Original Paper

Nutritional indicators in the technological process of sausage processing

Dušan Solár[1], Ondrej Bučko[1], Juraj Čuboň[3], Marko Halo Jr.[2], Martin Massányi[1], Marko Halo[1], Peter Massányi[3]
[1]*Slovak University of Agriculture in Nitra, Faculty of Agrobiology and Food Resources, Slovakia*
[2]*Slovak University of Agriculture in Nitra, AgroBioTech Research Centre, Slovakia*
[3]*Slovak University of Agriculture in Nitra, Faculty of Biotechnology and Food Sciences, Slovakia*

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According to biological and nutritional value, meat and meat products are among the most important components of human nutrition. The risk of meat contamination is a great concern from the point of view of food safety, and especially human health. The aim of this study was the determination of nutritional values in meat samples of fresh and smoked sausage. From a technological point of view, the water content was the highest in meat samples and continually decreased in the samples that underwent processing. The water content of the meat samples was 68.2%. In the samples of unsmoked and smoked sausages, the measured values were slightly lower. In the samples of unsmoked sausages, the water content was 63.1%. As the water content decreased, the fat content of the sausages increased. The protein content has not changed significantly in the production process. In the meat the value of proteins was 19.07 g 100 g^{-1} and in the samples of smoked sausages the result was 18.78 g 100 g^{-1}. The content of essential fatty acids was the highest in meat samples. This value decreased in unsmoked as well as smoked sausages. Cholesterol levels were rising over the course of the experiment. Results of this study clearly show difference in technological parameters related to technological process.

Keywords: meat, sausage, technological process, nutritional indicators

1 Introduction

Nutrition is necessity for life of animals, as it supplies the body with the energy and nutrients needed for physical and mental development. In a broader sense, nutrition is one of the most important factors in human health and directly impacts lifespan (Grusak et al., 1999).

On the one hand, developing countries suffer from food insecurity, and on the other hand, in developed countries, the population suffers from civilization diseases caused by excess food. The increased incidence of civilization diseases such as obesity, hypertension, cancer, cardiovascular diseases and allergies also lead to decreased immunity response to infectious diseases (Sharma et al., 2009; Gupta et al., 2017).

Knowledge about the impact of nutrition on the health of the population in developed countries has led to the design and enforcement of recommended nutritional doses for the consumption of individual foods. The recommended nutritional doses tend to be adjusted to the physiological requirements of the human body, taking age, gender, amount of physical activity, health status and other aspects (Preziosi et al., 1998).

With the biological and nutritional value, meat and meat products are among the most important foods needed for adequate human nutrition. The meat and slaughter by-products processing into meat products, require certain expertise in addition to practical experience. Correct meat processing ensures meat products quality and satisfactory hygienic conditions during the handling of the meat and use of the correct technological methods to avoid meat spoilage. Food quality and safety of nourishment is the priority for customers which also effects global food markets. Health protection of consumers can be only secured by more strict monitoring and regulation of foods (Hird et al.,

***Corresponding Author:** Dušan Solár, Slovak University of Agriculture in Nitra, Faculty of Biotechnology and Food Sciences, Department of Animal Husbandry, Tr. Andreja Hlinku 2, 949 76 Nitra, Slovakia

2014; Cole et al., 2020). Meat is a spoilable food due to its composition, thus the aim of the producer is to produce the most durable meat products intended for the consumer consumption (Steinhauserová et al., 2015). Additives, storage temperature, raw meat quality, production conditions and processing conditions all affect the overall quality of meat products (Zajác et al., 2015).

The consumption of meat in individual countries depends on the production capabilities, the economic power of the population and the tradition of meat consumption. Nowadays, the demand for low fat and health safety in developed countries is becoming more and more relevant. The number of opponents of meat produced with a growth stimulator is also increasing. Various diseases such as BSE, avian flu, etc. have had a strong negative effect on meat consumption. On the other hand, there is a growing interest in meat produced under organic farming conditions (Delgado et al., 2003; Stoll-Kleemann et al., 2017).

The aim of the present study was to investigate basic composition, amino acids and fatty acids content in the raw material and in processed sausages compared to basic components.

2 Material and methods

2.1 Sample processing

In our experiment, we focused on monitoring of the specific processed product. Pork meat was used in this study. Later cured trimmed meat mix was divided into equal parts. Currently available conventional spices paprika, pepper, caraway, garlic and spicy paprika were added. Each part of sausage mixture was separately minced and filled into natural sausage casings, smoked and ripened in climatic chamber (Kročko et al., 2016).

In a total of 8 samples were collected (fresh meat mixture, unsmoked sausage, later smoked) in various stages of food processing (total 24 samples; 8 × 3 in each sample). Each sample consisted of frozen piece. The frozen samples were – raw pork meat (shoulders and pork belly) with a size of approx. 2 × 2 cm, unsmoked sausage with a size of approx. 2 × 2 cm and smoked sausage with a size of approx. 2 × 2 cm. The samples were frozen immediately after collection (-18 °C) and later analysed after final collection. All sausages were made using the same methodologic recipe and hot smoking. Samples originated from campus of SUA in Nitra and domestic slaughterhouses.

2.2 Analysis of nutritional parameters in muscle and products

The chemical composition of meat was determined from the muscle homogenate as well as the final product – sausage (50 grams), from which a sample was prepared. The chemical composition was determined using the FT IR method on a Nicolet 6700 (Thermo Scientific, Waltham, MA, USA). Fourier-transform infrared spectroscopy (FTIR) is a technique used to obtain an infrared spectrum of absorption or emission of a solid, liquid or gas. An FTIR spectrometer simultaneously collects high-resolution spectral data over a wide spectral range. This confers a significant advantage over a dispersive spectrometer, which measures intensity over a narrow range of wavelengths at a time (Griffiths and de Hasseth, 2007).

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Sample of transversely striated muscle and product was collected during meat processing. After collection, the samples were placed into freezer at the temperature of -18 °C. Total water content, total protein content, fat, essential amino acids, cholesterol and fatty acids were measured according to previous reports (Čuboň et al., 2019; Haščík et al., 2019a; Haščík et al., 2019b; Angelovičová et al., 2016). These analysis (infrared spectrum determination of muscle homogenate) were performed by spectroscopy. Principle of the method is the absorption of infrared radiation passing through the sample in addition to changes in the rotational vibrational energy states of the molecule depending on changes in the dipole moment of the molecule. We obtained the infrared spectrum (analytical output), which is actual graphical representation of the functional dependence of energy, which is expressed in units of absorbance (A) or in percent of transmittance (T) at the wavelength of incident radiation. The intensity ratio (I) of the radiation transmitted by the sample compared to the intensity of the radiation emanating from the source (Io) is defined as the transmittance. The definition of absorbance is the decimal logarithm of 1/T. Reason why we used wavenumber is because it is a logarithmic dependence of energy on wavelength. A wavenumber is defined as inverse of a wavelength. Thus, it is a linear function due to the dependence of energy on the wavenumber (Lípová et al., 2019).

2.4 Statistical analysis

Statistical analysis was executed using the GraphPad Prism 8 (GraphPad Software Inc., USA) software. The individual values of the elements contained in meat, uncooked sausage, smoked sausage was expressed as average values and the results were given with a standard deviation. All statistical tests were carried out at levels of significance at $^{*}p < 0.05$.

3 Results and discussion

The water content of the meat samples (shoulders and belly) was 68.2%. In the samples of unsmoked and smoked sausages, the measured values were slightly lower. Through the production process, we obtained unmixed sausage, which already contained fat (approximately 25–35%), characterized by a lower water content (15%), which caused an overall decrease of water content to 65.81%. The course of maturation (fermentation and drying) is characterized by the water removal and therefore we obtained the desired consistency, taste and aroma. In the samples of unsmoked sausages, the water content was 63.1% and would continue to decrease in the maturing process. Before the smoking itself, the sausages are dried, and smoking with warm smoke was used, which is common in the case of domestic slaughterhouses, water evaporates through the vapor-permeable containers into which the sausages were inserted. This might have also caused the decrease in water content in the samples of the final product (Table 1).

As the water content decreased, the fat content of the sausages increased. We can also monitor this on measured values of intramuscular fat. In the lean muscle samples of pigs for slaughter, the fat content was only 7.71% and after the production process, it increased to 9.3%. The process of maturation increased its content up to 11.44%.

The protein content has not changed significantly in the production process. The values rather depend on which part of the sausage the sample was taken from, even though the homogenate was used. Some parts contained more fat and therefore there was relatively less protein, which was reflected in the results of unsmoked sausages, where the value of 15.85 g 100 g^{-1} was measured. On the other hand, in the meat the value of proteins was 19.07 g 100 g^{-1} and in the samples of smoked sausages the result was 18.78 g 100 g^{-1}. The content of essential fatty acids was the highest in meat samples (8.51 g 100 g^{-1} FAME). Value decreased in unsmoked sausages to 4.85 g 100 g^{-1} FAME and in smoked sausages to 4.7 g 100 g^{-1} FAME.

Cholesterol levels were rising over the course of the experiment. A value of 0.53 g 100 g^{-1} in meat samples was detected. The measured value was higher in sample of unsmoked sausages – 1.34 g 100 g^{-1} as well as in smoked sausages – 1.6 g 100 g^{-1} (Table 1).

Comparing the chemical component of pork meat (cut average), we found that the average water content measured in our samples was 68.2%. It has been stated that the average value is usually about 50.9% (Čuboň et al., 2012). Our samples were frozen and condensed during their homogenization, which resulted in higher measured water content. Higher temperature may cause protein denaturation and a lowering water holding capacity. The water holding capacity, the status of muscle proteins and its microscopic structure designate the rehydration property of the dehydrated meat. The muscle fiber diameter and also the space between the groups of muscle fibers reduce during dehydration (Gómez et al., 2020). The average measured protein content is 15.2 g 100 g^{-1} FAME (Čuboň et al., 2012), which is 3.87 g 100 g^{-1} FAME less than the average value of proteins measured in our samples (19.07 g 100 g^{-1}

Table 1 Composition of macronutrients, amino acids and fatty acids in the raw meat and unsmoked/smoked sausage

Parameter	Meat		Unsmoked sausage		Smoked sausage	
	average	*SD*	average	*SD*	average	*SD*
Water (g 100 g^{-1})	68.20	0.87	65.81	3.20	63.61	4.12
Protein (g 100 g^{-1})	19.07	1.41	15.85	1.12	18.78	1.501
Fat (g 100 g^{-1})	7.71	0.95	9.03	4.69	11.44	5.94
Essential amino acids (g 100 g^{-1})	8.51	0.94	4.85	2.86	4.70	3.42
Arginine (g 100 g^{-1})	1.08	0.16	1.55	0.11	1.38	0.15
Histidine (g 100 g^{-1})	0.69	0.12	0.97	0.08	0.74	0.16
Isoleucine (g 100 g^{-1})	0.66	0.10	0.95	0.05	0.83	0.10
Leucine (g 100 g^{-1})	1.32	0.19	1.89	0.12	1.70	0.18
Lysine (g 100 g^{-1})	1.44	0.22	2.10	0.15	1.87	0.20
Methionine (g 100 g^{-1})	0.56	0.09	0.85	0.08	0.83	0.10
Phenylalanine (g 100 g^{-1})	0.69	0.10	0.97	0.07	0.86	0.10
Threonine (g 100 g^{-1})	0.70	0.08	0.97	0.08	0.89	0.10
Cysteine (g 100 g^{-1})	0.23	0.04	0.40	0.07	0.44	0.10
Valine (g 100 g^{-1})	0.74	0.07	0.89	0.09	0.71	0.14
Cholesterol (g 100 g^{-1})	0.53	0.11	1.34	0.48	1.60	0.59
SAFA (%)*	33.06	0.90	29.07	2.71	27.35	3.01
MUFA (%)*	49.34	1.17	58.24	5.85	62.42	6.82
PUFA (%)*	12.21	1.05	6.99	3.56	6.37	3.73
Omega-3 fatty acids*	0.49	0.08	0.70	0.10	0.74	0.14
Omega-6 fatty acids*	8.91	0.93	4.51	3.20	4.76	3.10
C12:0 (lauric acid)*	0.12	0.01	0.08	0.04	0.06	0.04
C14:0 (myristic acid)*	1.38	0.06	1.31	0.04	1.30	0.03
C16:0 (palmitic acid)*	24.26	0.40	24.12	0.24	24.27	0.15
C17:0 (heptadecanoic acid)*	0.28	0.04	0.20	0.05	0.19	0.04
C18:0 (stearic acid)*	10.50	0.22	10.87	0.14	11.02	0.19
C18:1 cis11/trans15t (vaccenic acid)*	5.01	0.20	4.61	0.11	4.61	0.17
C18:1 cis9c (oleic acid)*	33.62	7.67	49.71	4.74	54.94	8.38
C18:2 cis9c/trans11 (conjugated linoleic acid)*	0.17	0.11	0.10	0.02	0.09	0.02
C18:3 n-3 (linolenic acid)*	0.13	0.03	0.19	0.06	0.23	0.08
C18:2 n-6 (linoleic acid)*	5.84	1.03	4.75	1.11	5.32	1.11
C20:1 (eicosnoic acid)*	0.62	0.14	0.69	0.33	1.35	0.62
C20:4 n6 (arachidonic acid)*	1.78	0.32	0.90	0.48	0.88	0.52
C20:5 n3 (eicosapentaenoic acid)*	0.10	0.01	0.05	0.03	0.04	0.03
C22:5 n-3 (docozapentaenoic acid)*	0.14	0.01	0.12	0.01	0.12	0.01
C22:6 n-3 (docosahexaenoic acid)*	0.03	0.01	0.03	0.01	0.03	0.01

*g 100 g^{-1} (FAME) of fatty acid methyl esters; $p > 0.05$

FAME). The average fat content should reach 33%, but in our samples the value reached only 1.71% because we observed only intramuscular fat, not total fat. Different effects in meat as fat retention due to protein denaturation was reported (Gómez et al., 2020).

The measured value of cholesterol in muscles and fat repositories was very similar and only varies from 0.6 g kg^{-1} to 0.85 g kg^{-1} (Čuboň et al., 2012). In our samples, the average cholesterol content in meat was 0.53 g kg^{-1}. Reducing fat content in meat products does not reduce cholesterol content. It was published that when fat is reduced and lean meat is increased, the cholesterol content of the meat product may increase (Jiménez-Colmenero et al., 2001). Our average values are in accordance with previously published data of the chemical composition observed by multiple authors focusing on physical-chemical meat quality indicators in different breeds of pigs (Orzechowska et al., 2008; Debrecéni et al., 2016; Imrich et al., 2020).

After comparison, we found that the average values of the chemical compounds do not differ significantly in comparison with other studies. We compared physical-chemical quality indicators measured in the Slovak Large White breed with our samples, which also come from the same breed of pig. In the previous research done by Debrecéni et al. (2016), the average water content was 74.3% compared to our samples, where the average water content (68.2%) was 6.1% less. The average content of proteins found in our study was 19.07%. Debrecéni et al. (2016) report an average protein content of 23.71%, which does not correspond with our measured results. The average value of intramuscular fat was 1.71%, which is 0.47% more than the findings of Debrecéni et al. (2016).

We also compared the of selected fatty acids profile measured in our meat samples with the values reported in literature (Čuboň et al., 2012). The value of myristic acid in our samples was 1.38 g 100 g^{-1} FAME and its reference value in pork belly stated in the textbooks is 1.5 g 100 g^{-1} FAME. The standard value for palmitic acid is 23.2 g 100 g^{-1} FAME. In our experiment, we measured a similar value – 24.26 g 100 g^{-1} FAME. The value of stearic acid in our samples was 10.5 g. 100 g-1 FAME. We found a certain difference with oleic acid (33.62 g 100 g^{-1} FAME), while its reference value is 45.3 g 100 g^{-1} FAME. Linoleic acid was 5.84 g 100 g^{-1} FAME in our samples, but in the literature the value is higher, up to 13.2 g 100 g^{-1} FAME. The reference value for linolenic acid is 1.4 g 100 g^{-1} FAME, but in our samples, we measured a value of only 0.13 g 100 g^{-1} FAME (Čuboň et al., 2012), although generally our measured data are comparable with yet published data.

4 Conclusions

The aim of our study was to determine the nutritional content in raw meat samples (mixture), unsmoked sausages and smoked sausages. From a technological point of view, the water content was highest in raw meat samples, because pigs going for slaughter, are characterized by a higher water content. The water content in the production process decreased due to the addition of fat, other substances and drying processes. After the start of the maturing process of the final product, the water content continued to decrease, which is typical for this meat product. As the water content of the production process decreased, the fat content increased. Furthermore, the measured results showed that the cholesterol content had an increasing character over the production process.

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