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EFFECT OF TRADITIONAL AND OHMIC HEATING ON FAT STABILITY OF PUFA-FORTIFIED COOKED SAUSAGES

Sergey Patyukov[1], Nikola Pacinovski[2]

[1]*Odessa National Academy of Food Technologies, Odessa, Ukraine*
[2]*Institute of Animal Science, Skopje, "Ss. Cyril and Methodius" University in Skopje, Blvd. Ilinden 92A, 1000 Skopje, Republic of Macedonia*
spatyukov@mail.ru

The results of comparative study of two types of thermal treatment of cooked sausages – traditional and ohmic heating – are presented in this paper. It has been shown that conventional way of cooking leads to noticeable quality decline of fat fraction of cooked sausages enriched with PUFA. Triglycerides are hydrolyzed and highly unsaturated fatty acids of linseed oil are oxidized during prolonged thermal treatment when sausages are produced in large diameter casings. Ohmic heating has significant advantages in comparison with traditional technology. The main reason of quality enhancement is reducing of heating time and thus decreasing highly unsaturated fats deterioration. At the same time ohmic heating has a negative impact on the process of color formation in cooked sausages.

Key words: traditional heating; ohmic heating; fat stability; PUFA-fortified cooked sausages

ВЛИЈАНИЕТО НА ТРАДИЦИОНАЛНОТО И ОМСКОТО ЗАГРЕВАЊЕ ВРЗ СТАБИЛНОСТА НА МАСТИТЕ КАЈ БАРЕНИТЕ КОЛБАСИ ЗБОГАТЕНИ СО PUFA

Во трудот се презентирани резултатите од споредбените испитувања на два вида термички третирани барени колбаси, со традиционално и омско загревање. Се покажа дека при конвенционалниот начин на готвење доаѓа до забележливо опаѓање на квалитетот на масната фракција кај барените колбаси збогатени со PUFA. Триглицеридите се хидролизираат, додека високо незаситените масни киселини од ленено масло се оксидираат за време на продолжениот термички третман, кога колбасите се произведуваат во црева со голем дијаметар. Омското загревање има значајни предности во однос на традиционалните технологии. Главната причина за подобрувањето на квалитетот е скратувањето на времето на загревање, со што се намалува деградацијата на полинезаситените масти. Во исто време, омското загревање има негативно влијание врз процесот на формирање на бојата кај барените колбаси.

Клучни зборови: традиционално загревање; омско загревање; стабилност на масти; барени колбаси збогатени со PUFA

INTRODUCTION

Fortification of food and particularly meat products with polyunsaturated fatty acids (PUFAs) is currently a very important problem due to their high biological activity and their numerous health benefits (Calder et al., 2006; Buckley et al., 2010; Mason et al., 2013; Ganesan et al., 2014; Ma et al., 2015).

PUFA, especially omega-3 fatty acids are vital factor in food because humans as well as other mammals are unable to synthesize them. At the same time, during processing and storage of food products containing a significant amount of lipids, fat degradation processes are observed to form their destruction products such as free fatty acids, peroxides and a variety of other (Tsanev et al., 1988; Sirri et al., 2003). The more unsaturated the fatty acids are, the more unstable they become and the problem of their preservation is more substantial (Betti et al., 2009; Rymer et al., 2010).

One of the processes that affect the acceleration of degradation of lipids is heating. The traditional method of sausage heating in the meat industry presuppose heat input to the surface of the product, followed by transfer of heat to its center.

As a heating media, hot air, mixture of air and smoke fume, water vapor or water is used. The process of heat transfer is long enough, especially in the case of large geometric dimensions of the product. The total duration of the heat treatment of some kinds of cooked sausages can be up to 6 hours. When using fats with a low degree of unsaturation in particular backfat of pigs, it does not obstruct to produce high quality foods because of their high thermal stability. As for raw materials containing PUFAs, it may lead to a considerable decrease of quality and product safety.

The final temperature in the center of a sausage is predefined. In this case it is 72°C. The temperature decrease is unacceptable because of bacterial safety considerations. To reduce the probability of degradation of lipids it is necessary to reduce the heating time. The ohmic heating is one of the promising methods of heat treatment (Shirsat et al., 2004; Varghese et al., 2014). When we use this technology the heat is produced simultaneously in the entire volume of the product because of the electric current passage through it and the heating rate is independent of its geometrical dimensions, so the ohmic cooking is a perspective way to enhance meat products quality (Piette et al., 2004; Ruri et al., 2014). In this regard, the aim of our study was to investigate the possibility of increasing fat quality indicators of sausages fortified with polyunsaturated fatty acids.

MATERIALS AND METHODS

As material for experiment Bologna type sausage was used. As a source of omega-3 polyunsaturated fatty acids linseed oil obtained by method of cold pressing was used. On the base of linseed oil the emulsion was produced in accordance with traditional technology of mayonnaise sauce (chicken egg mélange – 100 g, mustard sauce – 20 g, salt – 10 g, sugar – 10 g, 9% acetic acid – 15 g, linseed oil – 850 g). Emulsion was obtained using laboratory blender at 15 000 rpm speed, duration of emulsification – 5 min. Abovementioned emulsion was added to Bologna sausage-meat (beef meat – 40%, lean pork meat – 40%, pork fat tissue – 20%, salt – 2%, spice mixture – 0,1%, sodium nitrite – 7 mg per 100 g, phosphate mixture – 0,2%, added iced water – 20%). Linseed emulsion substituted a part of pork fat tissue. Dosage of emulsion was 5 – 10 – 15 – 20%. Sausage-meat was ground in the laboratory cutter at 4 000 rpm and was either stuffed into 120 mm dia natural casing (beef caecum) or into 30 mm dia tube for ohmic heating made of food grade teflon with titanium electrodes and K-type thermocouple mounted in the geometrical center of the tube.

Sausages in natural casing undergone standard thermal treatment in the smoke-house (drying – 50 min at 40°C, smoking – 20 min at 55°C, boiling – 170 min at 74 °C or until temperature in the center of the product will reach 72°C). Immediately after thermal treatment sausages were cooled by cold water shower for approximately 20 – 25 min followed by immersion in an iced water bath until temperature in the center reached 18 – 20°C and stored overnight in the +2°C cold room. On the next morning the products were analyzed.

Ohmic heating was carried out at constant 100 V voltage applied to electrodes until temperature reached 72°C. The cooked products were transferred to thermostat with 72° temperature and maintained there for 20 min to ensure proper antibacterial effect. After this time the teflon tubes were immersed in an iced water bath and cooled and stored as described above.

The quality of product lipid fraction was assessed using data on acid value using ISO 660:2009 method and peroxide value using ISO 3960:2010 method. Each test was determined for three times and results are presented as mean value plus/minus corrected sample standard deviation (SD_{N-1}). P-values were calculated to determine the statistical significance of the differences between the indicators of quality of the fat fraction of the samples obtained by the new and traditional technology.

RESULTS AND DISCUSSION

The duration of ohmic heating of Bologna sausages in the condition of experiment was approximately 120 – 140 seconds at 100 V depending on the percentage of pork fat substituted by linseed emulsion – the more emulsion was added the shorter is cooking time. It proves that oil emulsion has better current conductivity compared with pork fat tissue probably due to a larger amount of added electrolytes.

Difference in cooking duration (20 minutes instead of 4 hours) led to significant distinction in sausage quality. The changes of the quality indicators of fat fraction of the sausages after different types of thermal treatments are given in Tables 1–2. The differences between the samples and the control were statistically significant ($p < 0,001$).

The data presented in tables show that enrichment of sausages with PUFA is the cause of increasing both acid value and peroxide value during storage. The more fat tissue is substituted by linseed emulsion the more significant is increase of these indicators. As a control were used the specimens without emulsion. Immediately after thermal treatment both acid value (1.74 ± 0.04 and 1.56 ± 0.03 mg KOH, $p < 0.001$) and peroxide value (0.039 ± 0.002 and 0.035 ± 0.003 % J, $p < 0.001$) in control specimens were very similar independent of way of cooking – conventional or ohmic. The more time specimens were stored the bigger became difference between control and experimental specimens especially in high fortified ones. The statistical significance of differences between the peroxide values of the samples obtained by the two technologies also increases with storage time increasing from $p < 0.05$ to $p < 0.01$ and even to $p < 0.001$ (Tables 3 – 4).

Table 1

Acid value of fat fraction of Bologna after conventional cooking, mg KOH ($X \pm SD_{N-1}$)

% emulsion	Days of storage				
	1	2	3	4	5
0	1.74 ± 0.04	1.83 ± 0.03	2.01 ± 0.06	2.17 ± 0.05	2.41 ± 0.07
5	2.00 ± 0.05	2.14 ± 0.04	2.36 ± 0.04	2.57 ± 0.06	2.82 ± 0.06
10	2.23 ± 0.04	2.46 ± 0.06	2.70 ± 0.05	2.94 ± 0.08	3.22 ± 0.07
15	2.42 ± 0.06	2.66 ± 0.07	2.95 ± 0.06	3.18 ± 0.08	3.47 ± 0.09
20	2.48 ± 0.05	2.80 ± 0.09	3.15 ± 0.08	3.36 ± 0.07	3.64 ± 0.11

X – mean, SD_{N-1} – corrected sample standard deviation; number of pieces *n* = 3

Table 2

Acid value of fat fraction of Bologna after ohmic heating, mg KOH ($X \pm SD_{N-1}$)

% emulsion	Days of storage				
	1	2	3	4	5
0	1.56 ± 0.03	1.66 ± 0.04	1.74 ± 0.03	1.83 ± 0.04	1.94 ± 0.05
5	1.66 ± 0.04	1.84 ± 0.03	1.93 ± 0.05	2.05 ± 0.06	2.22 ± 0.04
10	1.75 ± 0.05	1.99 ± 0.04	2.10 ± 0.06	2.27 ± 0.04	2.49 ± 0.05
15	1.84 ± 0.04	2.11 ± 0.05	2.26 ± 0.07	2.45 ± 0.06	2.68 ± 0.07
20	1.90 ± 0.06	2.18 ± 0.08	2.36 ± 0.06	2.56 ± 0.09	2.79 ± 0.08

X – mean, SD_{N-1} – corrected sample standard deviation; number of pieces *n* = 3

Table 3

Peroxide value of fat fraction of Bologna after conventional cooking, % J ($X \pm SD_{N-1}$)

% emulsion	Days of storage				
	1	2	3	4	5
0	0.039 ± 0.002	0.044 ± 0.002	0.053 ± 0.004	0.062 ± 0.003	0.078 ± 0.004
5	0.044 ± 0.002	0.052 ± 0.003	0.060 ± 0.003	0.070 ± 0.005	0.084 ± 0.004
10	0.053 ± 0.003	0.063 ± 0.005	0.071 ± 0.003	0.083 ± 0.005	0.096 ± 0.005
15	0.065 ± 0.004	0.077 ± 0.005	0.088 ± 0.004	0.100 ± 0.006	0.112 ± 0.008
20	0.077 ± 0.005	0.091 ± 0.004	0.107 ± 0.008	0.118 ± 0.008	0.129 ± 0.009

X – mean, SD_{N-1} – corrected sample standard deviation; number of pieces *n* = 3

Table 4

Peroxide value of fat fraction of Bologna after ohmic heating, % J ($X \pm SD_{N-1}$)

% emulsion	Days of storage				
	1	2	3	4	5
0	0.035 ± 0.003	0.039 ± 0.003	0.043 ± 0.005	0.048 ± 0.004	0.054 ± 0.006
5	0.037 ± 0.002	0.041 ± 0.003	0.047 ± 0.005	0.051 ± 0.004	0.058 ± 0.004
10	0.040 ± 0.003	0.047 ± 0.004	0.053 ± 0.003	0.058 ± 0.006	0.067 ± 0.005
15	0.045 ± 0.004	0.055 ± 0.005	0.061 ± 0.005	0.069 ± 0.005	0.078 ± 0.007
20	0.049 ± 0.004	0.064 ± 0.009	0.071 ± 0.008	0.081 ± 0.006	0.093 ± 0.008

X – mean, SD_{N-1} – corrected sample standard deviation; number of pieces $n = 3$

For greater convenience, the data presented in Figures 1 and 2.

The main reason of the peroxide value increase is the bigger content of double bonds in such PUFA as linoleic and especially linolenic acid, which are the major components in linseed oil fatty acid composition. The increase of acid value in the specimens rich in PUFA can be explained by that fact that linseed oil was non-refined and thus contained various plant components including enzymes. Hydrolytic enzymes of plant origin are more durable and heat-stable in comparison with the enzymes of animal origin. As it is known, the temperature optimum of action of mammalian enzymes is within the range 35 – 45°C, sometimes – up to 50°C. At higher temperatures, they quickly lose their activity up to complete inactivation (Соколов, 1965). Because enzymes of plant origin, e.g., ficin, papain and others have temperature optimum of action in the range 60 – 80°C (Соколов, 1965), they are frequently used in the food technology. Some other plant enzymes are even more heat-stable – soybean peroxidase activity perfectly preserved after heating for 15 minutes at a temperature of 70 – 110°C, followed by heating for 5 hours at 45°C. Even heating at 200°C does not lead to complete inactivation of the peroxidase – enzyme activity is 25% of the original (Кузнецова, 2012).

The influence of storage time is quite predictable – fat deterioration has positive correlation with the storage time despite the low storage temperature. It is especially noticeable in sausages which had undergone prolonged heating during conventional cooking (Figs. 1a and 2a). The ohmic heating takes so short time that both hydrolytic and oxidative processes has no time to develop to significant extent (Figs. 1b and 2b), prompt consequent chilling is slowing these processes again.

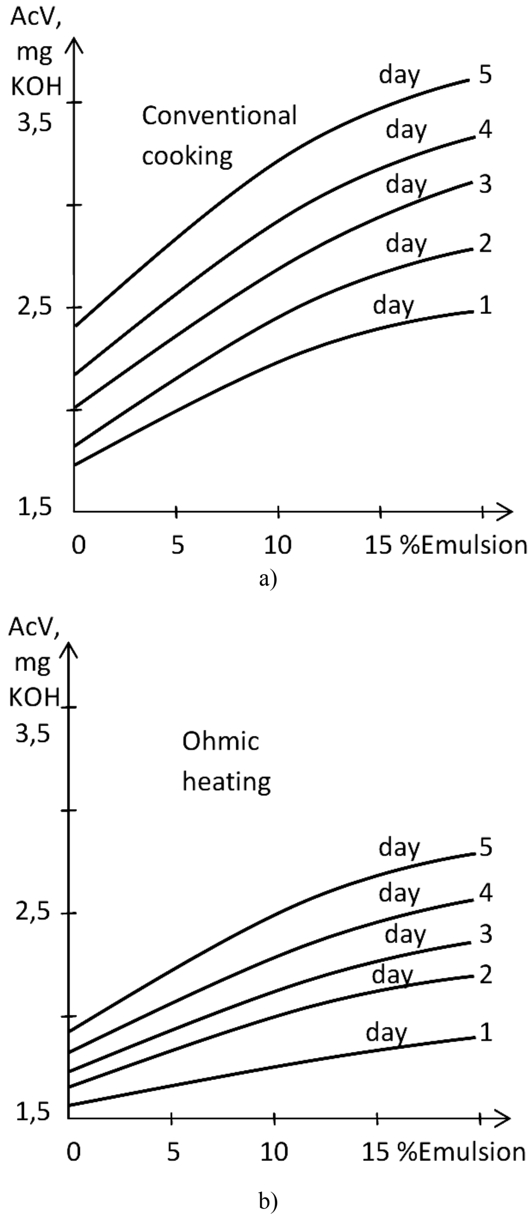

Fig. 1. Influence of linseed emulsion upon acid value (AcV, mg KOH per 1 g of fat) of lipid fraction of sausages after different thermal treatments during storage

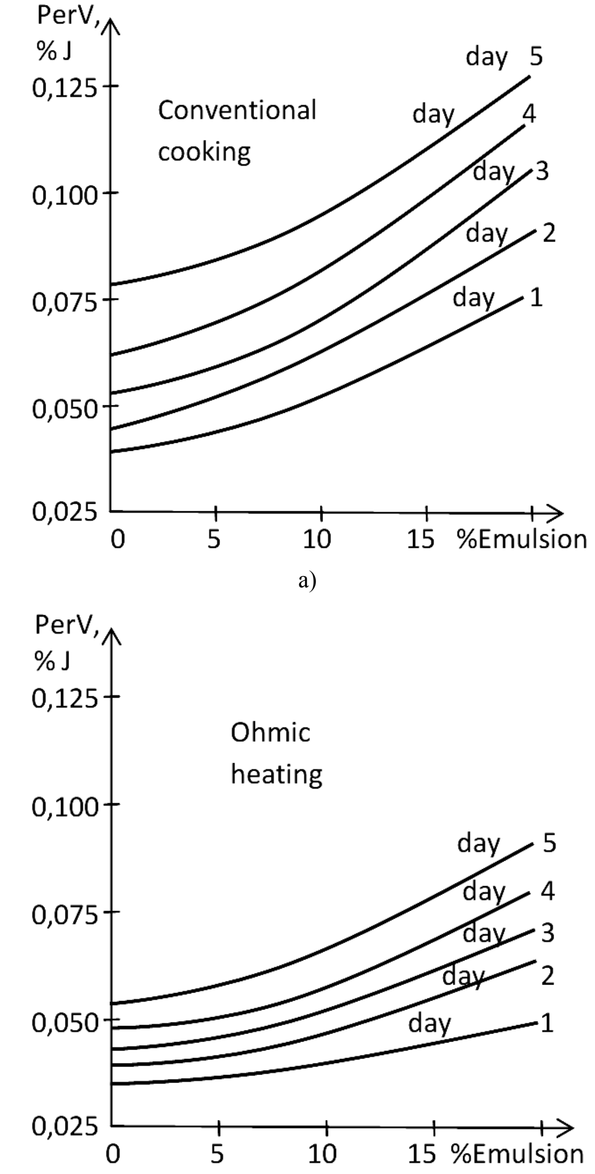

Fig. 2. Influence of linseed emulsion upon peroxide value (PerV, % J) of lipid fraction of sausages after different thermal treatments during storage

Despite abovementioned positive results ohmic heating causes some negative effects. The color of Bologna sausages produced by the new technology was pale and not typical for cooked sausages. It can be explained by the high-speed heating whereby the reaction between sodium nitrite and myoglobin does not have time to go. The optimum temperature for the reaction of color formation of meat products is 40 – 45°. At this temperature the reduction of metmyoglobin and formation of nitrosomyoglobin taking place. The animal tissue enzymes and bacterial enzyme nitrite reductase are involved in this process (Sokolov, 1965). This process need certain time for fulfilment, so the technology of ohmic heating should be modified to ensure proper color formation.

CONCLUSIONS

The obtained results show that traditional technologies of sausage cooking are not suitable for PUFA-fortified products when using casings of large diameters and in some other cases. Due to drastically reduced cooking time ohmic heating can reduce fat deterioration that is very important for high unsaturated fats and oils, such as linseed oil. So this innovative technology has several advantages in comparison with traditional cooking. Among these advantages are: the speed of process, the economy of casings, energetic resources and manufacturing areas, and, that is the most important, ohmic heating is capable to enhance quality of functional products. However ohmic cooking may cause problems with color of cooked sausage and this problem should be solved in the course of future investigation.

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