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REVEALING THE INFLUENCE OF PLANT-BASED ADDITIVES ON QUALITATIVE INDICATORS OF A SEMI-FINISHED PRODUCT MADE FROM CAMEL MEAT

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This paper considers the influence exerted on the qualitative indicators of boiled camel sausage by plant-based additives. The study's results were used to improve the technology and determine the levels of application of plant-derived extracts with antioxidant properties in the production of boiled sausages. The effect of plant extracts with antioxidant properties on oxidative processes in boiled sausages has been investigated. Camel meat contains phosphorus, magnesium, and potassium. This meat has a large content of vitamins A, B1, B2, C, and E. In terms of protein content (15.1 %), camel is inferior to beef; in terms of fat (11.5 %), it is inferior to other types of meat. However, camel meat is rich in vitamins and trace elements. In addition, the composition of camel meat contains phosphorus, 216–234 mg, which is higher than that of beef.

The disadvantage of boiled camel sausages is a short shelf life. Therefore, it was decided to add plant-based supplements with antioxidant properties. In addition, to ensure minimal lipolytic changes and changes in lipid oxidation in meat, the rational concentration of added antioxidants was determined. Using the response surface methodology, a three-level factor plan was constructed for two variables – the concentration of ginger root powder and sea buckthorn powder. The minimum acid number was manifested at 0.018 % of ginger root powder and 0.035 % of sea buckthorn powder. The minimum peroxide number was obtained at 0.028 % of the L-root of ginger and 0.010 % of the powder of sea buckthorn; the minimum TBARS was detected at 0.030 % of the powder of ginger root and 0.050 % of the powder of sea buckthorn. The concentration of ginger root powder with optimal resistance to oxidation and lipolysis is proposed. The shelf life was also determined in comparison with the control

Keywords: camel meat, lipolysis, oxidative stability, ginger root powder, antioxidants, sea buckthorn powder

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1. Introduction

Meat is one of the most important sources of proteins, lipids, vitamins, and minerals for the human body. However, in recent years, their consumption has been associated with chronic degenerative diseases, which is why it is perceived as «junk food». Given that meat is an affordable source of quality protein, improving it entails a huge challenge for the industry and science. Functional products must meet certain requirements. Functional products should be obtained from natural ingredients, and should help the human body in regulating specific processes. As an example, we can cite slowing down the aging process, preventing the risk of disease, improving immunity, etc. In addition, a mandatory requirement is to use them as part of a daily diet [1].

Spoilage of raw meat can occur for two reasons: microbiological contamination and chemical spoilage. The most common form of chemical breakdown is oxidative rancidity, as lipids are integral components of muscles. Oxidation is a well-known non-microbial cause of meat quality loss. Lipid oxidation leads to the formation of many other compounds that negatively affect the quality characteristics and nutritional value of meat products; this process often limits the shelf life of processed meat.

Lipids undergo oxidation when catalytic systems such as light, heat, enzymes, metals, metalloproteins, and microorganisms are present. The presence of intermediate reactive particles and free radicals, as well as those conditions, lead to autooxidation, photooxidation, and thermal or enzymatic oxidation. However, lipid oxidation caused by autooxidation is a spontaneous reaction of the substrate with oxygen through a chain reaction followed by a cascade. It is well known that lipid deterioration occurs slowly in the beginning; however, after induction, the process proceeds rapidly and involves three phases: initiation, propagation, and completion [2].

There are different approaches to controlling lipid oxidation in meat and meat products. Among them, the use of antioxidants is considered a pragmatic choice, since antioxidants can slow down the rate of oxidation of meat and meat products, ultimately increasing the oxidative stability of products [3].

Adding plant-based fillers with antioxidant capacity to a variety of fresh and cooked meat products can reduce oxidation issues by inhibiting the formation of free radicals.

In addition, it is reported that natural antioxidants are more powerful than synthetic ones. The demand for natural antioxidants has recently increased due to the toxicity and carcinogenicity of synthetic antioxidants [4]. Many natural plant extracts contain mostly phenolic compounds, which are powerful antioxidants [5].

Reducing sodium nitrite in formulations is also an urgent task. In [6], fruit extracts were added to the recipe of boiled sausages in order to increase the nutritional value, reduce the dose of sodium nitrite in the formulation; as a result, the yield of finished products increased by 2.3 %. At the same time, microbiological indicators improved, the shelf life reached 21 days.

Many works focus on increasing the shelf life of sausages but it is the shelf life of camel sausages, ways to improve the recipe that are rarely covered. Many studies tackle the replacement of fats with oils, to prolong the shelf life of sausages.

Thus, the effect of chia oils, flaxseed, and olive oil as substitutes for backbone fat on the physicochemical, oxidative stability and organoleptic properties of lamb sausages when stored at 2 °C was investigated. Batches of boiled lamb sausages with chia butter, linseed oil, and olive oil reduced the atherogenicity and thrombogenicity indices ($P<0.05$). However, only in samples with chia oil and linseed oil, the ratios n-6/n-3 (0.86 and 0.92, respectively) and PUFAs/EFAs were within the recommended range. Regarding the organoleptic analysis of cooked foods, the processing of samples with flaxseed oil did not differ from control samples, while samples with chia oil and olive oil caused a deterioration in taste. During storage, there were no differences in the color, discoloration, and smell of raw foods ($P>0.05$). Control samples showed the highest value of a^* over time but this was not noticed by the participants in the discussion [7].

Many papers address barrier technologies to increase the shelf life of sausages using modified films. For example, the efficacy of chitosan and whey protein films impregnated with garlic essential oil (2 wt% or nano-encapsulated (2 wt %) was evaluated to extend the shelf life of refrigerated products in vacuum packaging. The sausages were evaluated and compared over a period of 50 days. An initial evaluation of garlic essential oil-impregnated and garlic oil-nano-encapsulated sausage films showed that garlic oil has a significant amount of active compounds derived from diallyl sulfide (~67 %), and the average size and zeta potential of the nano-encapsulated essential oil films are 101 nm and –7.27 mV, respectively. Based on microbiological analysis and sausage lipid stability analysis, all active films slowed down lipid oxidation and the growth of major groups of spoilage-causing bacteria. After analyzing, it was found that compared with the control, and the film with chitosan, the film containing nano-encapsulated essential oil of garlic showed a better result with a peroxide number, reactive substances of thiobarbituric acid, and the number of aerobic cups of 0.37 (mequiv./kg lipids), ($P<0.05$) [8].

The disadvantage of boiled camel sausages is a short shelf life compared to traditional sausages using classical technology. Work on the development of technologies that make it possible to prolong the shelf life without loss of quality of food products, as well as enrichment of the composition, is relevant. There is a shortage of raw materials in the world, and technologies with an extended shelf life could save resources. In addition, products with a long shelf life are needed in the defense and food security of any country.

2. Literature review and problem statement

There are many strategies for changing the composition of meat products by changing the content of protein, vitamins, fats, as well as fatty acid composition [9].

In Arab countries, the use of camel meat in food is increasingly being studied. Study [10] aimed at examining the effect of adding flax seeds on the nutritional value of camel meat sausage at a ratio of 0 (control), 10, 20, and 30 %. The chemical composition of both the raw material and the product was assessed by standard methods. The antioxidant activity in sausages was assessed by estimating oxidation rates. Microbiological analysis and organoleptic changes in sausage were also evaluated at a zero term and during the freezing period at –18 °C for three and six months. The results showed that flax seeds are rich in fat, protein, crude fiber, and elements such as calcium, iron, magnesium, phosphorus, potassium, and zinc. The amount of peroxide was evident from the results; the peroxide number (million equiv./kg of lipids) ranged from 5.04±0.04 to 5.32±0.41 at zero time. The highest value of the peroxide number was noted in control samples, and the lowest – in the prepared samples. When frozen and stored, the thiobarbituric number of ready-made camel sausages decreased from 1.17±0.03 to 1.11±0.07 malonaldehyde/kg of meat at zero time until values from 0.91±0.09 to 93±0.07 at the end of storage. The cited study recommends that flaxseed in powder form can be used up to 30 % in the production of sausages; it retains its nutritional and microbiological value for up to six months. In addition, plant-based supplements such as Siberian larch dihydroquercetin (*Larix sibirica Ledeb*) have recently been discovered [11]. It has already been used in meat products and its antioxidant ability has been proven. However, it has its drawbacks, in particular, the dose of application should be strictly standardized since there are risks of mutational behavior.

Dihydroquercetin is often used to prevent oxidative stress and is well accepted as a treatment for certain carcinomas and cardiovascular and liver disease. The antiradical activity of DHA (dihydroquercetin) is manifested in a concentration of about 0.0001–0.00001 % – at these concentrations, there is no mutagenic activity [12].

Distilled rose petal extract (*Rosa damascena Mill.*) [13] is not advisable to use in meat products. Goji berries (*Lycium barbarum*), dried fruits, and pumpkin powder [14] have been used in meat semi-finished beef products. Goji berries would be most suitable for boiled camel sausages but they have already been used in meat product formulations and there are studies on the effect of this additive on the stability of meat products.

All these plants and other substances have been investigated for food benefits and stability. Wild onions [15] were used as part of processed cheeses. There is evidence of an increase in the shelf life of processed cheeses and an increase in the nutritional value of the product. At the same time, wild onions in a meat product cannot be used, despite all the benefits, because of the color that it gives to meat products.

Extracts of rose petals improve the color stability of canned food; they were also used in the composition of a strawberry drink [16]. A dietary supplement made from dry rose petals (*Rosa damascena Mill*) or dihydroquercetin in chicken meat cuts improve their quality [17].

Camel meat has a sweet taste, which remains in the products during processing. The shelf life of boiled camel sausages is 6 days under refrigerated conditions. Therefore, an unresolved issue is how to increase the shelf life and improve the taste characteristics of meat products.

3. The aim and objectives of the study

The purpose of this study is to identify the effect of plant-based additives on the quality of semi-finished camel meat for enrichment and prolongation of the shelf life of boiled sausages.

This will make it possible to produce new types of sausages from cheap raw materials with good taste and improved shelf life.

To accomplish the aim, the following tasks have been set:

– to determine the effect of a rational ratio of antioxidants on the indicators of lipolysis, expressed by the acid number; lipid hydroperoxides expressed in peroxide number, secondary products of lipid oxidation expressed by reactive substances of 2-thiobarbithuric acid (TBAR);

– to establish the effect of plant-based additives on the taste of the finished boiled sausage.

4. The study materials and methods

The object of our study is the technology of production of boiled sausages from camel meat with an extended shelf life and good organoleptic characteristics.

It is assumed that the sweet taste of camel meat can be corrected by adding spices while the shelf life can be extended by adding antioxidants of plant origin. Based on the conducted search experiments, the choice stopped at the powder of sea buckthorn and the powder of ginger root.

With the help of search experiments, the upper and lower levels of factors were identified. In this case, x_1 is taken as a factor of the dose of ginger powder (Gr), and x_2 as a factor of the dose of application of sea buckthorn powder (Sb). The resulting factors are taste, thiobarbituric number, peroxide number, acid number.

The thiobarbituric number of lipids characterizes the accumulation in the products of malonaldehyde, formed during the oxidation of fat and reacting with 2-thiobarbithuric acid $C_4H_4N_2O_2S$. We determined it as follows.

A weighted batch of minced meat of 10 g is subjected to three times grinding in a micro shredder. At the same time, 40 ml of 0.5H hydrochloric acid HC1 is added; the grinding continues for 5 minutes at a speed of 3000 rpm. We add 15 ml of 20 % trichloroacetic acid and continue to homogenize the mixture for 1 min. The mixture is then filtered through a folded filter. 15 ml of the resulting filtrate is placed in a test tube with a tight stopper; 5 ml of 0.36 % thiobarbituric acid is added. The test tube is boiled in a water bath for 15 minutes, then cooled. The resulting solution is measured at FEC-M, the light filter is green, the wavelength is 535 nm.

The acid and peroxide numbers were determined by standard methods.

The experiment was carried out as follows: powders from ginger root and sea buckthorn were added to the composition of minced camel meat and internal camel fat in different proportions; the samples were encrypted while nothing was added to the control sample. The results and data treated in the Statistica 12.0 software (USA, Tibsco empowers) are given [18, 19].

5. Results of studying the effect of an additive on the quality of boiled camel sausage

5. 1. Determining the effect of a rational ratio of antioxidants on lipolysis indicators

Experiments were conducted to determine the optimal ratio of ginger powder and sea buckthorn powder for adding to boiled camel sausage minced meat. The experiment was carried out as follows: powders from ginger root and sea buckthorn were added to the composition of minced camel meat and internal camel fat in different proportions; the samples were encrypted while nothing was added to the control sample. The samples were examined for the acid, peroxide, and thiobarbituric numbers. The results and data processed in the Statistica 12.0 software are given.

Determining the acid number – AV (AN). The acid number indicates the degree of hydrolytic cleavage of lipids, in this case, boiled camel sausages. When processing experimental data, the following mathematical and statistical indicators were derived: R^2=95.891 %, R^2 (adjusted for d. f.)=94.711 %, Standard Error of Est.=0.006, Mean absolute error=0.002, Durbin-Watson statistic=1.843 (P=0.326), Lag 1 residual autocorrelation=0.078.

According to the results of the mathematical-statistical analysis with a reliability of 94.7 %, we can say that the concentration of ginger powder (Gr=0.018 %) and the concentration of sea buckthorn powder (Sb=0.035 %) are optimal for minced camel meat. Fig. 1 shows the results of data treatment demonstrating the optimum of values.

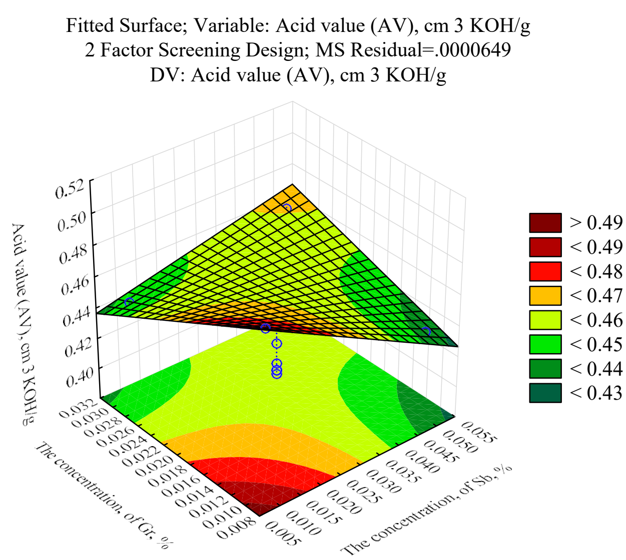

Fig. 1. The minimum value of AV (acid number) at the concentration of ginger powder (Gr=0.018 %) and the concentration of sea buckthorn powder (Sb=0.035 %). Gr is the concentration of ginger powder, %. Sb is the concentration of sea buckthorn, %

When processing data in the Statistica 12.0 software, an equation of the second degree was built, indicating the dependence of AN on the concentration of two antioxidants:

$$AV=0.6-8.7Gr-4.2Sb+110.9Gr^2+$$
$$+83.6GrSb+33.0Gr^2,\ cm^3\ KOH/g. \quad (1)$$

The reliability of the model was checked statistically, the following data were obtained: $r^2=0.97$; $R^2=0.94$; Fit Std Err=0.006, F-val=43.96.

Fig. 2 shows the critical boundary of AN, based on the Fisher criterion (red line) and the degree of significance of various factors.

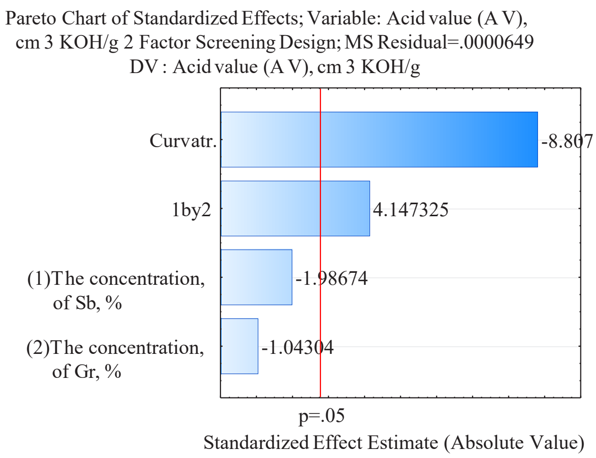

Fig. 2. Critical acid number boundary

When determining the peroxide number POV, data with the following mathematical and statistical indicators were obtained: $R^2=98.5$ %, R^2 (adjusted)=98.13 %, Standard Error of Est.=0.03, Mean absolute error=0.026, Durbin-Watson statistic=2.53 ($P=0.77$), Lag 1 residual autocorrelation=–0.321.

According to the results of mathematical and statistical analysis, one can see that the model is described with an accuracy of 98.5 %.

Fig. 3 demonstrates that the minimum values of the peroxide number are achieved at the concentrations of powders of ginger (Gr=0.030 %) and sea buckthorn (Sb=0.010 %) or at the concentrations of powders of ginger (Gr=0.010 %) and sea buckthorn (Sb=0.050).

Fig. 4 shows the critical boundary of the peroxide number, based on the Fisher criterion (red line) and the degree of significance of various factors.

An equation of the second degree has been constructed, indicating the dependence of the peroxide number (POV) on the concentration of two antioxidants:

$$POV=0.144561+37.47Sb+90.18Gr-$$
$$-832.59Sb^2+642.145SbGr-2980.36Gr^2,\ meqv/kg. \quad (2)$$

The reliability is statistically proven by the following results: $R^2=0.98$; DF Adj $R^2=0.99$; Fit Std Err=0.002; F-val=273.92.

The thiobarbituric number TBARS was determined in the same way: it indicates the degree of secondary oxidation of lipids and the production of secondary oxidation products – malonaldehyde. When treating the results of the experiment, the following mathematical and statistical indicators were derived: $R^2=97.08$ %, R^2 (adjusted for d.f.)=95.34 %, Standard Error of Est.=0.08, Mean absolute error=0.05.

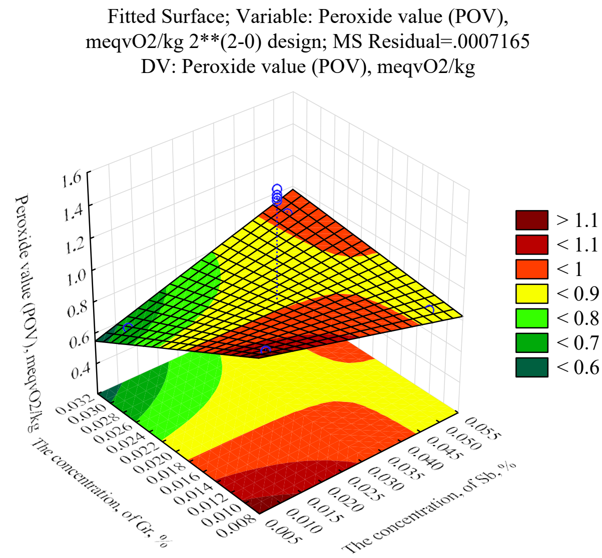

Fig. 3. The minimum values of POV (peroxide number): Gr – concentration of ginger powder, %; Sb – concentration of sea buckthorn, %

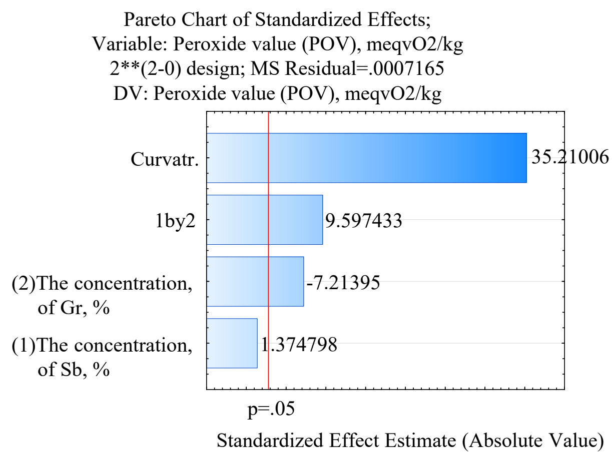

Fig. 4. Critical boundary of the peroxide number

In accordance with the results of the mathematical and statistical analysis, the reliability of the resulting model is 97 %, the standard error is 0.08. Fig. 5 shows that the minimum values of TBARS are achieved at the concentration of ginger powder (Gr=0.032 %) and the concentration of sea buckthorn powder (Sb=0.055 %).

The minimum values of TBARS are achieved at the concentration of ginger powder (Gr=0.032 %) and the concentration of sea buckthorn powder (Sb=0.055 %).

Fig. 6 shows the critical boundary of the TBARS thiobarbituric number, based on the Fisher criterion (red line) and the degree of significance of various factors.

Fig. 5 shows that when one adds the maximum quantity of both additives, the minimum value of the thiobarbituric number is obtained. However, when the maximum values of both antioxidants are added, the acid number increases. And the peroxide number grows at the same doses.

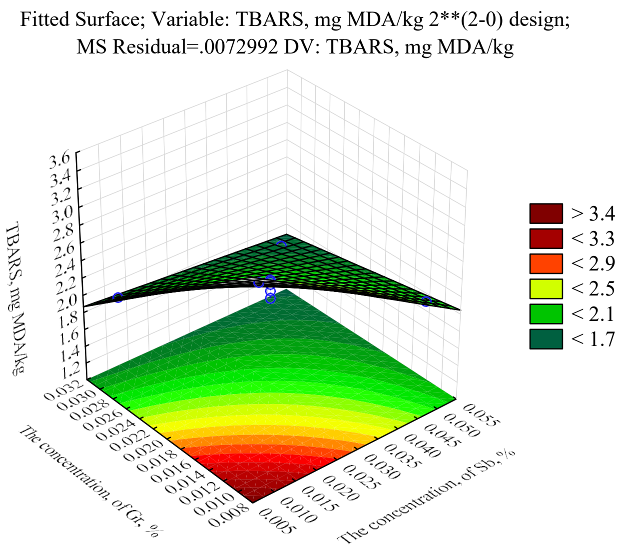

Fig. 5. The values of the thiobarbituric number: Gr is the concentration of ginger, %; Sb is the concentration of sea buckthorn, %

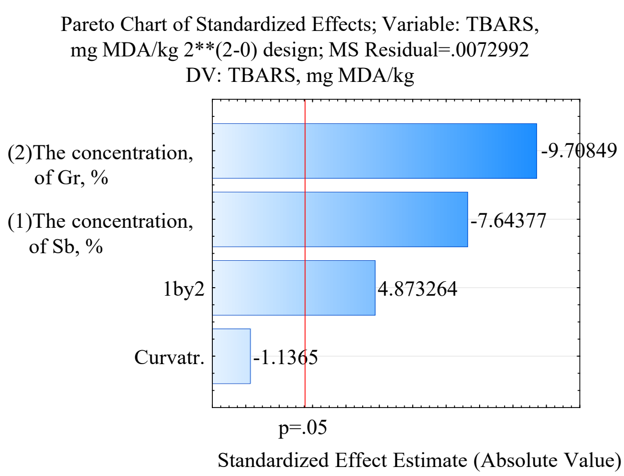

Fig. 6. Critical boundary of the thiobarbituric number TBARS

5. 2. Determining the effect of additives on the taste of boiled camel sausage

By the method of planning a full-factor experiment, it is determined that there should be 9 samples. The results are treated in the Statistica 12.0 software.

The coefficient of determination, which demonstrates the significance of the derived coefficients, is 0.8. The plot of the distribution of residues is shown in Fig. 7. The plot of residues helps define the model. If the points are randomly distributed around the horizontal axis, then a linear regression model fits the data. Fig. 8 shows the response surface of the resulting model. Fig. 9 shows the profile of the predicted values of the desirability function.

Fig. 9 consists of two lines of plots. The plot in the upper right corner displays the desirability function. The plots in the top line, in addition to the desirability function, display slices of the fitted dependence function Gr on the corresponding dependent variable when fixing the remaining variables at their optimal levels. The optimal levels of independent variables are displayed on the charts at the bottom of the figure in red lines. The lower series of plots shows the changes in the desirability function as the corresponding explanatory variables variation.

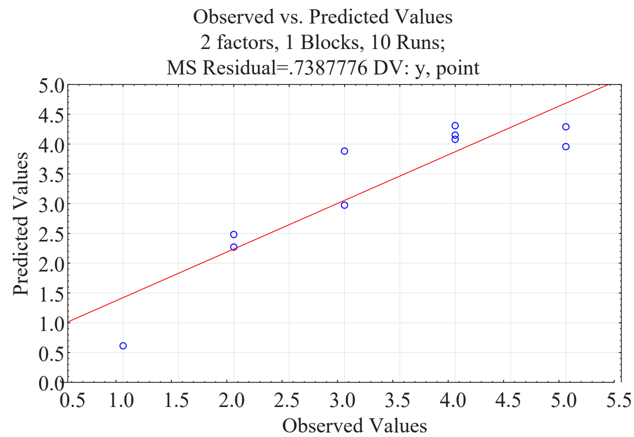

Fig. 7. Residue distribution plot

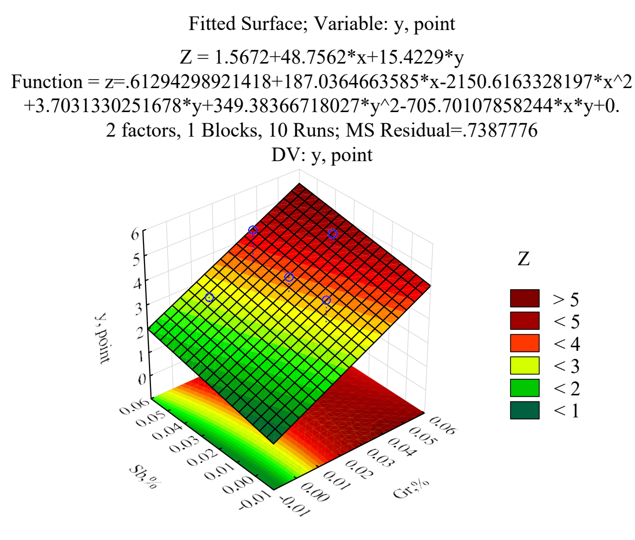

Fig. 8. Response surface of the model of organoleptic analysis of boiled camel sausages

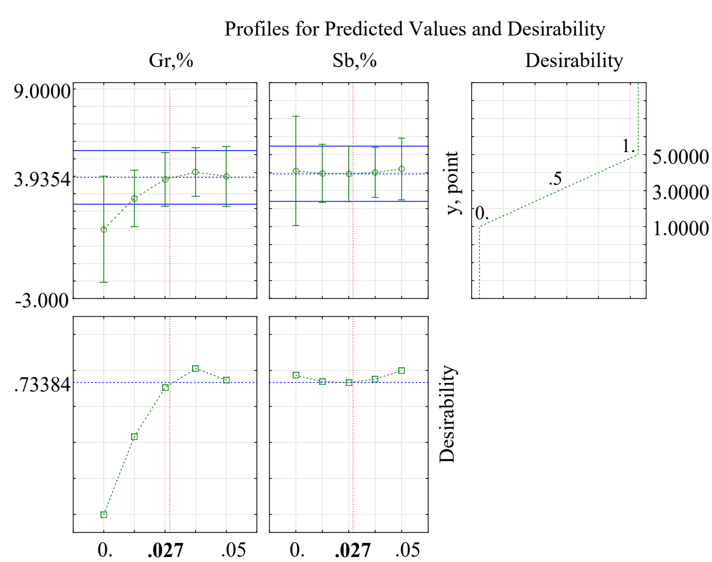

Fig. 9. Desirability profile

Analyzing Fig. 8, 9, it can be concluded that the experimental data showed the quantity of additives of ginger powder and sea buckthorn powder in different proportions. Nevertheless, the theoretical data shown in Fig. 9 indicate that the optimal values for the taste of boiled camel sausage are achieved at values of 0.27 % ginger powder and 0.27 % sea buckthorn powder.

6. Discussion of results of studying the effect of a plant-based supplement on qualitative indicators

The peroxide number is a parameter of lipid oxidation; it is used to assess the quality of fat. A high PV is an indicator of unwanted changes in fats.

Our findings are explained by the fact that both supplements are antioxidants, but both affect different oxidative processes in different ways. As shown in Fig. 1, ginger powder does not affect the acid number but it is considerably affected by the concentration of sea buckthorn powder.

As can be seen in Fig. 3, the effect on the peroxide number is greater from the ginger powder.

In comparison with [10], where the peroxide number was determined in samples of camel sausage with the addition of dried flaxseed powder, the sausage with the addition of antioxidants (Gr, Sb) was kept in refrigerated storage. The sausage with flax seeds was stored frozen. The results in [10] demonstrate that PV (million equiv./kg of lipids) ranged from 5.04 ± 0.04 to 5.32 ± 0.41 at zero time. Note that in the samples reported in our study, the peroxide number is 1.23 ± 0.35, due to the synergistic effect of ginger and sea buckthorn powders.

The thiobarbituric number of boiled camel sausages showed the following results in comparison with [10]. According to the results reported in [10], the thiobarbituric number decreased from 1.17 ± 0.03 to 0.91 ± 0.09 at zero time. At the same time, the value of the thiobarbituric number after six months of storage ranged from 1.11 ± 0.07 to 0.93 ± 0.07. In our study, at the zero point, the value of the thiobarbituric number is 1.9 ± 0.07, and, with refrigerated storage after 6 days, the value of the thiobarbituric number was recorded at 1.51 ± 0.04. As can be seen, when stored under refrigerated conditions, the thiobarbituric number decreases. In contrast to the compared study, the samples of boiled sausages were stored not under freezing conditions but under refrigerated conditions.

When choosing the ratio of powders, it was revealed by the desirability function (Fig. 9) that the optimal to taste would be a ratio of 0.27 % for both powders. In addition, the desirability function indicates a complete and reliable processing of the obtained experimental data.

The area of further research may be to identify the effect of additives in the form of ginger root powder and protein fat composition from sea buckthorn on the shelf life of the finished product. It is assumed that when using a protein fat composition from sea buckthorn, the shelf life of boiled sausages could be even longer and more stable.

7. Conclusions

1. A rational ratio of antioxidants to lipolysis indicators has been determined. After processing the results obtained, based on the desirability function and the analysis of all three indicators (acid number, peroxide number, thiobarbituric number), we concluded that the ratio should be 50 to 50, in the amount of 0.27 % of sea buckthorn powder and 0.27 % of ginger powder. Analysis of the factor design of the response surface with two variables makes it possible to minimize the acid number at 0.020 % of ginger root powder and 0.035 % of sea buckthorn powder. Accordingly, the analysis shows that for the peroxide number at 0.028 % of ginger root powder and 0.010 % of sea buckthorn and for TBARS at 0.030 % of ginger root powder and 0.050 % of sea buckthorn, minimum values are reached. Thus, a new functional minced meat for boiled sausage was obtained, enriched with 0.27 % ginger powder and 0.27 % sea buckthorn powder with optimal oxidative stability.

2. A tasting evaluation of the samples of boiled sausages was carried out with the participation of 7 experts. The samples were encrypted and evaluated on a 5-point scale. The results were treated in the Statistica 12.0 software. Fig. 8 indicates that the function has a linear character, that the taste of boiled camel sausage depends more on ginger root powder than on sea buckthorn powder. The dependence is confirmed by a profilogram (Fig. 9); the coefficient of determination is 0.87. Based on the function of desirability of the predicted values, the option with 0.27 % addition of both powders was chosen as optimal.

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