dimethyl sulfoxide (DMSO) + sodium chloride or $(CH_3)_2S = O + NaCl$), introduced into sausage mince in exchange for lard. Mince was grinded and packed into protein shell, fried, boiled, and smoked. Obtained semi-smoked sausage product became more stable in storage than boiled sausage because it contained less moisture, had a high nutritional value and functionality. DMSO has been proven to have antioxidant effects. It prevents the oxidation of lipids by H_2O_2 and inhibits free radicals such as OH.

Keywords: dimethyl sulfoxide; microorganisms' development; bacterial movement; chemotaxis; food value; radioprotective properties.

Practical Application: The lack of the food for many people are obvious in many countries all around the world. It is caused either the lack of material to product this food, or the lack of people's money to buy the food or the lack of the quality of food that is the obstacle to consume it. The possible practical solving to all these problems is presented within this article. It is technology of the production of the of cost-effective functional meat products with many useful for the people qualities from the secondary raw materials.

1 Introduction

Biotechnologies for the production of functional food additives, collagen ingredients from collagen-containing raw by-products provide technical and economic advantages in comparison with analogues, reducing the production cycle by an average of 5-6 times, thereby increasing the yield by 2-3% and improving the quality by expanding their functionality and applied aspects (Glotova, 2004). Food security is of great social importance – the exercise of the human right to life. And also, the creation of functional products with protective properties for special purposes is based on the principle of supplementation of food with drugs. These products are intended for certain groups of people in extreme conditions such as those associated with radiation. In this regard, the authors set the task of expanding the range of meat products based on the use of by-products as a source of bio- and radioprotective compounds of modified collagen.

An attempt to maximally involve collagen-containing raw by-products in the production of food within the framework of traditional technologies did not give the desired results due to the low functional and organoleptic properties of the native components of connective tissue in the compositions of meat products. The following scientifically grounded requirements are imposed on functional products: the ratio of protein/fat should be equal to 1:1-1.2; the ratio of saturated and polyunsaturated fatty acids in the product is 3:1; mass fraction of protein – 12-16%; and the product must be balanced in minerals and vitamins. Food production can be viewed as a targeted combination of raw material properties and technological process parameters. As an alternative to heat treatment, an electromagnetic field, mechanical pressure, etc. can be used. To inactivate microorganisms, as well as to change the structure of the product, by creating new options, non-thermal processing methods are used, which open up new opportunities for targeted modification of the structure and functional properties of food products (Skliarov et al., 2021; Polupan et al., 2021). At the same time, the mechanisms of action of most of the processing are based on the interaction of chemical, physical and biotechnological factors (Budaeva, 2016).

A thorough analysis of the literature revealed that the proposed methods are designed for wider industrial use, it is scalable. The disadvantages include the mandatory adherence to certain processing regimes, a large amount of raw materials, as well as the high cost of equipment, safety measures and highly qualified personnel (Sokolov, 1970; Toepfl, 2011; Heinz et al., 2003). The most promising for expanding the capabilities and application of collagen-containing raw materials should be preliminary processing by biotechnological methods for targeted biomodification of the structure and, on this basis, the development of new approaches to food technology (Glotova,

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2003). According to the literature, by-products from pulp (liver, kidney, heart, diaphragm, tongue, head meat, lungs) have a high nutritional value because they have a high protein content (17 to 20%). The high collagen content in the tripe (from 8.3 to 10.2) is almost 2-3 times higher than in meat by-products (Budaeva, 2016). Note that the production concept of the tripe includes the tripe itself and the reticulum (Glotova, 2003).

This paper focuses on well-grounded approaches to the rational use of collagen-containing by-products in the meat production technology, taking into account the medical and biological requirements for nutritionally adequate diet. The aim of the paper is to change the physical properties of the structural biopolymer of the protein – collagen, in order to form food products with biological value and functional nature – radioprotective properties intended to improve the health of certain groups of people in extreme radiation conditions.

2 Materials and methods

Before the treatment with dimethyl sulfoxide (DMSO), the tripe is cleaned according to the appropriate rule: separation of fat tissue, clearing out the contents, scalding – short-term heat treatment of the inner and outer surfaces of the tripe with hot water, separation of the mucous membrane, cooling in running water (Glotova et al., 2003). The tripe was crushed on a grinder with a grid opening diameter of 2-3 mm. Dimethyl sulfoxide and common salt – diocyte, of the authors choice, were added: sodium chloride at the rate of 3 kg (3%) and DMSO – 200 mL (0.25%) per 100 kg of tripe (Dzhabbarov et al., 1992; Shukurlu, 2010). The resulting mass was thoroughly mixed for 3-5 minutes and placed in a refrigerator (temperature 275-277K). After storage for 24 hours, mince was prepared. Before preparing mince for a regular sausage, the liquid separated by storing the tripe in a salt mixture was drained. In order to prepare a functional product, the separated liquid is not drained.

Before salting, beef was pulverised in a meat grinder with a grid opening diameter of 16-22 mm, and for pork meat – 8-12 mm. They were salted and kept at a temperature of 275-277 K for a day. When kept in salt, the raw materials were placed in basins with a layer of 15 cm. After salting, the modified and ordinary (control, which is contained in salting under the same conditions and without DMSO), samples were subjected to infrared spectroscopy. The purpose of this research was to investigate the possibility of penetration of the inner layers of the tripe by the DMSO molecule, while maintaining its characteristic properties.

After rinsing with water, the samples were ground up in an agate mortar and dried in a freeze dryer. Sublimation process of dehydration of the control and test tripe samples were pre-frozen under deep vacuum with vapor condensation in surface condensers cooled by a circulating refrigerant. Drying was carried out at a residual pressure in a vacuum apparatus of the order of 0.4-0.7 mm Hg. To obtain tablets with a transparent lumen without cracks and opaque inclusions, 3 mg of dried and finely ground tripe powders were thoroughly mixed with 400 mg of KBr, which serves as a "filler", in an agate mortar and pestle. The resulting mixture was then compressed for 3 minutes in a special holder (mold) into tablets at high pressure (about 10 t/cm^2) in the form used in the SPECORD 75IR spectrophotometer, to obtain samples of tablets with a disk diameter of 10 mm. Registration of infrared transmission spectra of tripe samples was taken in automatic mode in the range of wave numbers 4000 ÷ 400 cm^{-1}.

Before preparing the mince, the salted beef was pulverised in a meat grinder with a grid opening diameter of 2-3 mm. The preparation and processing of mince was carried out in a mixer. Shredded beef head, tripe, diaphragm, and esophagus meat were mixed with spices and auxiliary materials for 2-3 minutes. To evaluate the influence of the composition of the mince with the participation of the tripe on the quality of the sausage product, six batches of mince were produced according to the first option and one batch according to the second option, which are presented in the Table 1.

Hog casings were filled with mince from each batch, and then twisted in the form of sausages 20-25 cm long. After the sausages had settled at a temperature not exceeding 281 K for 2-4 hours, they were roasted at a temperature of 363 ± 5 K for 90 minutes. The fried sausages were steamed at a temperature of 358 ± 5K for 60 min, until the temperature in the sausage thickness reached 348 ± 2 K. Then the sausage was cooled at a temperature not exceeding 293 K for 3 hours and smoked in fumatory at a temperature of 318 ± 5 K for 18 hours. After smoking, the sausage was cooled at a temperature of 286 ± 2 K. Spices and auxiliary materials included the following components (g/100 kg, raw material): sodium nitrite (solution) – 5; granulated sugar – 100; black pepper powder – 100; allspice powder – 100; coriander – 150; fresh garlic – 200. During the ruminal collagen modification, the introduction of a small amount of DMSO was chosen in such a way so that the total content of glycine, proline and hydroxyproline, which play a key role in the formation of

Table 1. Protein content in the pink slime from beef.

Beef offal by-products	The protein content, %			Collagen from total protein	*pH*	Lysine, % protein
	of common	collagen	salt soluble			
Lips	20.3 ± 2.9	13.40 ± 1.40	0.60 ± 0.01	66	7.1	7.1
Abomasum	14.4 ± 1.5	5.90 ± 0.80	0.70 ± 0.02	41.2	7	5.9
Tripe	17.1 ± 1.8	10.50 ± 0.80	0.80 ± 0.02	61.3	7.1	5.5
Esophagus meat	16.3 ± 1.4	5.70 ± 0.70	1.90 ± 0.01	34.7	6.2	6.5
Spleen	16.4 ± 0.6	1.90 ± 0.40	7.90 ± 0.20	11.3	–	6.6
Lungs	16.1 ± 1.0	4.30 ± 0.50	4.40 ± 0.08	26.6	–	5.5
Beef diaphragm	15.6 ± 0.8	6.20 ± 0.94	–	39.5	–	4.4
Meat from the head	18.8 ± 0.0	6.50 ± 0.00	–	36.3	–	6.2

a stable collagen structure, would amount to 20.6-30.9% of the total amino group (Shukurlu, 2010). However, the high degree of purification of collagen substances confirms the absence of tryptophan, the low content of methionine and tyrosine (Pauling & Pauling, 1978).

3 Results and discussion

In the set of by-products obtained from slaughter, the most significant source of collagen is the tripe, in which more than half of the proteins make up connective tissue, and this causes reduced levels of nutritional and biological value. As can be seen from Table 2, more than half of the proteins in the tripe form connective tissue and contain 61.3% of total collagen (Salavatullina, 2005). At the same time, a tripe with a high collagen content has the best amino acid balance, the absorption of muscle tissue and enzymes of the gastrointestinal tract, has a number of positive properties: it contains 5.5% lysine in relation to the total protein.

However, beef tripe is a good breeding ground for microorganisms, so they unstable during storage and are a perishable raw material. To prevent this activity of microorganisms, the authors used various methods of product treatment: antibiotics, salt, alkalis, acid, etc. Finally, the most appropriate way to solve this problem is to inhibit the chemotactic process with inhibiting agents on the molecular mechanisms of the signalling response. In chemotaxis, the "memory" of bacteria undergoes a rigorous selection aimed at the survival of the organism (Koshland et al., 1982). The duration of this memory action depends on the rates of methylation and demethylation of sensory receptors (Koshland, 1980). Chemoreceptors detect chemical gradients, determining changes in concentration over time and space (Hirota & Imae, 1983). Hyperpolarisation (the addition of an attractant or repellent results in a change in charge) is part of the chemoattractant-elicited response. All tested attractants cause it, while neutral substances have no effect, so it was necessary to create exactly this neutral environment.

Chemotaxis and hyperpolarisation have been detected in methionine (2-amino-4-(methylthio) butanoic acid – $C_5H_{11}NO_2S$) (Szmelcman & Adler, 1976). It serves as a supplier of the -CH_3 group to the membrane protein. Receptors bind to these groups and their structural counterparts, resulting in biological responses and hormone imitation. Consequently, -CH_3-groups are agonists, and it looks as if methylation is controlled by an ion channel, the opening of which depends on the presence of methionine (Springer et al., 1975). Considering that the dimethyl sulphide present in the chemical hydrolysate of defatted soybeans is formed by the decomposition of methyl sulfonium methionine, which itself is formed by the reaction between methionine and methyl chloride (Chichester et al., 1986). S-methylmethionine sulfonium (SMMS) is a methionine derivative most commonly found in plant sources. Commonly referred to as "vitamin U". Due to its powerful therapeutic effect in preventing erosion of the gastrointestinal tract (Cheney, 1950), as well as based on the conclusions of the authors (Kwak et al., 2009), who have shown that DMSO inhibits the reduction of methionine sulfoxide in yeast and mammalian cells in vivo, the authors selected DMSO processing of cleaned and minced tripe.

Another important reason for choosing DMSO was the property of this compound as a free radical scavenger and the suppression of hydroxyl (•OH) radicals caused by ionizing radiation. The authors (Kurmaz et al., 2013) show that the intermediate particles are identical in these systems, since the primary product of the capture of OH-radicals by the dimethyl sulfoxide molecule is the adduct – $(CH_3)_2SO^{\bullet}(OH)$. This compound decomposes spontaneously in a short time – $< 2.10^{-5}$s, forming $^{\bullet}CH_3$. G. Kashino et al. (2010), introducing a lower non-toxic concentration of DMSO before irradiation and studying its radioprotective effects, suggested that the radioprotective effects were not associated with the suppression of the general indirect effect with a decrease in the DMSO concentration and showed that a low concentration of DMSO has radioprotective effects and promotes the restoration of double-stranded breakdown of the saccharine phosphate nucleus of DNA, and does not suppress the indirect effect. DMSO was found to be protective only when administered prior to exposure; post-exposure dimethyl sulfoxide treatment had no effect on mortality. DMSO not just affects the initial biological damage caused by radiation, but it can even inhibit subsequent recovery processes (Kim & Moos, 1967).

Semi-smoked sausage is a highly profitable product, and the acquisition of radioprotective properties in such products is already unique. Consuming "Sheki" semi-smoked sausages protects against the development of radiation diseases in extreme conditions. It should be noted that sausages and other processed meat products are indeed recognised by the International Agency for Research on Cancer (IARC) as foodstuffs with proven carcinogenic activity. This does not mean that consumption of

Table 2. Recipe for a finished sausage product with beef tripe.

Ingredients, %	Samples						
	1						2
	A	*B*	*C*	*D*	*E*	*F*	-
Beef Head Meat – meat without bone cut off from beef head	40	45	48	50	55	55	50
Beef of the utility grade – muscle tissue with a mass fraction of connective and fat tissue of not more than 20%.	20	15	12	10	10	10	10
Semi-fat pork– muscle tissue with a mass fraction of adipose tissue of 30-50%	20	15	13	13	7	7	15
Beef diaphragm – an offal of the first grade	10	12	11	10	10	9	10
Beef esophagus – an offal of the second grade	5	6	6	5	5	4	5
The beef tripe (refers to cow (beef) stomach) – an offal of the second grade	3	5	7	8	9	11	7
Starch flour	2	2	3	4	4	4	3

sausage will necessarily cause cancer, but the risk does increase. During the heat treatment of meat, when amino acids are heated in the presence of carbohydrates, some carcinogenic nitrogen-containing substances are formed. But this applies not only to sausages, but also to processed meat products in general. So fried meat in this regard is much more harmful than sausage, which is cooked at relatively moderate temperatures (Bolshakov et al., 2002).

The sausage contains sodium nitrite or potassium nitrite colourants added as a fixative – they give the sausage familiar pink colour, and they also prevent the development of deadly botulism pathogens in the sausage. It is clear that it is impossible to produce sausage without nitrites, but it is important to understand: when getting into the human intestinal tract, these substances can be converted there into carcinogenic nitrosamines. However, nitrites can also be converted into nitrates, which are found in abundance in many vegetables and a variety of greens, including natural ones, grown in compliance with all the requirements of organic production. Therefore, the authors have to accept that a certain amount of nitrosamines is always formed in the human intestinal tract. Of course, excessive consumption of sausage increases this risk, which is why nitrites are used in much smaller quantities in the production of sausages for children. Against the background of other risks associated with ambient air pollution, active and passive smoking, carcinogens migrating into the air from the coating materials in the rooms, this risk is not very high – it is possible to live with such risk. The "Sheki" sausage has radioprotective properties, as well as most sausages that contain benzopyrene (the correct name of the isomers of this compound is 3,4-benzpyrene) below the detection threshold. Such sausage does not fit into a healthy diet at all, especially in extreme conditions.

Figure 1 presents the IR spectra of the control sample passing through all processes identical to the test sample, only without DMSO. Analysis of the IR spectra of beef tripe before and after treatment with diocide allowed to detect absorption bands characteristic of collagen molecules: 3264, 2914, 1620, 1520, and

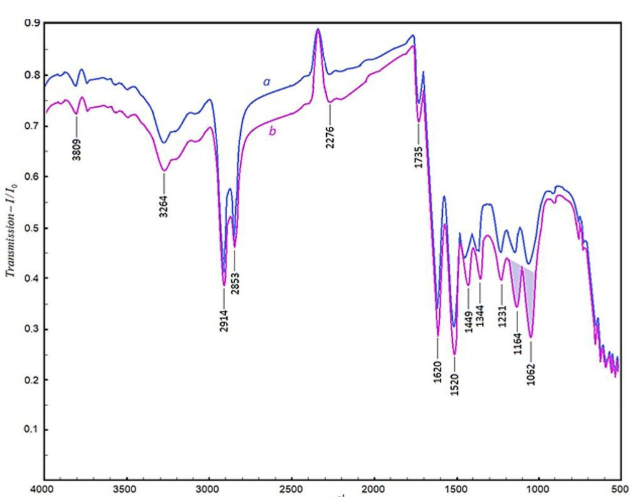


Figure 1. IR spectra of beef tripe: a – control sample (without dimethyl sulfoxide treatment); b – test.

1449 cm-1, which, according to literature data (Vidal & Mello, 2011; Belbachir et al., 2009), corresponds to the compounds of functional groups of collagen protein, which is involved tripe and occupies a significant part of this by-product. The most characteristic vibrational modes of DMSO are those in which S-O stretching predominates. The author (Skripkin et al., 2004) showed that the strong Raman band at 104.6 cm-1 and intense IR absorption at 1062.6 cm-1 was attributed to the stretching frequencies of S–O dominant particles in dimethyl sulfoxide liquid, estimated as centrosymmetric dimers with antiparallel polar groups S–O. The influence on the vibrational spectra of weak intermolecular C–H···O interactions and dipole-dipole interactions in liquid dimethyl sulfoxide is estimated, in particular, for the S–O stretching mode.

The study of the main physical, rheological, functional, chemical, technological and organoleptic indicators was carried out in accordance with the methods described in GOSTs, which are still used in the CIS countries and in the following sources (Antipova et al., 2001; Zhuravskaya et al., 1985). Tables 3 and 4 show the results of laboratory analysis of the obtained semi-smoked sausage of second-grade "Sheki".

To determine the organoleptic and physicochemical indicators, as well as for the output of products, samples were taken from each batch and analysed in the central laboratory of the Sheki Meat and Dairy Plant according to the established rule (Antipova et al., 2001; Zhuravskaya et al., 1985). As can be seen from Table 3, in terms of organoleptic index, batches A, B, C and D meet all the requirements for semi-smoked sausages of the second-grade. From the point of view of the profitability of raw materials used and the possibility of using the optimal amount of tripe, it is assumed that the recipes of batches C and D will be used. The recipes of batches E and F do not meet the requirements for the semi-smoked sausage in terms of taste, smell, colour, texture, and also moisture content. As can be seen from Table 4 – physicochemical indicators of second-grade semi-smoked sausages, the recipe of sausages shown in sample 2 – under the name "Sheki", turned out to be the best (Dzhabbarov et al., 1992). For a comparative analysis of the production cost and its high biological value, Table 5 shows the total protein and collagen content in the "Sheki" sausage.

Studies have revealed that the shelf life of the considered sausage is no more than 100 days at a temperature no higher than 285 K and relative humidity of 75-78%. The moisture content in the finished product is 57-60%, salt – 3%. The output of finished products – sausages to the mass of unsalted raw materials – 70-74%. Note that depending on the type and variety of sausages, the meat is crushed to varying degrees: into pieces weighing up to 400 g, up to 16-25 mm (meal) or to a finely ground (pulverised) state, up to 2-3 mm. When preparing second-grade semi-smoked sausage "Sheki", it was experimentally found that grinding the tripe into particles of 2-3 mm in size is more expedient than other methods. It should be emphasised here that salting the offal before grinding is unprofitable. When grinding in a salt + DMSO medium, there is an increase in the diffusion transfer from the rumen to the brine of protein, extractive and mineral substances. Therefore, it is necessary to keep the tripe in brine after grinding. Stirring the crushed tripe for 3-5 minutes is

Table 3. Organoleptic characteristics of sausages with different recipes.

Samples	Experienced batches	Appearance	Taste and smell	Section View
1	A	Sausages with a clean, dry surface without stains, slips, stuffing	Corresponds to the characteristic of this type of product, with a pronounced aroma of spices, smoking and garlic odour, with a pleasant taste, the taste is slightly sharp, moderately salty	Mince is uniformly mixed, the mince colour is pink, without grey spots, voids and contains pieces of tripe not more than 2-3 mm
	B	–	–	–
	C	–	–	–
	D	–	–	–
	E	–	The appearance of taste and smell unusual for this type of product begins	Looseness of mince appears on the section
	F	–	The taste and smell unusual for this type of product are enhanced	The looseness of mince increases
2	–	–	Characteristic of this kind of product, with the aroma of smoked spices and the smell of garlic, with a pleasant taste, the taste is slightly sharp, to the extent of salting	The looseness of mince increases. Mince is uniformly mixed, pink colour without grey spots, voids and contains pieces of tripe not more than 2-3 mm

Table 4. Physical and chemical indicators.

Samples	Experienced batches	Consistence	Content of		
			Moisture, %	Salt, %	$NaNO_2$, in mg/100 g
1	*A*	Elastic	57.0	2.9	0,004
	B	–	57.9	3.0	–
	C	–	58.3	2.9	–
	D	–	59.6	–	–
	E	Crumbling appears	62.0	2.8	–
	F	Crumbling increases	63.4	2.6	–
2	-	Elastic	59.5	2.9	–

Table 5. Results of laboratory analysis of second-grade semi-smoked sausage – "Kolkhiskaya" and "Sheki".

Offal	Semi-smoked sausage of the 2nd grade	Content in 100 kg of minced meat		
		offal	total protein	collagen
Beef of the second grade – muscle tissue with a mass fraction of connective and fat tissue of not more than 20%	Kolkhiskaya	45	7.97	1.81
	Sheki	10	1.77	0.4
Semi-fat pork – muscle tissue with a mass fraction of adipose tissue of 30-50%	Kolkhiskaya	15	1.94	0.22
	Sheki	15	1.94	0.22
Beef Head Meat – meat without bone cut off from beef head	Kolkhiskaya	6	1.08	0.39
	Sheki	50	9	3.25
Meat trimming	Kolkhiskaya	12	2.15	0.46
	Sheki	-	–	–
Beef diaphragm	Kolkhiskaya	8	1.24	0.15
	Sheki	10	1.55	0.19
Esophagus meat	Kolkhiskaya	4	0.64	0.2
	Sheki	5	0.8	0.25
Salted pork fat	Kolkhiskaya	7	0.01	0.01
	Sheki	–	–	–
The beef tripe (refers to cow (beef) stomach) – an offal of the second grade	Kolkhiskaya	–7	–	–
	Sheki		1.26	0.7
Starch or wheat flour of high quality	Kolkhiskaya	3	–	–
	Sheki	3	–	–
Total:	Kolkhiskaya	100	15.03	3.24
	Sheki	100	16.32	5.01

necessary in order to obtain a homogeneous salt + DMSO medium. Stirring the rumen for less than 3 minutes does not make it possible to completely dissolve the salt in the tripe + DMSO medium, and stirring for more than 5 minutes leads to the already known transition of valuable substances from the tripe to the brine. Note that the combined use of salt and DMSO in the treatment of the tripe can reduce the labour intensity of the process.

By the intensity in the IR spectrum of the absorption band $\nu_{S=O}$ groups in the region of 1070-1030 cm^{-1}, the diffusion penetration of DMSO into the tripe tissue was studied. It was found that during the preliminary treatment of the rumen with dimethyl sulfoxide, at the rate of 200 mL per 100 kg of offal and holding in the salt pickling for 24 hours at a temperature of 275-277 K, the concentration of DMSO at a depth h ($h = H/2$, where H is the thickness of the tissue and in the case H = 2-3 mm) takes on a constant value. This data suggests that a decrease in the amount of DMSO in the brine would lead to a defect in the tripe and an increase in the loss of this substance. The choice of the time of holding in salt – 24 hours, at a temperature of 275-277 K, is associated with the peculiarity of the native structure, composition and properties of the by-product, as well as with the inevitability of the loss of crushed tripe during salting, i.e., diffusion transfer from meat to brine of protein, extractive, mineral substances, vitamins.

It should be noted that the concentration of DMSO in the proposed sausage is 0.015%, which is significantly lower than the organosulfur compounds in garlic. The specified content of DMSO is achieved even if it would not suffer any losses in the various sausage production processes. In conclusion, the authors emphasise that sausage with such DMSO content cannot be harmful to health and, when applied, can show radioprotective properties; at normal air temperature, it is preserved for a long time. The safety of this product has been thoroughly tested by the authors in the Central Laboratory of the Sheki Meat and Dairy Plant over an experimental animal. It is known that chemotaxis gives mobile cells the ability to respond quickly to environmental challenges by moving cells into growth-friendly niches. This property is the result of the activity of specialised signal transduction systems on the mobility device, such as flagellum, pili type IV and sliding mechanisms. Once cells have reached a niche with favourable conditions, they often stop moving and group into complex communities called biofilms. An intermediate and reversible stage that precedes adherence to permanent adhesion often involves transitional contacts between mobile cells. Chemotaxis signalling has been implicated in modulating transient aggregation of mobile cells. In addition, the data show that chemotaxis-dependent transient cell aggregation events are behavioural responses to changes in metabolic traits that temporarily inhibit persistent attachment while maintaining mobility and chemotaxis. This mini-presentation considers several examples illustrating the role of chemotactic signalling in initiating inter-cellular contacts in bacteria moving through flagellum, pili, or sliding mechanisms (Alexandre, 2015).

In 1975 M.S. Springer et al. (1975), conducting on wild-type of *Escherichia coli* and four mutants, auxotrophic for methionine, came to the conclusion that methionine or one of its metabolites is involved in the movement of bacteria. After the methionine was removed, the mutants became unable to move at various intervals. The authors came to the conclusion that methionine or some methionine derivative is involved in the transduction of chemical stimuli that induce bacteria to move. Figure 2 presents a simple schematic model of the function of methionine. Methionine is used in the synthesis of the compound methionine sulfoxide (Met-O) reductase (Msr) – important enzymes that repair proteins damaged by oxidant and act as antioxidants to protect cells from oxidative stress (Springer et al., 1975).

Methionine sulfoxide reductases (Msr) are found in all spheres of life and play an important role in the elimination of oxidative damage to free and protein forms of methionine, a sulphur- containing amino acid, especially sensitive to reactive oxygen species (ROS) (Maupin-Furlow, 2018). These enzymes are involved in various physiological and pathological processes, including aging and neurological degenerative diseases (Schöneich, 2005). The two main families of Msr, MsrA and MsrB, differ in sequence and structure. MsrA stereospecifically catalyses the reduction of the Met-O S-epimer (Met-S-O) to Met, while MsrB catalyses the reduction of the R-form (Met-R-O). MsrA enzymes in yeast and mammals have a significant ability to reduce both free and protein bound Met-S-O. However, the MsrB enzymes in mammals reduce protein bound Met-R-O primarily because they have a lower activity against free Met-R-O (Lee et al., 2008). In addition to these two types of Msr, Lin et al. have recently discovered and described a new type of

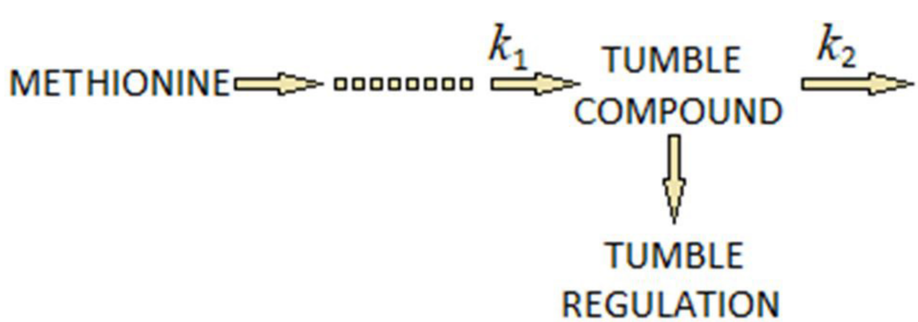
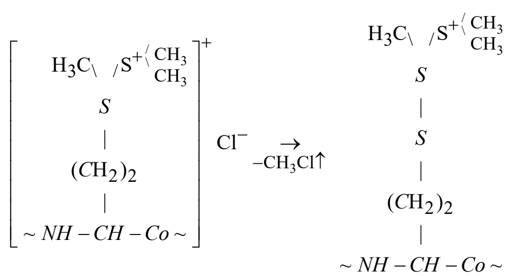


Figure 2. Model of methionine function in regulation of bacterial tumbling: k_1 and k_2 – rate constants of tumbling, the frequency of tumbling increases as the concentration of tumble compound rises; when k_2 reaches a high value, this results in the regulation and suppression of tumbling.

Msr enzyme from *Escherichia coli*, designated fRMsr (Lin et al., 2007). This enzyme catalyses the reduction of free Met-R-O, but it is not capable of reducing protein-bound Met-R-O or free Met-S-O. fRMsr is found in many unicellular organisms, including Saccharomyces cerevisiae, but is absent in all multicellular organisms (Le et al., 2009).

Instead, it became known that DMSO in mammalian cells affects various cellular processes, including the cell cycle, differentiation, apoptosis, inflammation, and lipid metabolism (Santos et al., 2003). In some bacteria, DMSO is used as a terminal electron acceptor under anaerobic conditions. DMSO reductase, which contains the molybdopterin cofactor, catalyses the reduction of DMSO to dimethyl sulphide and is well characterised at the biochemical and molecular levels (Schindelin et al., 1996). It was found that DMSO is reduced by methionine-S-sulfoxide reductase (MsrA). However, little is known about the ability of DMSO to reduce methionine-R-sulfoxide reductase (MsrB) or its effect on catalysis of the reduction of methionine sulfoxide. Kwak et al. (2009) show that DMSO acts as an inhibitor of MsrA and MsrB2 in the reduction of methionine sulfoxides by various inhibition mechanisms. DMSO competitively inhibited MsrA activity but acted as a non-competitive inhibitor of MsrB2 activity. Their study also demonstrated that DMSO inhibits the reduction of methionine sulfoxide in yeast and mammalian cells in vivo. Their subsequent research revealed that dimethyl sulfoxide can be reduced to dimethyl sulphide using MsrA, which stereospecifically catalyses the reduction of methionine-S-sulfoxide to methionine. Using mutant yeast cells with an Msr deletion, they demonstrated selective inhibition of the antioxidant function of MsrA by DMSO in *Saccharomyces cerevisiae*, resulting in an increase in oxidative stress-induced cytotoxicity (Kwak et al., 2010).

Thus, based on the literature data, the authors have put forward the assumption that DMSO can be used as an antagonist and it will form compounds with the methionine residue of the bacterial receptor protein *S-di-methyl-sulfonium-methionine* according to the following reactions (Equation 1):



(1)

This type of compound can also be formed by an intermediate product resulting from electrophilic substitution in the thioether group of methionine protonated with DMSO by analogy with the reaction observed in the series of phenols and their ethers. During the experiment, NaCl was used as a catalyst for the elimination of DMSO during tripe treatment. The choice gave a positive effect, and the authors assume that this is due to the combined action of DMSO + NaCl, as a *diocide*: antiseptic + detergent. In this case, sodium and liquid ammonia, formed as a result of the vital activity of microorganisms, catalytically participate in the S-dimethylation of the methionine residue to form *S-dimethyl sulfonium methionine*. Highly volatile methyl chloride – CH_3Cl is released.

It is known that one of the methods for detecting methyl chloride is its burning with a distinctive green flame. Therefore, when storing the mass, tripe + NaCl + DMSO in the refrigerator, a gas sampling tube made of silicone rubber with an inner diameter of 4 mm and a length of 70 cm was placed in a sealed vessel. One end of the tube was in the middle of the lid – inside the vessel, and the other end of the tube was attached to laboratory gas tank. At the end of the day, the collected gas in the gasholder was ignited in an open place, near the outlet pipe of the gasholder. The gas burned with a greenish flame. This was an indirect way of confirming that DMSO binds to receptor methionine of the bacteria. Note that peroxides and other oxidants (for example, under certain conditions, atmospheric oxygen and even DMSO, which is often used in peptide syntheses) lead to the formation of methionine S-oxide. In the vast majority of cases, because of this, peptides are deprived of their biological activity. One of the most promising ways to control tumor growth may be the use of enzymes that reduce the concentration of certain amino acids in plasma, in particular, asparagine, arginine, phenylalanine, and methionine (Pokrovskii et al., 2017). In this sense, "Sheki" semi-smoked sausage is one of the most promising means of protecting people from radiation.

4 Conclusion

It has been determined that the optimal way of cost-effective use of ruminal collagen is the use of tripe for the production of semi-smoked sausages. It has been determined that in the production of second-grade semi-smoked sausage, mince is prepared in the following composition: beef head meat – 48-50%, tripe – 6-8%, beef of the second grade – 10-15%, semi-fat pork – 10-15%, diaphragm – 10-11%, esophagus meat – 5-6%, wheat flour or starch – 2-4%. A distinctive feature of this recipe is reduction of the amount of second-grade beef by 30-35% and the use of tripe instead of bacon, which undergoes a special treatment with dimethyl sulfoxide, in its raw form It has been determined that the shelf life of the considered sausage does not exceed 100 days at a temperature not exceeding 285 K and relative humidity of 75-78%. The moisture content in the finished product is 57-60%, salt – 3%. Output of finished products – sausages, to the mass of unsalted raw materials: 70-74%.

Modern trends in the field of nutrition are associated with the creation of an assortment of functional products that contribute to the sustentation and correction of health during their daily consumption due to a regulating and normalising effect on the body as a whole or its certain organs or functions. A large role in this is assigned to connective tissue proteins as dietary fibres with all their inherent physiological properties. The second focus is on DMSO, which is used to treat a wide variety of different conditions. DMSO has an antiseptic effect as it is a good oxidising agent. DMSO microcirculation has a vasodilating effect and reduces the stability of peripheral blood vessels. Improves microcirculation in brain tissues. This reduces the possibility of erythrocyte accumulation, increases the permeability of the haematological barriers of the lungs and liver, but this does not affect the kidneys, etc. A formulation of a profitable product has been composed; second-grade semi-smoked sausage "Sheki" has a functional property, which is especially important in conditions of frequent extreme situations, the presence of zones of environmental risk and man-made disasters that occur in almost all countries of the world, including Azerbaijan.

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