

# USE OF THE COMPLEX CRITERION FOR ASSESSMENT OF THE INFLUENCE OF THE MEAT THERMAL CONDITION ON SAUSAGE STABILITY TO OXIDATIVE SPOILAGE IN THE MGA CONDITIONS

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**Abstract** – Manufacture of meat products packed in the conditions of the modified gas atmosphere (MGA), which use allows maintaining high consumer properties of sausage products, is gaining in topicality. However, taking into consideration a significant number of factors that influence the formation of quality and safety of packed products, a complex approach to assessment and improvement of the technological process of sausage product packaging is necessary. The aim of this work was to develop a complex criterion for meat product stability to the oxidative spoilage on the basis of the comparative influence of the thermal condition of the initial meat on the rate of fat oxidation in semi-smoked sausages packed in the conditions of MGA. To assess the stability of the quality and safety indicators of sausages depending on the thermal condition of initial meat raw material, the whole semi-smoked sausages were packed in the prepared gas mixture (80% nitrogen and 20% carbon dioxide). The packed products were stored at a temperature of 2 to 6°C for 54 days. In the framework of the experiment, the correlation between the occurrence of the processes of the oxidative spoilage (acid value, peroxide value and thiobarbituric acid value), changes in color and decrease in the concentration of carbon dioxide was established; with that, it was shown that the relationship in the development of these processes was higher in the products made from frozen raw material compared to the chilled meat.

**Key Words** – oxidation, color characteristics, semi-smoked sausage

problem of fat oxidation in meat products is connected largely with the fact that the oxidative processes affect formation of quality and safety of meat and meat products, cause changes in food value (a decrease in the content of essential fatty acids and vitamins) and the organoleptic indicators (deterioration of color, taste, consistency and appearance of off-odor), and also reduce product shelf-life. Prevention of fat oxidation has the utmost importance for the meat industry facilitating an increase in production of high-quality products and prolongation of their shelf-life.

The previous studies of the oxidative changes in fats upon production of semi-smoked sausages packed in the conditions of MGA at the different stages of their storage before and after package opening showed the positive dynamics (increase) in the indicators of the oxidative spoilage compared to the initial (background) values [7]. To study a comparative effect of the thermal condition of initial meat on the rate of fat oxidation and changes in color characteristics of sausage products in the framework of this work, the authors proposed the complex criterion for meat product stability to oxidative spoilage, and established the correlation between the processes of carbon dioxide dissolution, changes in product color and indicators of oxidative spoilage of semi-smoked sausages packed in the conditions of MGA at the different stages of storage before and after package opening.

## I. INTRODUCTION

Modern requirements to the conditions of meat product sale envisage use of technologies that ensure high stability of product quality and maximally allowable prolongation of their shelf-life [1-3]. In this connection, there is an increasing interest in developing and improving methods of meat product packaging using MGA [4-6]. The risks of deterioration of quality and safety of packaged products can be associated not only with the microbiological processes, but also with the oxidative changes in fats. Such high attention to the

## II. MATERIALS AND METHODS

The subjects of research were the samples of semi-smoked sausages (40.0% of beef, 30.0% of pork, 30.0 % of pork belly) produced from chilled and frozen meat raw material and packed in the MGA conditions with different periods of storage. Sausages were produced according to the traditional technological scheme and packed in the prepared gas mixture (80% nitrogen and 20% carbon dioxide). The packed products were stored at a temperature of 4±2 °C for 30, 45 and 54 days. On the 30<sup>th</sup> and 45<sup>th</sup> days of storage, part of packages

was opened and additionally stored for 10 and 15 days. During storage, the samples were taken for measurement of the color characteristics in the CIELab system using a spectrophotometer "Spectroton", acid value (AV) by the method based on titration of free fatty acids in the ether-alcohol solution of fat with the aqueous solution of alkaline; peroxide value (PV) by the method based on oxidation of iodhydric acid with peroxides contained in fat with the following titration of released iodine with sodium thiosulphate; thiobarbituric acid value (TBAV) by the method based on the development of the stained substances as a result of interaction of the fat oxidation products with 2- thiobarbituric acid and measurement of the color intensity on aspectrophotometer. During storage of packed products, the ratio of gases in a package was determined using a gas analyzer.

### III. RESULTS AND DISCUSSIONS

The analysis of the oxidative spoilage indicators in the semi-smoked sausages showed that the samples made from chilled meat raw material had higher background values of oxidative spoilage [7]. However, by the end of shelf-life, leveling of the values of the oxidative spoilage indicators was mainly observed for the sausages made from frozen meat, which suggested the different rate of the oxidative spoilage during storage of sausages made from raw material with different thermal conditions, and, consequently, about their different stability to oxidative spoilage.

Taking into account the necessity of the comparative assessment of sausage stability to oxidative spoilage, a complex criterion was proposed for this purpose:

$$K_{st} = 0.5 \sqrt{\left(\frac{T_k - T_n}{T_n}\right)^2} + 0.4 \sqrt{\left(\frac{P_k - P_n}{P_n}\right)^2} + 0.1 \sqrt{\left(\frac{K_k - K_n}{K_n}\right)^2},$$

where:

$K_{st}$  – complex criterion of the stability of the oxidative spoilage indicators;

$T_n, P_n, K_n$  – thiobarbituric acid value (TBAV), peroxide value (PV) and acid value (AV) at the initial moment of storage (background);

$T_k, P_k, K_k$  – TBAV, PV and AV at the end of storage; 0.5; 0.4; 0.1 – coefficients of weightage.

With the stable (unchanging during the process of storage) indicators of the oxidative spoilage ( $T_k = T_n, P_k = P_n, K_k = K_n$ ), the complex criterion is equal zero. The more accumulation of fat oxidation products

( $T_k > T_n, P_k > P_n, K_k > K_n$ ), the higher value of the criterion  $K_{st}$ .

The coefficients of weightage were obtained by the expert method. When determining the coefficients of weightage, the experts took into account the influence of the products of fat oxidation on changes in the organoleptic characteristics of sausage products. The results of the organoleptic assessment were largely connected with TBAV followed by PV. AV, as a rule, does not influence the assessment of products by a taste panel. The results of the calculation of the complex criterion values are presented in Fig.1.

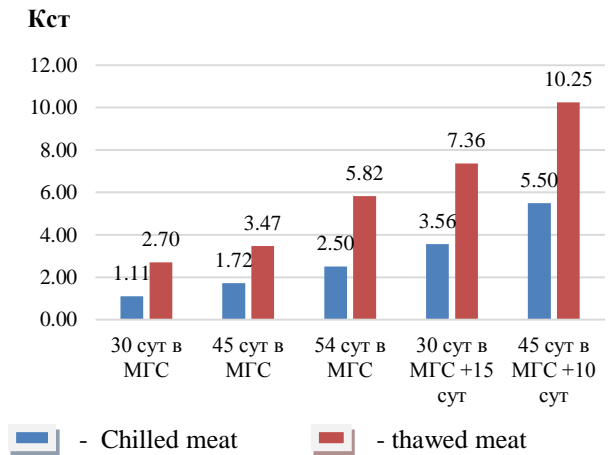


Fig. 1. Values of the complex criterion  $K_{cr}$  for semi-smoked sausages made from chilled and thawed meat raw material

The analysis of the calculated  $K_{st}$  values showed that, in general, the rate of the oxidative processes with accumulation of the oxidative products, which can negatively affect the organoleptic characteristics of sausage products, was higher in the semi-smoked sausages produced from thawed meat raw material. At different periods of storage, including without opening a package and with a period of storage after package opening, the  $K_{st}$  values were 1.9-2.4 times higher. With that, it was noticed that package opening and following storage without a package practically did not influence the  $K_{st}$  values. Calculation of the  $K_{st}$  values for the stages of sausage storage without packaging showed that there were no significant difference in the value of this criterion for sausages from chilled meat ( $K_{st} = 1.18-1.40$ ) and sausages from thawed meat ( $K_{st} = 1.19-1.56$ ).

At the same time, it is necessary to note that the maximum allowable values of the oxidative spoilage

indicators were not reached during storage of sausages. With this connection, the hypothetical value  $K_{st}$  was calculated, which corresponded to the limit levels of peroxide value (10 mmol  $O_2$ /kg), acid value (4 mg KOH/g) and thiobarbituric acid value (0.5 mg/kg). For the sausages made from thawed meat raw material, this value would be 22.7. Thus, with consideration for the maximum value achieved in this experiment (max  $K_{st}$  =10.25), the sausages from thawed raw material had a significant marginal stability to oxidative spoilage.

Taking into account the changes in the carbon dioxide concentrations in a package during sausage storage [1], it was interesting to compare the correlation between the processes of carbon dioxide gas dissolution, changes in product color and the indicators of oxidative spoilage. The results of the calculation of the correlation coefficients are presented in Table 1 and Table 2.

The data analysis has confirmed the presence of correlation dependence between the concentration of carbon dioxide, color characteristics and the indicators of the oxidative spoilage. With that, high correlation dependence was revealed between the concentration of carbon dioxide and the complex criterion of product stability to oxidative spoilage ( $K_{st}$ ): correlation coefficients were -0.9980 and -0.9258 for sausages from chilled and frozen raw material, respectively.

For the sausages from frozen meat, high correlation dependence was observed between the concentration of carbon dioxide, lightness, yellowness, TBA and total color stability. And for the sausages from chilled meat, high correlation dependence was noticed between the carbon dioxide content and TBA. This allows making a conclusion that there is a close relationship between the processes of carbon dioxide gas dissolution, accumulation of fat oxidation products and changes in the color of a packed product. The development of this relationship leads to a progressive decline in product quality.

Table 1 – Coefficients of correlation between the experimental data sets for the changes in the carbon dioxide concentration, color indicators and oxidative spoilage

Used data sets	Value of correlation coefficient for the data set obtained at analysis of sausage samples during storage in MGA for 54 days, prepared from	
	chilled raw material	frozen raw material

CO <sub>2</sub> concentration – lightness	0.8903	0.9785
CO <sub>2</sub> concentration – redness	-0.9850	-0.7910
CO <sub>2</sub> concentration – yellowness	-0.8476	-0.9949
CO <sub>2</sub> concentration – AV	-0.8032	-0.8235
CO <sub>2</sub> concentration – PV	-0.7001	-0.7505
CO <sub>2</sub> concentration – TBAV	-0.9743	-0.9633
CO <sub>2</sub> concentration – Color stability	0.8844	0.9842
CO <sub>2</sub> concentration – Criterion of stability to oxidative spoilage	-0.9380	-0.9258

At the same time, study of the correlation between the data sets for the changes in color characteristics and oxidative spoilage indicators also allowed revealing the close relationship in occurrence of these processes, in particular, for indicators of color and TBA, and between the general color stability and criterion of product stability to oxidative spoilage. With that, this relationship was more pronounced for the sausages made from frozen raw material compared to the sausages produced from chilled meat. For the data on color and oxidative spoilage indicators obtained as a result of the analysis of the sausages from frozen raw material, 22 correlation coefficients had the values higher than 0.9000; while, for the sausages from chilled raw material there were only 17 correlation coefficients. This once again confirms higher risks of quality deterioration of packed products with long shelf-life when using frozen meat.

Table 2 Coefficients of correlation between the experimental data sets for the color indicators and oxidative spoilage

Used data sets	Value of correlation coefficient for the data set obtained at analysis of sausage samples			
	chilled raw material		frozen raw material	
	54 days in MGA (No 1)	45 days in MGA + 10 days (No 3)	54 days in MGA (No 4)	45 days in MGA + 10 days (No 6)
lightness– AV	-0.9628	-0.8707	-0.9216	-0.9726
lightness– PV	-0.9216	-0.8507	-0.8585	-0.9388
lightness– TBA	-0.9698	-0.9356	-0.9903	-0.9947
redness– AV	0.8926	0.9743	0.9913	0.9984
redness– PV	0.8110	0.9606	0.9968	0.9840
redness– TBA	0.9911	0.9967	0.9235	0.9898

yellowness– AV	0.8708	0.7907	0.8458	0.8492
yellowness– PV	0.8243	0.7739	0.7599	0.7720
yellowness– TBA	0.9334	0.8618	0.9610	0.9088
Color stability– $K_{st}$	-0.9631	-0.9078	-0.9677	-0.9258

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#### IV. CONCLUSION

Therefore, taking into account the higher rate of the oxidative processes in the sausages made from thawed meat in the presence of insignificant residual levels of oxygen in a package with a gas mixture, it is necessary to carry out incoming inspection of frozen raw material (especially with long storage duration) by the indicators of oxidative spoilage.

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