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Perspectives for the application of the sous-vide cooking in the development of products for public catering

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ABSTRACT
The effect of different sous-vide cooking temperature-time combinations on beef steak's microbiological, physicochemical, and organoleptic parameters were analysed. The organoleptic quality of souse-vide beef steaks was excellent. The sous-vide cooking had a considerable impact on the physical and chemical parameters of the product. The amino acid composition of the sous-vide cooked meat was similar to the original fresh beef. Souse-vide meat cooking does not denature proteins as much as conventional cooking and frying. In some cases, the microbiological parameters exceeded the expected legislation limit. We recommend additional antimicrobial barriers, such as lower pH and antimicrobial extracts from ginger in a concentration of 0.5 – 1.5% of the weight of fresh meat, combined with garlic powder. The final product had an extended shelf life compared to control samples prepared by boiling and frying.

Keywords: sous-vide, beef, meat, microbiological quality, microstructure, weight loss, product yield, ginger

INTRODUCTION
The sous-vide cooking consists of preparing products closed in a thermally stable vacuum package under strictly controlled temperature and heating duration (Figure 1) **[1]**. The development of this technology responds to the population's need for ready-to-eat, microwave-usable semi-finished products with a high nutritional value, do not contain additives and preservatives, and are affordable **[2]**.

Products prepared by the sous-vide cooking has several advantages. The economic benefits of preparing products using sous-vide cooking are a more efficient use of labour and equipment due to centralised production and an increase in the product's shelf life due to vacuum packaging **[3]**. Sous-vide cooking can be a good solution for reducing food waste in public catering enterprises, where it is impossible to predict the demand for specific menu items **[4]**. In sous-vide products, the growth of aerobic bacteria is limited, and the risk of contamination of the product is reduced. Also, heat transfer to the products inside the vacuum packaging is optimised. Sous-vide cooking can produce food products with constant, reliable, and reproducible organoleptic characteristics. The plastic film prevents the loss of volatile flavours and water during cooking in the sous-vide, which improves the organoleptic quality, promotes juiciness and tenderness of the meat, and increases the product's yield. Sous-vide heat processing preserves the nutritional value of products. It minimises the content of harmful chemicals that are formed during incomplete combustion or pyrolysis of organic substances and are concentrated in meat during frying on coals, grilling, and smoking **[2]**. Thermal denaturation of proteins in cooked meat should be expected. It includes aggregation, binding, oxidation and solvability. These processes affect the release of nutrients and minerals and their bioavailability during digestion, which, in turn, can affect the commercial value of the product. In some studies, the influence of the sous-vide method on the kinetics of protein digestion and the release of minerals such as Cu, Fe, Zn, and Se was studied **[5]**.

Figure 1 Food preparation by the sous-vide method.

The microbiological risks associated with sous-vide cooking is the growth of the spore-forming *Clostridium botulinum* pathogen bacteria and the production of toxins. Non-spore-forming food pathogens in sous-vide products include *Escherichia coli*, *Salmonella*, *Staphylococcus*, *Listeria*, and *Yersinia*. These pathogens must be destroyed during heat processing. However, they can affect consumer health if the raw ingredients are of low microbiological quality when they are secondarily contaminated during production due to improper manufacturing practices **[6]**. Thus, the primary attention in developing the technology for sous-vide production should be directed to ensuring the product's microbiological safety.

The issue remains relevant since no research has been conducted in the Republic of Kazakhstan on using sous-vide technologies for public catering production using regional raw materials. The purpose of this work was to compare the organoleptic, physicochemical, microbiological parameters of beef steak prepared by the sous-vide method and using conventional boiling and frying methods. Ginger was included in the recipe of the sous-vide product, which, according to the literature data **[7]**, has antimicrobial properties.

Scientific Hypothesis

The sous-vide cooking would result in a product with increased shelf life and better organoleptic quality than conventional cooking and frying.

MATERIAL AND METHODOLOGY

Samples

We have used fresh beef meeting the requirements of quality standard GOST 33818-2016 **[8]**. Other ingredients include ginger, salt, garlic powder, butter. Components were obtained from the grocery shop.

Instruments

Beef packaging for the production using the sous-vide method was carried out in a vacuum packaging machine manufactured by Besservacuum of the FAVORIT series with a final pressure of 200 Pa. The heat processing of meat by the sous-vide method was carried out on the Stebra sous-vide SV 2 equipment. During cooking, the meat temperature was controlled by an infrared thermometer with a laser designator and a penetrating food probe Testo 826-T4.

Laboratory methods

Microbiological testing was performed according to technical standard GOST 10444.15-94 **[9]**. The number of mesophilic aerobic and facultative anaerobic microorganisms was analysed. According to legislation, the number of microorganisms in food products should not exceed $1x10^3$ CFU/g.

The content of amino-ammonium nitrogen in meat was determined by standard GOST 55479-2013 **[10]**. The method is based on binding amino groups and ammonia with formaldehyde in a neutral medium, followed by titration with alkali of carboxyl groups, equivalent to the number of free amino groups.

The amino acid composition of the products was determined by standard GOST 55569-2013 **[11]**. The method's principle is to decompose the sample for analysis by acid hydrolysis with the conversion of amino acids into free forms, the production of FTC-derived amino acids, their further separation, and quantitative determination by capillary electrophoresis.

The acidity of meat was determined by standard GOST R 31470-2012 **[12]**. The method is based on titrating an aqueous extract from the product with an alkali solution. The acidity is expressed in Turner degrees (°T), equal to the number of cubic centimetres of a sodium or potassium hydroxide solution with a molar concentration of 1 mol/dm^3 used to neutralise the acids contained in 100 g of the product.

The pH of the products was measured according to the standard GOST R 51478-99 **[13]**.

The organoleptic evaluation of the product was carried out according to the standard GOST 9959-2015 **[14]** using the method of quantitative descriptive analysis.

Description of the experiment

Firstly we have prepared the product according to the internal recipe. The recipe includes fresh beef meat, ginger in 0.5 – 1.5%, garlic powder – 1.0%, salt – 1.5%, and butter – 2.0% of the mass of raw meat steak. The meat was marinaded in the mixture of above mentioned ingredients. Consequently the prepared meat products were devided into several gropus to be cooked by conventional heat processing (boiled at 100 °C, fryied at 180 °C), and cooked by sous-vide technology. Sous-vide product was vacuum packed and cooked at temperature of 55, 65, 75°C and during 45, 60, and 90 minutes. Another groups of samples was boiled during 30 – 165 min and sous-vide cooked at 70 °C during 30 – 315 min.

The mass of one steak for packaging in a vacuum film was 105 ±8 g. The bags were made of high-density polyethylene with a thickness of 85 – 105 microns. This material is safe and resistant to aggressive environments withstands temperature conditions from -80 to +110 °C. The meat preparation consisted of rubbing the meat with oil, salt, and spices.

Secondly, the final product were analysed.

The microbiological (Quantity of Mesophilic Aerobic and Facultative Anaerobic Microorganisms QMAFAnM) and physical-chemical (pH, acidity and amino-ammonia nitrogen content) parameters of sous-vide meat steaks cooked in the temperatures mentioned above and times were analysed. Also, the dependence of the product's acidity on the content of amino-ammonia nitrogen in 10 cm^3 of the product extract was investigated.

The weight loss of the product during conventional regular boiling and sous-vide boiling at 70 °C, depending on the ageing time (30 – 165 min) was analysed.

The amino acid composition of raw, boiled, fried, and sous-vide cooked meat steak was analysed.

The QMAFAnM of meat steak prepared by the sous-vide method at 70 °C for 90 minutes and control samples prepared by cooking (100 °C) and frying (180 °C) after 5, 24, 48, 72, and 168 hours of storage at a temperature of 2 – 4 °C was analysed.

Finally, the organoleptic evaluation of meat steak prepared by the sous-vide method, in the mode of 70 °C 90 min, was analysed by a trained expert commission. Qualitative organoleptic parameters of the product were determined by the scoring method.

Statistical Analysis

The mass loss during the heat processing in the cooked meat samples was determined as the ratio of the mass of meat before and after heat processing, expressed as a percentage. Experimental results concerning this study are reported as means ± standard deviation (SD). The Student's t-test was used to test the statistical significance of the results at alpha level 0.05. We have used the Xlstat version 2022.1 (Addinsoft) statistical software.

RESULTS AND DISCUSSION

The results of the first experiment are present in Table 1. The pH of the sous-vide products varied in intervals 5.76 – 6.79. We have not found an increase in the pH in all sous-vide products with the same ginger content, ageing time, and different cooking temperature. The pH decreases slightly at temperatures 55 °C and 65 °C, except for the temperature of 75 °C with ginger in concentrations 1.0 and 1.5%. The sous-vide cooking affected the amino-ammonia nitrogen in the product. It can be assumed that under certain conditions of preheating, pH, and microbiological quality of raw materials, the destruction of protein proceeded rapidly, which led to the accumulation of biogenic amines. The increased content of amino-ammonia nitrogen in the product does not corresponds to a high number of mesophilic aerobic and facultative anaerobic microorganisms in all cases. It is possible to note a tendency to decrease the product's acidity with an increase in the content of amino-ammonia nitrogen in it (Figure 2).

Table 1 Microbiological and physicochemical parameters of the sous-vide beef steaks.

Pasteurisation temperature°C	Duration of ageing, min	QMAFAnM, CFU/g*10^{-3}			pH			Acidity, °T			Amino-ammonia nitrogen, mg/10 cm^3 extracts		
		Part of weight of ginger, %											
		0.5	1.0	1.5	0.5	1.0	1.5	0.5	1.0	1.5	0.5	1.0	1.5
55	45	6	18	1	6.35	6.58	6.59	4.55	3.90	4.80	1.25	1.93	1.10
	60	3	1	3	5.79	5.97	5.81	5.55	3.36	5.28	0.95	2.01	1.05
	90	3	1	4	6.17	5.85	6.03	5.99	3.93	3.96	0.91	1.78	0.91
65	45	2	3	7	6.32	6.79	6.40	5.88	4.85	3.85	1.01	1.33	1.85
	60	8	1	5	6.19	6.07	6.19	3.70	5.64	3.90	1.93	0.90	1.93
	90	6	8	3	5.98	5.91	6.08	5.35	5.16	5.25	0.81	0.89	0.91
75	45	6	4	7	6.02	5.94	5.90	5.81	5.85	3.94	0.75	0.93	1.88
	60	7	6	12	5.77	6.40	6.41	3.96	5.99	5.00	1.92	1.01	1.09
	90	6	3	3	6.02	6.60	5.76	4.80	3.96	5.88	1.27	1.85	0.97

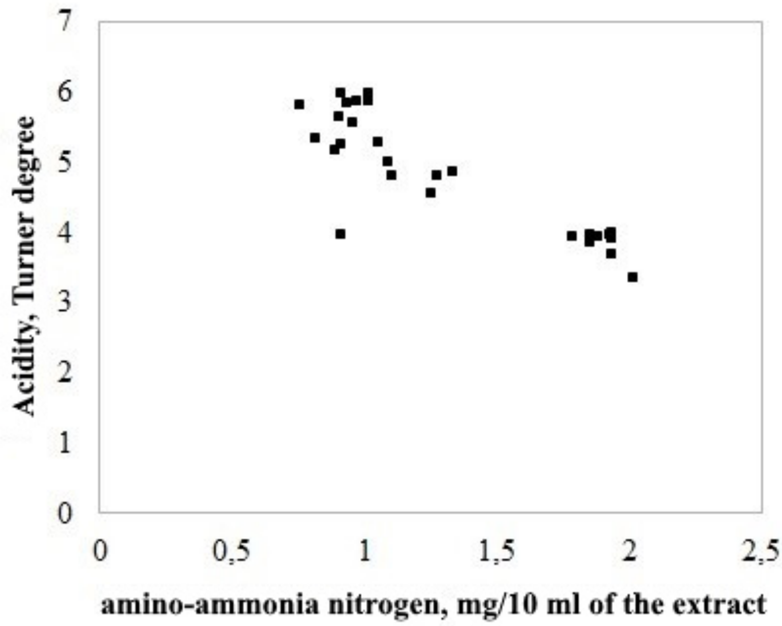

Figure 2 The dependence of the product's acidity on the content of amino-ammonia nitrogen in 10 cm^3 of the product extract.

Table 2 shows the weight loss of meat subjected to conventional boiling and sous-vide cooking at 70 °C, depending on the ageing time. With an increase in the meat ageing from 30 to 165 minutes, the loss of meat mass increased both in the normal and the sous-vide cooking samples, but in the second case, the losses were less. The weight loss decreased with further ageing of sous-vide meat and cooking at 70 °C.

The amino acid composition of the fresh meat cooked by boiling, frying, and sous-vide is presented in Table 3. The amino acid content in the fresh meat and the sous-vide steak is very similar. Therefore the protein denaturation in the sous-vide product is less than in the boiled or fried products. Also, there is no considerable moisture loss from the vacuum-packed steak. The content of all amino acids in the boiled meat increased. It is the consequence of the moisture and fat content decreasing in the sample during the cooking. When frying, it is possible to note a decrease in the content of lysine and alanine in the sample compared to the fresh meat, which may be a consequence of the protein denaturation during frying. There are also small differences in leucine + isoleucine, glycine, histidine, and proline in fried meat compared to fresh meat.

Table 2 Weight loss of the product during conventional boiling and sous-vide boiling at 70 °C, depending on the ageing time.

Ageing, min	Mass loss, %	Ageing, min	Mass loss, %	Ageing, min	Mass loss, %
Regular boiling		The sous-vide method			
30	35	30	35	180	36
45	42	45	38	195	39
60	48	60	39	210	34
75	44	75	32	225	37
90	46	90	42	240	41
105	46	105	40	255	39
120	47	120	42	270	40
135	47	135	40	285	31
150	46	150	44	300	30
165	46	165	41	315	40

Table 3 Amino acid composition of raw, boiled, fried, and cooked using sous-vide method meat steak.

Amino Acid	Mass fraction of amino acid, % in a sample of meat steak prepared by the method:			
	raw	boiled	fried	sous-vide
Arginine	0.95 ±0.38	1.39 ±0.56	1.13 ±0.45	0.89 ±0.35
Lysine	0.85 ±0.29	1.04 ±0.35	0.39 ±0.13	0.78 ±0.27
Tyrosine	0.50 ±0.15	0.64 ±0.19	0.51 ±0.15	0.49 ±0.15
Phenylalanine	0.71 ±0.21	0.93 ±0.28	0.80 ±0.24	0.63 ±0.19
Histidine	0.43 ±0.21	0.48 ±0.24	0.36 ±0.18	0.35 ±0.17
Leucine+	0.79 ±0.20	1.01 ±0.26	0.61 ±0.16	0.72 ±0.119
Methionine	0.40 ±0.14	0.48 ±0.16	0.38 ±0.13	0.38 ±0.13
Valine	0.64 ±0.26	0.83 ±0.33	0.53 ±0.21	0.63 ±0.25
Proline	0.55 ±0.14	0.69 ±0.18	0.71 ±0.19	0.52 ±0.14
Threonine	0.48 ±0.19	0.62 ±0.25	0.47 ±0.19	0.49 ±0.19
Serine	0.28 ±0.07	0.38 ±0.10	0.26 ±0.07	0.29 ±0.08
Alanine	0.63 ±0.16	0.72 ±0.19	0.31 ±0.08	0.54 ±0.14
Glycine	0.43 ±0.14	0.51 ±0.17	0.35 ±0.12	0.38 ±0.13

Notably, on average, there are more acceptable microbiological parameters of the product prepared at a temperature of 55 °C, compared with temperatures of 65 and 75 °C (Table 1). Unfortunately, only in some cases, the microbiological indicator of the product does not exceed the standard value of ($1x10^3$ CFU), for example, at modes 55 °C, 45 min, 1.5%, 55 °C, 60 and 90 min, 1% and 65 °C, 60 min, 1%. These results indicate the antimicrobial properties of ginger are probably maintained only if the temperature does not exceed 55 °C.

The number of mesophilic aerobic and facultative anaerobic microorganisms in meat steaks prepared by the sous-vide cooking (at 70 °C for 90 minutes) and control samples prepared by cooking (100 °C) and frying (180 °C) was analysed after 5, 24, 48, 72, and 168 hours of final product storage at a temperature of 2 – 4 °C (Table 4). Based on this data, the shelf-life of the sous-vide product should not exceed 72 hours.

Table 4 The QMAFAnM (CFU/g) of meat steak prepared by the sous-vide method in the mode of 70 °C for 90 minutes, conventional boiling and frying, after storage at a temperature of 2 – 4 °C.

Time, h	Raw materials	Boiled	Fried	Sous-vide 70 °C 90 min
5	continuous growth	$3.5x10^2$	$2x10^2$	not detected
24	continuous growth	$13x10^2$	$9x10^2$	not detected
48	continuous growth	$22x10^2$	$17x10^2$	$2x10^2$
72	continuous growth	continuous growth	continuous growth	$8x10^2$
168	continuous growth	continuous growth	continuous growth	$36x10^2$

The microstructure of raw, boiled meat prepared using the sous-vide method is shown in Figure 3 and Figure 4. With an increase in the duration of the processing, the bundles of muscle fibres become looser. There are noticeable changes in the meat structure after 130 minutes of cooking, and respectively after 165 min for sous-vide (70 °C, 90 min) cooking.

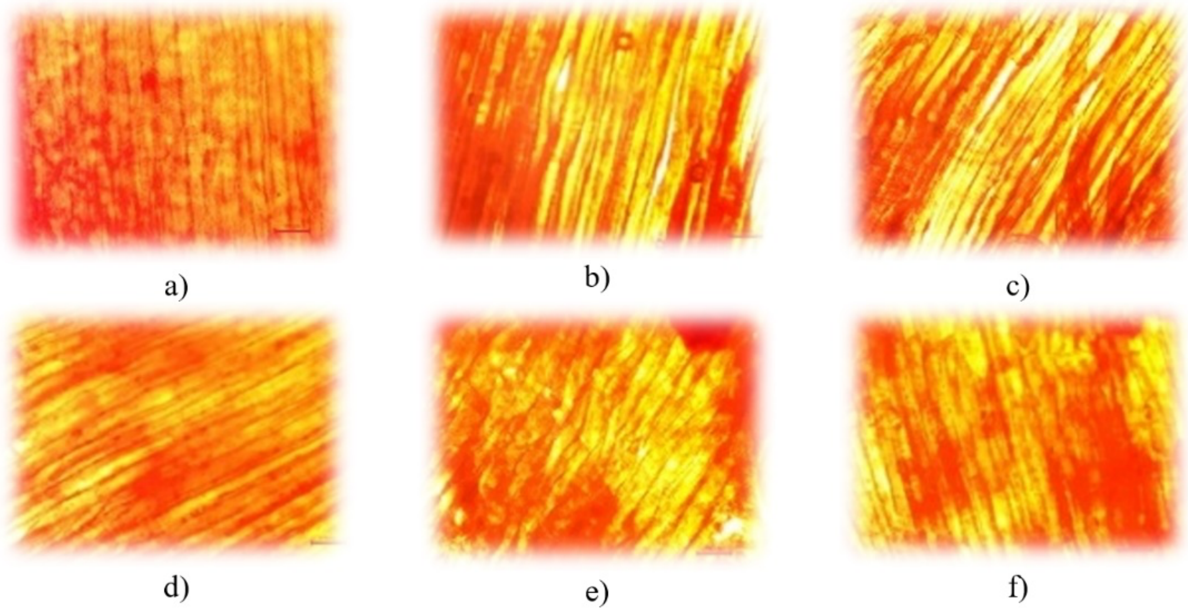

Figure 3 Micrographs of raw and boiled meat.
Note: a) raw meat b) boiled 60 min/70 °C; c) boiled 75 min/70 °C; d) boiled 90 min/70 °C; e) boild 130 min/70 °C; f) boiled 165 min/70 °C (magnified ten times).

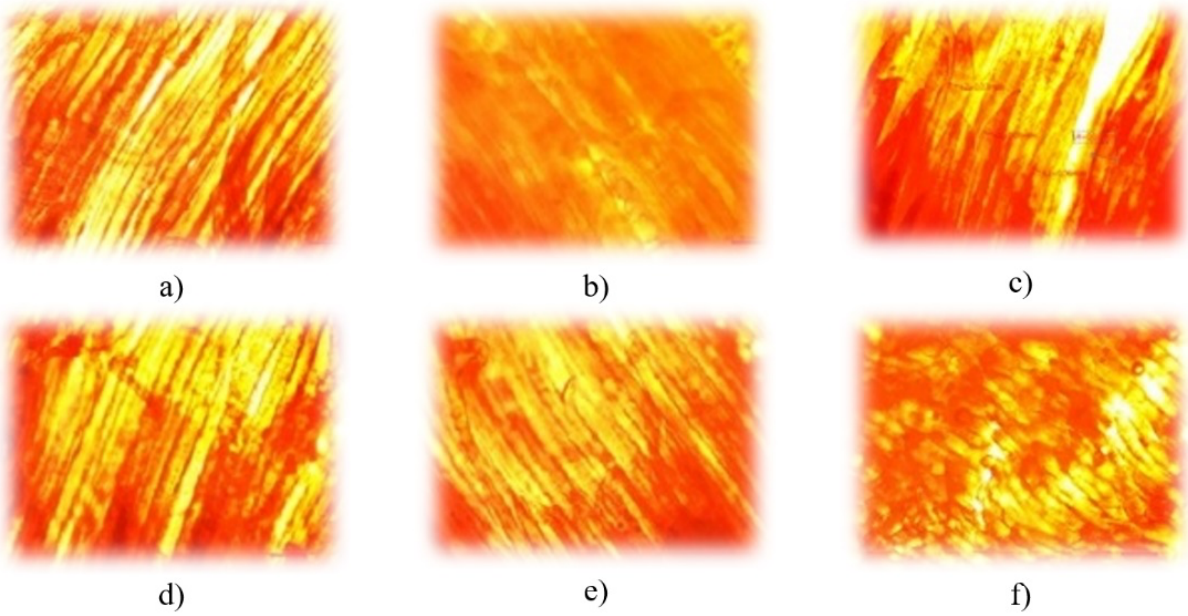

Figure 4 Micrographs of meat prepared by the sous-vide method.
Note: a) 75 min/70 °C; b) 95 min/70 °C; c) 105 min/70 °C; d) 120 min/70 °C; e) 135 min/70 °C; f) 165 min/70 °C (magnified ten times).

The indicators of the organoleptic analysis of the sous-vide product (70 °C, 90 min) are present in Table 5. This cooking mode was the best in comparison with other sous-vide modes tested. The final product reached the best for smell, colour, taste, and consistency characteristics.

Table 5 Indicators of organoleptic evaluation of meat steak prepared by the sous-vide method at 70 °C, 90 min.

Indicator	Evaluation by the commission
The appearance of the base	4.8
Smell	5.0
Taste	4.9
Colour	4.8
Consistency (succulence, tenderness)	4.8
Total	4.9

The most significant technological and organoleptic properties of meat depend on the meat tissue's ability to retain water and form a gel. Myofibrillary proteins retain most of the water inside the muscle. An increase in temperature from 40 °C to 90 °C causes denaturation and compression of these proteins. Also, at 56 – 62 °C, the irreversible change in collagen occurs. Up to 60 °C, the muscle fibres contract in the transverse direction, and the gap between the fibres increases. Above this temperature, the muscle fibres contract in the longitudinal direction, which causes a significant loss of water, the degree of loss increases with the cooking temperature **[15]**. Prolonged meat cooking at a low temperature can lead to protein proteolysis by heat-resistant enzymes, affecting water retention and cooking losses **[16]**. The sous-vide cooking at 70 °C for 30 to 165 minutes was accompanied by a meat steak weight loss of 35 to 44%. After the usual cooking for 30 minutes, the weight loss of the steak was 35%, which is less than with the 3-hour sous-vide cooking at 70 °C. This finding is similar to other research **[17]**. Thus, the duration of cooking in the sous-vide mode has a considerable impact on the yield of the product.

In another study **[18]**, the influence of various combinations of temperature (70 °C and 80 °C) time (60, 90, and 120 minutes) on the yield of the beef sous-vide was studied. The beef meat was marinated in teriyaki sauce or beer. The mass loss ranged from 5.11 to 8.17%. As the temperature increased, there was an increase in weight loss of beef prepared by the sous-vide method. The longer the cooking time, the greater the water loss in the beef samples was **[18]**. The marinating process increases the yield of beef, pork, and poultry; this may be why the loss of beef mass in work **[18]** was less than in the present work. In work **[15]**, the influence of the cooking mode of lamb meat by the sous-vide method on the moisture content and product yield was investigated. Various combinations of temperatures (60, 70, and 80 °C) and cooking time (6, 12, and 24 hours) are considered. Weight losses during the preparation of lamb sous-vide at 60 °C during 6, 12, and 24 hours were 20.77%, 24.72%, and 28.78%; at 70 °C the weight losses were 30.67%, 33.42%, and 32.80% and at 80 °C the weight losses were 35.22%, 35.61%, and 39.41%, respectively. Our results of weight loss are similar to these results. In another work **[4]**, the product yield from chicken breast prepared by the sous-vide method was analysed. The product yield were: 89.4% (1 h, 64°C), 82.4% (80 min, 66°C), and 83.1% (35 minutes, 75 °C). After conventionally cooking steamed chicken breast, the yield was 72.4% and when boiling 69.5%. The product yield from the semitendinous beef muscle prepared by the sous-vide method at 60 °C with 4.5 and 10 hours of ageing was evaluated **[5]**. The weight loss of the product was 20.89 and 28.67%, respectively. The sample size, heating schedule, and raw material history (for example, freeze-thawing cycles) can affect the kinetics of water loss by the product **[16]**.

The formation of amino compounds and ammonia bases during the heat processing of meat products occurs due to the deamination and decarboxylation of both free amino acids and amino acids in proteins and polypeptides. The higher the quality of the heat-processed product, the less ammonia it contains. However, since the initial content of amino-ammonia nitrogen in meat can be different, its absolute content after pasteurisation cannot be used to judge the qualitative changes in the product **[19]**. In this work, the content of amino-ammonia nitrogen in meat samples prepared in different sous-vide modes, depending on the cooking mode, ranged from 0.81 to 2.01.

The content of amino-ammonia nitrogen in vacuum-packed beef processed with a pressure of 400MPa for 3 minutes was 0.10; 0.17, and 0.21 mg/10 cm^3 extracts after 10, 30, and 39 days of storage, with the norm for fresh meat – less than 1.26/10 cm^3 **[20]**. This fact indicates the safety of the protein components of meat. The deterioration of raw meat quality is associated with proteolysis and the growth of microorganisms. The amount of biogenic amines formed under the action of decarboxylase of amino acids of microbial origin depends on several factors, such as raw materials (meat composition, pH, hygienic conditions), additives (salt, sugar, nitrites), storage conditions, meat processing mode **[21]**. In this paper, the increased content of amino-ammonia nitrogen in some sous-vide modes corresponds to samples with a low microbial load (for example, 55 °C, 60 min and 90 min ageing, 1.0% of ginger). However, in most samples with increased content of amino-ammonia nitrogen, the microbiological indicator was higher than average.

Regarding the safety of biogenic amines after the preparation process, the literature data are contradictory. Some authors have concluded that these compounds are heat-resistant, and their level does not considerably decrease during heat processing. According to other authors, heat processing can affect the content of amines **[22]**.

The change in pH is associated with a different degree of increase in the number of free NH_{2}- and COOH- groups during pasteurisation **[19]**. As a rule, thermal exposure contributes to the rise in the pH of meat, which is explained by a decrease in the available carboxyl groups in boiled meat **[18]**. After marinating and cooking by the sous-vide method (70, 80 °C, 60 to 120 minutes), the pH of beef steak was 5.19 – 6.17, which is lower than in our work 5.76 – 6.79. However, the fresh meat in this work **[18]** had a reduced pH after marinating (4.67 – 5.00). In the research **[5]**, the pH of the semitendinosus beef muscle cooked by the sous-vide method (60 °C for 4.5 and 10 hours) was 5.79 and 5.78. The authors concluded that the beef sous-vide cooking has a negligible effect on the pH of the product. In our work, we have found an increase in the pH of the product was observed with an increase in the temperature and duration of preparation, but not in all cases.

The amino acid composition of poultry meat was studied depending on the cooking method **[23]**. Heat processing led to a certain decrease in the content of all amino acids. Meat samples processed under pressure retained the highest content of total essential, non-essential, and total amino acids. Then, in descending order of the number of amino acids, the following thermal processing methods followed: boiling, microwave processing, and frying. The decrease in the content of amino acids can be associated with both the loss of meat fluid and the denaturation of proteins during heat processing. Several studies have shown a considerable decrease in the amount of sulfur-containing amino acids, i.e., leucine, tyrosine, phenylalanine, and lysine (as essential amino acids), as well as serine, glycine, alanine, histidine, and arginine (as interchangeable amino acids). At the same time, there was a slight decrease in the content of other amino acids after heat processing of chicken breast or thigh meat samples. This work established significant losses of lysine and alanine from meat steak during frying. The loss of amino acids in the preparation of meat steak by the sous-vide method is the smallest compared to other processing methods. Principles of the GMP and HACCP should be applied **[23]**. The HACCP approach is a preventive approach to microbiological quality control and is designed to prevent problems before they occur and not to find them in the finished product **[6]**.

The selected souse-vide mode allowed obtaining a product with a longer shelf life than conventional cooking and frying (Table 4). The microbiological quality of the fresh meat used for cooking is important. The packaging material decreased the risk of the secondary contamination of the product, and the vacuum does not allow the growth of aerobic microorganisms. The microbiological index did not exceed the legislation limit for the sous-vide product within 72 hours after cooking, while conventional boiling and frying – within 12 and 24 hours, respectively. The possibility of extending the shelf-life of sous-vide meat semi-finished products in the refrigerator compared to products prepared using conventional technologies makes the sous-vide method attractive for manufacturers of public catering products. However, the sous-vide method allows increasing the product's shelf life only if the pasteurisation standard is chosen correctly. The data in Table 1 showed that this cooking method can lead to an unsafe product in some cases, which is confirmed by the literature data. For example, in work **[3]**, the safety of sous-vide products against *Clostridium botulinum* was evaluated using control tests with low (2.0 lg CFU/g) and high (5.3 lg CFU/g) contamination. After heat processing, the products were stored at 4 and 8 °C and were checked for botulinum and neurotoxin spores on the end date of the sale period and seven days after the sale date. It was found that most of the thermal processes are unsatisfactory, even with a low level of initial microbial load. Only 2 of the 16 products were negative for botulin and neurotoxin spores in both analysis cases. Based on this study, it was concluded that the safety of sous-vide products requires constant, careful assessment. The time and temperature combinations used in heat processing should be reviewed to improve the processing efficiency and use additional barriers, such as bio preservatives.

The main pathogenic bacteria of concern for sous-vide products are *Salmonella*, *L. monocytogenes,* and pathogenic strains of *Escherichia coli* since they are relatively heat-resistant. The maximum ageing time of the product at a specific temperature will depend on the types and number of microorganisms infecting the product and the heat resistance of each organism. Many pathogenic microorganisms' maximum growth temperature range is 42 – 49 °C, and some can grow at 50 – 55 °C. The temperatures used in the sous-vide cooking modes must be above this range. Slow heating of the product to the cooking temperature can increase the microbial load of the product, so it is recommended to preheat the bain-marie to the cooking temperature **[24]**. The temperature of the fresh meat should be maintained at 2 – 4 °C at all stages before the heat processing. This temperature minimise the growth of pathogens. The correct choice and constant monitoring of the storage modes of raw materials, preparation and storage of the finished product, it can be recommended to use the sous-vide method in the "preparation-serving" option.

A more popular version of the sous-vide "cooking-freezing" processing method, in which products are reheated after several days or weeks of storage in the refrigerator, poses a higher threat to consumers' health. The spore-forming pathogen *Clostridium botulinum* of types A, B, and E can withstand moderate heat processing of sous-vide, and the presence of anaerobic packaging conditions promotes the growth and production of *C. botulinum* toxins in the finished product. *C. botulinum* strains can grow and produce toxins at low temperatures, while *C. botulinum* spores of types A and B can grow at a temperature of 10 – 12°C **[6]**. To reduce *C. botulinum* by six lg, an exposure time of 8 hours 40 min at 75 °C, 75 min at 80 °C, or 25 min at 85°C is required **[1]**. To destroy the spores, it is necessary to apply a pasteurisation temperature above 100 °C. To prevent the reproduction of *C. botulinum* and accumulation of deadly neurotoxin in meat, rapid cooling of the product immediately after pasteurisation is recommended, and then the storage regimes: below 2.5 °C – less than ten days; below 3.3 °C – less than 31 days; below 5.0 °C – less than ten days; below 7.0 °C – less than five days **[1]**. There is a possibility of temperature disturbances during the distribution of sous-vide products, especially in the retail environment. Therefore, additional barriers may be required to ensure the microbiological safety of the final product. These barriers can be combined with pasteurisation to suppress surviving microorganisms in sous-vide products,

including water activity, pH, and preservatives. For example, combinations of water activity and pH reduction have proven effective in controlling the growth of *C. botulinum* type E in caviar stored at room temperature **[6]**. For ready-made chilled products with a shelf life of more than ten days, as additional controlling factors of *C. botulinum*, it is recommended to use:
1) heat processing at 90 °C for 10 minutes or equivalent;
2) pH = 5.0 or less;
3) the minimum salt level is 3.5% in the aqueous phase of the product;
4) water activity 0.97 or less;
5) using a combination of pasteurisation and preservatives **[6]**.

An effective barrier is marinating the meat before cooking. The thermal stability of a mixture of five strains of *Salmonella* and five strains of *L. monocytogenes* in chicken breasts marinated in teriyaki sauce (pH = 4.2) was studied and then prepared by the sous-vide method in the modes 55; 57.5, or 60 °C for an hour **[25]**. The results prove marinades' effectiveness against *L. monocytogenes* and *Salmonella* and other pathogens in meat have been published. The low pH of the marinade reduces the number and increases the sensitivity of pathogenic microorganisms to heat stress. The results of our work suggest that ginger can be used as an additional barrier that reduces the number of microorganisms in combination with a temperature of 55°C and the heating time 45 to 90 min. This antibacterial effect of ginger was also confirmed by **[7]**. Ginger and garlic's antimicrobial effect of aqueous and alcoholic extracts against *Staphylococcus aureus*; *Bacillus spp*., *Escherichia coli*, and *Salmonella spp*. was investigated by **[26]**. Both garlic and ginger's water and alcohol extracts separately did not suppress any test organisms. However, in combination with lime, they suppressed *Bacillus spp*, *Staphylococcus spp*. A combination of alcoholic extracts of ginger and garlic suppressed *S. aureus* and *Bacillus spp. Salmonella* was resistant to almost all extracts. There were no literature sources on the use of ginger as an additional antimicrobial barrier in the preparation of meat products by the sous-vide method. The effect of ginger extract in combination with citric acid on the tenderness of duck breast was studied by **[27]**, since ginger has enzymatic activity and promotes the degradation of myofibrillar proteins during long marinating. Additional studies are needed to confirm the possibility of using ginger as an additional antimicrobial barrier for meat steak prepared by the sous-vide method.

An increase in the gaps between the fibres at 60 °C, and a more compact arrangement of the fibres at 70 – 80 °C was noted by **[15]**. There was no noticeable effect of the cooking time on the microstructure of the fibres. In the works of some authors, a decrease in the diameter of the fibres at 60 °C was observed at 60 °C, followed by an increase in the diameter at 70 – 80 °C. They attributed this shrinkage to the thermal denaturation of intramuscular collagen at temperatures from 60.7 to 61.7 °C. At the same time, further heating leads to the formation of a denatured collagen gel around each muscle fibre. In another research **[28]**, authors found fibre compression and the intercellular space increased in beef meat cooked by the sous-vide method (60 °C for 12 hours). In our work, the change in the fibre structure in micrographs became noticeable after 165 minutes of sous-vide cooking at temperature 70 °C.

The colour stability of the sous-vide product depends on the cooking mode. The darker appearance of the meat may be explained by the higher moisture content of the meat cooked at a lower temperature, which leads to deeper penetration of light into the tissues. The intensity of redness in cooked meat is inversely proportional to the degree of denatured myoglobin. The denaturation process occurs at a temperature from 55°C to 65°C but continues up to 75 – 80 °C **[18]**. Beef cooked at 80 °C with a long ageing time has a more tender consistency than cooked at 125°C in a short time, which emphasises the importance of slowly increasing the temperature to obtain a more acceptable organoleptic quality product. Prolonged ageing affects the tenderness and juiciness of the meat in the opposite way. Sometimes more tender meat was described by experts as less succulent and crumblier.

Given that succulence and tenderness are the most important sensory characteristics of cooked meat, any sous-vide process should be designed in such a way as to obtain optimal values of both characteristics **[16]**. We agree with these authors. The sous-vide temperature and time are important for the final product organoleptic properties. In our study, we produced beef steak with excellent organoleptic properties.

CONCLUSION

The microbiological, physicochemical, and organoleptic parameters of sous-vide beef meat product were analysed. The meat ageing leads to the product's weight loss in conventional (100 °C) and sous-vide (70 °C) cooking. The souse-vide product's weight loss ranged from 36 – 41%. In comparison with traditional cooking, the weight loss was lower. The sous-vide cooking method affected the content of amino-ammonia nitrogen, which varied in the range of 0.81 – 2.01 mg/10 cm^3 of the product extract. The increased values of this indicator in the product could result from increased content of proteases in raw materials with insufficient microbiological quality of fresh meat. The pH of the finished product was in the range of 5.76 – 6.79. The microbiological parameters of the finished products were not satisfactory in almost all sous-vide modes and exceeded the legislation limit. The antimicrobial properties of ginger are probably maintained only if the temperature does not exceed 55 °C. The addition of ginger and garlic extract with a pasteurisation temperature of 55 °C can be considered as a barrier to microbial growth. However, additional experiments are necessary to confirm this assumption. The use of a more severe pasteurisation regime brings the properties of the finished sous-vide product, such as the yield and the degree of protein denaturation, similar to conventional cooking methods. The sous-vide product shelf-life was max. 72 hours.

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