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EFFECT OF MANGOLD POWDER ON COLOR AND FLAVOR FORMATION IN MUSCLE PORK PRODUCTS

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Abstract

Processing of vegetables with high sodium nitrate content is of interest for the production of meat products without addition of nitrite. However, the use of nitrate-containing vegetable powders requires the changes in technological parameters. The aim of the study was to investigate the effect of mangold powder on the formation of organoleptic characteristics of muscle meat products. The subjects of the study were the samples of meat products, i.e. smoked-cooked pork neck: control with nitrite and salting mixture; experiment No. 1 with mangold powder and ascorbic acid-containing fruit powder; experiment No. 2 with mangold powder and ascorbic acid. To transform the nitrate ions contained in the mangold vegetable powder into nitrite ions using denitrifying culture, a preliminary heat treatment step was used: 1 and 2 hours at 40±2 °C followed by thermal treatment according to conventional technology. Samples were stored for 1, 5, and 11 days at 0-6 °C. As a result of pork neck ageing for 2 hours at 40 °C, a uniform pink color of pork products with vegetable powder was formed. Indicators of instrumental flavor evaluation in the investigated samples of pork products did not differ significantly. Color of the sample No. 1 had higher values of redness and yellowness. Samples with mangold powder were characterized by a higher color stability compared to the control. Mass fraction of sodium nitrite in the test samples after 1 day of storage was 64.5% and 50.0% higher compared to the control. As a result of pork products storage, the differences in the content of sodium nitrite in the control and in the samples from experiments No. 1 and No. 2 disappeared. During storage up to Day 11, the mass fraction of sodium nitrite in the test samples No. 1 and No. 2 decreased by 34.8% and 66.1%, respectively.

Keywords: *sodium nitrite, smoked-cooked pork products, vegetable powder, stability of color*

JEL Classification: *L66, O32, Q16*

1 Introduction

Sodium nitrite is an essential ingredient in the production of meat products due to its multifunctionality (color formation, preserving and antioxidant capacity, participation in flavor formation). The dosage of sodium nitrite is strictly limited by the current legislation because of the negative effect of its excess on human health. However, there is a positive effect of sodium nitrite on the improvement of cardiovascular system (Larsen, Ekblom, Sahlin, Lundberg & Weitzberg, 2006). As natural sources of nitrite, nitrate-containing vegetables are widely used in the production of raw dried meat products (Sindelar, Cordray, Sebranek, Love & Ahn, 2007a, and Eisinaite, Vinauskiene,Viskelis and Leskauskaite, 2016) and cooked sausages (Sindelar, Cordray, Sebranek, Love & Ahn, 2007b) in various countries around the world. Vossen, Utrera, De Smet, Morcuende & Estévez (2012) found that rosehip *Rosacanina L.* may be used as an antioxidant, but does not completely replace sodium nitrite in sausages due to decrease of redness in the absence of nitrite. Krause, Sebranek, Rust and Mendonca (2011) investigated the effect of the vegetable juice powder in brine composition on the color and content of residual nitrite in ham. The results of the studies found a higher a* (redness) index and a higher residual nitrite level in the control sample with sodium nitrite compared to the samples with vegetable juice powder. Studies of the products containing natural nitrate as a substitute for the food additive of sodium nitrite indicate a positive effect of the celery juice concentrate on the physicochemical and microbiological parameters of ham (Horsch, Sebranek, Dickson, Niebuhr, Larson, Lavieri, Ruther & Wilson, 2014). Tsoukalas, Katsanidis, Marantidou and Bloukas (2011) suggested the use of freeze-dried leek powder to reduce sodium nitrite in fermented sausages by 50%. However, in the scientific and technical literature there is no data on the appropriateness of using nitrate-containing vegetable powders in the production of smoked-cooked meat products, which are conventional products on the Russian market. In addition, the technology of meat products with vegetable powders is of interest from the point of view of processing vegetables with excess nitrate levels and their further use.

For more complete consumption of sodium nitrite for color formation and for decreasing its residual amount in the finished product, various reducing agents are used, i.e. ascorbic acid and its derivatives. When using nitrate-containing components, it is necessary to implement a number of additional techniques, for example, the stage of preliminary heat treatment, denitrifying cultures necessary for complete transformation of nitrate ions into nitrite ions, correct color formation process and minimum residual sodium nitrite content. Thus, the aim of the study was to investigate the effect of nitrate-containing mangold powder on the color formation in smoked-cooked pork products without sodium nitrite.

2 Materials and methods

Subjects of the study were samples of smoked-cooked pork neck, for the production of which pork neck was injected with brine in an amount of 30.0%of the meat weight. Brine formulation is presented in Table 1.

Table 1 **Formulations of smoked-cooked pork neck samples**

Ingredients	Brine specification, kg/100 L		
	Control	Sample No. 1	Sample No. 2
Water	89.53	88.30	89.57
Table salt	2.8	8.3	8.3
Salting mixture (with sodium nitrite content of 0.6%)	5.5	-	-
Granulated sugar	1.0	1.0	1.0
Ascorbic acid (E300)	0.17	-	0.17
Mangold vegetable powder	-	0.87	0.87
Ascorbic acid-containing fruit powder	-	0.44	-
Bactoferm CS-299 denitrifying culture *	-	0.087	0.087
Phosphates (E450, E451)	1.0	1.0	1.0
*** contains** *Pediococcus pentosaceus, Staphilococcus carnosus, Staphilococcus xylosus, Lactobactillus sake Deb. Hanseni*.			

Source: Author's calculations.

Before the addition of mangold vegetable powder to the brine, in order to avoid clumping and to facilitate mixing process, it was previously dissolved in a small amount of cold water with a temperature of 5±2 °C. The solution was characterized by a dark brown opaque color.

Further, the solution of mangold vegetable powder was added to the brine with slow stirring. Other ingredients, i.e. sodium chloride, food phosphates, sugar, and denitrifying culture, were added after the addition of vegetable powder. Ascorbic acid and ascorbic acid-containing fruit powder were added at the end of the brine preparation. No precipitate was observed.

To transform the nitrate ions contained in the mangold vegetable powder into nitrite ions, a preliminary heat treatment step was used: 1 and 2 hours at 40±2 °C followed by thermal treatment according to conventional technology.

After production, the samples wrapped in parchment were stored during 11 days under refrigeration conditions at 0-6 °C and relative humidity of 75-78%.

The definition of flavor "visual imprints" was carried out with the VOCmeter (Electronic nose). For the evaluationwith the VOCmeter, three subsamples were taken from each analyzed sample. To obtain the subsample, the analyzed sample (excluding the surface layers) was ground and appropriate quantity was placed in a special glass container (vial). Vialwas tightly closed and placed in a thermostat. At the end of thermal conditioning, needle was inserted into vial for automatic sampling of the analyzed gas, which was supplied to the VOCmeter. To visualize the results of the study, the readings of the MOS1-4 sensors were used. Determination of the color characteristics of meat products within the CIELab system was carried out using the Spectroton spectrocolorimeter while simultaneously measuring the reflection coefficients of the samples at 24 fixed wavelengths located in increments of 13 nm in the visible spectral range from 380 to 720 nm. Then, mathematical processing of measurement results was carried out by a microprocessor controller in the measuring unit.

To determine the stability of color during storage, the color stability test criterion (U,%) was used. Stability of color was calculated by the equation (1):

$$U = 1 - \frac{|L_1 - L_2|}{3L_1} + \frac{|a_1 - a_2|}{3a_1} + \frac{|b_1 - b_2|}{3b_1} 100 \qquad (1)$$

where: L_1, L_2 - lightness value before and after storage;
a_1, a_2 - redness value before and after storage;
b_1, b_2 - yellowness value before and after storage.

The mass fraction of sodium nitrite was determined by a method based on the reaction of nitrite with N-(1-naphthyl)-ethylenediamine dihydrochloride and sulfanilamide in a protein-free filtrate and subsequent photocolorimetric determination of the color intensity.

3 Results and discussion

To convert nitrate ions into nitrite ions, the conditions that are provided by the presence of denitrifying culture, the temperature and maintenance of the conditions created for transformation are necessary. The color formation reaction is activated when the product is heated above 30 °C and maintained up to 50 °C. With further increase of temperature to 60-70 °C, nitrosomyoglobin and nitrosohemoglobin lose their protein part due to denaturation and transform into nitrosohemochromogen and nitrosomiochromogen responsible for a red color of the meat product. In the absence of nitrite ions, the color formation reaction proceeds up to the formation of metmyoglobin, and the finished product will have gray color after heat treatment, which is unacceptable for most types of traditional meat products.

The described color formation mechanisms were taken into account when optimizing the transformation conditions of the vegetable powder during the aging in a thermal chamber. Therefore, in order to achieve uniform color, the pork neck was held at 40±2 °C for 1 hour and 2 hours. Ageing for 1 hour was insufficient to achieve a uniform pink color in a test sample section. The control sample was characterized by a uniform pink color.

Ageing of the samples for 2 hours at a temperature of 40 °C provided the formation of a uniform pink color of the test samples with vegetable powder. Thus, for the production of muscle pork products, additional ageing is necessary for 60 minutes at 40 °C for nitrate transformation.

After reaching a temperature of 72±2 °C, all of the samples were characterized by a color conventional for pork products. Based on the conducted studies, the modes of additional preliminary stage of heat treatment were established for smoked-cooked pork products to ensure the transformation of nitrate ions in the vegetable powder into nitrite ions with participation of denitrifying culture: at least 1 hour at 40 °C.

As a result of sensory evaluation, it was established that during storage, all of the samples studied had similar and acceptable consumer characteristics conventional for this type of meat products. During storage for 5 days, the samples were characterized by pink and red color of muscle tissue typical for this kind of meat products. The fat layers were white. By Day 11 of storage, samples were characterized by darkening.

Some differences were noted in color, which was more uniform in the control than in the test samples, and in flavor, i.e. sample 1 had higher flavor intensity than the control and sample 2.

Instrumental assessment of color characteristics indicated the absence of significant differences in lightness, redness and yellowness of the control and the test samples of cooked sausages No. 1 and No. 2 (Table 1). However, the color of the sample No. 1 was characterized by a higher value of redness and yellowness ($p < 0.05$).

The results of instrumental color assessment of the samples are given in Table 2.

Table 2 **Color parameters of smoked-cooked pork neck samples**

Sample designation	Color characteristics, color units			Color stability during storage, %
	L - lightness	a - redness	b - yellowness	
Day 1				
Control	56.9 ± 1.7	9.5 ± 0.4	9.1 ± 0.3	-
Sample 1	54.9 ± 1.2	10.5 ± 0.4	12.1 ± 0.6	-
Sample 2	55.6 ± 1.6	9.7 ± 0.5	11.4 ± 0.5	-
Day 5				
Control	55.6 ± 1.4	9.6 ± 0.3	8.6 ± 0.4	98.6
Sample 1	54.2 ± 1.4	10.5 ± 0.6	10.1 ± 0.4	95.9
Sample 2	55.9 ± 1.7	9.9 ± 0.3	10.8 ± 0.5	97.7
Day 11				
Control	59.6 ± 1.1	10.1 ± 0.2	11.8 ± 0.3	89.6
Sample 1	54.3 ± 0.9	11.4 ± 0.5	12.7 ± 0.3	94.9
Sample 2	56.5 ± 1.8	8.5 ± 0.6	10.4 ± 0.4	93.5

Source: Author's calculations.

By Day 5 of storage, the samples had high color stability; losses were only 1.4% to 4.1%. By Day 11, this indicator in samples No. 1 and No. 2 was significantly better compared to the control: their color loss was 5.1% to 6.5%, while color loss in the control was 10.4%.

The results of multisensory studies of pork neck samples are given in Table 3.

Table 3 **Areas of "visual imprints" of the sensor readings obtained with multisensory analysis of smoked-cooked pork neck samples**

Sample designation	Visual imprints area, $S_{BO}*10^7$	
	After 1 day	After 5 days
Control	22.2 ± 2.7	23.6 ± 2.4
Sample 1	27.5 ± 3.4	29.5 ± 3.2
Sample 2	25.0 ± 2.8	27.3 ± 3.1

Source: Author's calculations.

The results of M1-M4 sensors, which characterize the content of volatile flavor-forming components in the gas phase of the samples, did not differ significantly between the samples ($p > 0.05$).

Table 4 shows the study results of pH level. The control and the sample No. 1 had no significant differences in pH value ($p > 0.05$). The sample No. 2 was characterized by a lower pH level compared to the control and the sample No. 2. ($p < 0.05$), which, however, did not affect the sensory evaluation.

Table 4 **pH levels in smoked-cooked pork neck samples**

Sample designation	pH		
	Day 1	Day 5	Day 11
Control	6.27 ± 0.05	6.36 ± 0.07	6.49 ± 0.09
Sample 1	6.29 ± 0.08	6.33 ± 0.03	6.34 ± 0.08
Sample 2	6.04 ± 0.03	6.01 ± 0.04	6.01 ± 0.05

Source: Author's calculations.

During the storage, pH values of pork neck samples increased: for the control - by 3.4%, for the sample No. 1 - by 0.8%, while pH level of the sample No. 2 remained virtually unchanged.

Table 5 shows the results of sodium nitrite, sodium nitrate and ascorbic acid mass fraction evaluation.

Table 5 **Sodium nitrite mass fraction in smoked-cooked pork neck samples**

Sample designation	Sodium nitrite mass fraction, %
Day 1	
Control	0.00110 ± 0.00015
Sample 1	0.00181 ± 0.00013
Sample 2	0.00165 ± 0.00011
Day 5	
Control	0.00098 ± 0.00011
Sample 1	0.00154 ± 0.00018
Sample 2	0.00132 ± 0.00012
Day 11	
Control	0.00078 ± 0.00008
Sample 1	0.00118 ± 0.00012
Sample 2	0.00056 ± 0.00009

Source: Author's calculations.

During the storage, none of pork neck samples exceeded the specifications for sodium nitrite mass fraction, i.e. 0.005%.

When added to the meat system, sodium nitrite is reduced to nitric oxide and reacts with meat myoglobin. Amount of nitrite ions formed from nitrate ions of the used doses of vegetable powder was sufficient for desired pink-red color of the product.

During the storage, all smoked-cooked pork neck samples corresponded to the regulatory requirements of Russian legislation for the content of sodium nitrite of no more than 0.005%. Decrease in residual sodium nitrite content was observed in all samples. In the test samples with mangold powder, more intensive dynamics of nitrite level decrease was observed. After 11 days, mass fraction of sodium nitrite in the test samples No. 1 and No. 2 decreased by 34.8 and 66.1% ($p < 0.05$), respectively. After 5 days, the content of nitrite in the control did not change ($p > 0.05$) while after 11 days of storage, the mass fraction of sodium nitrite in the control decreased by 29.1% ($p < 0.05$). After 1 day of pork product storage, the mass fraction of sodium nitrite in the test samples was 64.5% and 50.0% higher compared to the control ($p < 0.05$). However, during storage, the value of sodium nitrite mass fraction in all ofthe test samples equalized and no significant differences were observed ($p > 0.05$). It is explained by the transformation of nitrogen oxide formed into nitrate under the influence of oxygen.

4 Conclusions

Based on the results of the studies, the preliminary heat treatment modes are established for smoked-cooked pork products to ensure the transformation of nitrate ions in mangold vegetable powder into nitrite ions with participation of denitrifying culture: at least 2 hours at 40 °C. During the storage, the control and the test samples had similar and acceptable consumer characteristics conventional for this type of meat product, which was confirmed by sensory evaluation and instrumental analysis of color and flavor after production and during the storage. The content of residual nitrite and nitrate in the samples with natural sources of nitrate corresponded to the regulatory requirements.

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