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Original scientific paper

Influence of Temperature and Heat Treatment Regime on Chemical Properties of Pork Meat

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Abstract: The real importance of meat in human nutrition has been defined during the last century. Professional and scientific publications of the twentieth century are often written about the nutritional value of meat. Thermal processing of meat is as old as civilization itself. Meat drying as a procedure for a longer shelf life, probably first appeared as a result of some accident in which the fresh meat has been exposed to heat. The first works about the problems of heat treatment of pork were published in the 1950s.

The aim of this paper was to investigate the effect of temperature and different methods of heat treatment on chemical properties of processed pork meat. To determine the optimal conditions for various heat treatment processes, in this paper, meat processing was performed at different temperatures, and set the temperature range from 51 ºC to 100 ºC. Therefore, the meat is processed by dry heat treatment (roasting) and cooking in water (at atmospheric pressure). Then, the change of chemical composition of processed meat was noted (moisture content, ash, fat, protein, micronutrients).

Keywords: meat, heat processing, the chemical composition of meat.

Introduction

Meat consists of different amounts of muscle and connective, fat, bone, and a small degree of nervous and epithelial tissues, which is removed from the bone, cartilage, coarse connective tissue, as well as larger outer layers of fat (Petrović, 1989). Muscle meat belongs to skeletal or cross-striped muscle and forms the main mass of muscle. The amount of other tissue in meat is variable and depends on the type of animal, breed, age, sex, nutritional status, position of the muscles in the body, etc (Petrović, 1989) (Perić, 2008).

Pork meat is highly rich in nutritive and valuable ingredients, including proteins, which is important to emphasize. Meat proteins in the diet are important both in terms of quantity as well as its high quality of amino acid composition. Pork meat contains a small amount of connective tissue, but it is very rich in highly charged proteins, which contain all the essential amino acids. Controlled pork breeding and their carefully regulated diet provide meat with exceptional nutritional value (Perić, 2008) (Toldrá, 2010).

Pork meat contains higher levels of the amino acid arginine, which participates in a number of biochemical processes and is a part of important molecules and hormones in the body. This amino acid is necessary to start the process of detoxification of the body, especially the liver. In addition, arginine can stimulate production of somatotrophs, the hormone or growth. Mineral matter from the pork meat in humans can put to good use, thanks to the quantity in which they are represented and easily adoptable biological form. Pork meat has high contents of zinc, iron, chromium and selenium in the form of "organic" compounds, which are readily absorbed from intestine into the blood. This type of meat is known for its high content of water-soluble vitamins, particularly vitamins from the B group (Santé-Lhoutellier et al., 2008).

It is less known that pork meat is rich in carnitine, a compound that is very popular among athletes and people who want to increase physical endurance. It is located in pork meat in its natural environment and there is no risk of possible side effects that may arise if the matter is taken in the form of finished products. Pork meat is one of the best sources of biotin, which is now added to many preparations to improve the general state of the organism and for energy in cells. The muscle tissue of pigs contains unsaturated fatty acids, particularly those that are called "structural" fatty acids such as phospholipids (Rede & Petrović, 1997) (Radetić & Matekalo-Sverak, 2010).

The content of cholesterol in pork meat, thanks to a controlled feeding during breeding, decreased substantially. Moreover, the content of highly valuable linoleic acid increased in meat, which is one of the essential fatty acid necessary for proper cell structure (Bašić et al., 2010). Pork meat obtained during the controlled production is considered as extremely safe food and is an important ingredient for proper diet. The adult human daily needs 0.8 g of proteins per 1 kg of body weight or an average of 45 to 55 g, which could be settled with about 250 to 300 g of meat. Because of the positive effect of nutritional fiber, it is desirable that 1/3 is animal protein, and 2/3 of plant origin, which means that it is enough to eat 100 -150 g of meat (Radetić & Matekalo-Sverak, 2010) (Grujić & Miletić, 2006).

Chemical composition of meat depends primarily on the relationship of the tissue in the muscle at the time of animal death. This ratio can vary greatly, depending on a number of complex pre-mortal factors. Skeletal muscles contain about: 75.0% water, 18.5% proteins, 3.0% lipids, 1.5% non-protein nitrogen compounds, 1.0% carbohydrate and non-nitrogen compound, and 1.0% inorganic matter in relation to fresh muscle mass (Perić, 2008).

Changes that occur in proteins (denaturation, coagulation, hydrolysis, oxidation, etc.) are causing changes in physico-chemical and sensory properties of heat-treated meat. Elevation of temperature during the heat treatment significantly affects the state of myofibrillar proteins, and based on the temperature reached in the thermal center of the piece of meat to be heat treated, can make conclusions about the expected properties of the meat, which is ultimately the most important factor for digestibility and protein content of free amino acid in the product. Besides temperature, the nature and speed of change is affected by the way of how meat is heat treated (dry or wet heat treatment). The heat treatment leads to denaturation and cleavage of certain proteins and the subsequent creation of large aggregates. Partly to higher temperatures of heat treatment in wet conditions myofibrillar proteins, like collagen hydrolysis. In addition to the structural role in mature tissues, collagen is directly involved in the development of tissue. The main characteristic of collagen is to form insoluble fibers with good mechanical properties. Collagen is a main factor that affects the texture of cooked meat (Toldrá, 2010) (Santé-Lhoutellier et al., 2008) (Grujić & Miletić, 2006) (Meinert et al., 2007).

The aim of this paper was to investigate the effect of heat treatment (modes of heat treatment, as well as the height of the final uniform temperatures in the thermal center) on change in the chemical properties of thermally processed pork meat.

Materials and Methods

To determine the influence of temperature of heat treatment on intensity of changes in meat, and to determine the optimal temperature, it was decided to examine in this paper, changes in chemical properties of pork meat. Therefore, the samples were thermally processed by dry heat treatment and by wet heat treatment to achieve the following cooking temperature at the center of the sample for both modes of heat treatment:

- 51°C; 61°C; 71°C; 81°C; 91°C and 100°C, while the fresh muscle was examined before the heat treatment.

Samples and sample preparation

The study was conducted on the pork meat, reared on the farm, "ZP Komerc" in Bijeljina. Pigs were bled under identical conditions and subjected to an identical procedure of primary treatment. After 24 hours cooling, samples of dorsal muscle were taken (Longissimus dorsi) from 6 pigs under one year of age and average gross weight about 130-140 kg. After separating muscles from the carcasses, the pieces were frozen and cut into slices thickness from 1.5 to 2.0 cm.

After a suitable labeling of the samples they were packed in polyethylene bags and stored at a temperature of -30°C. They were kept at this temperature until the moment of analyzing. Samples were packed in sealed boxes, and prior to testing they were thawed overnight in a refrigerator at a temperature of 4-5°C.

Heat treatment of samples

Dry heat treatment was carried out by roasting slices in the furnace like "Elite" 3 kW. Samples were wrapped in the bottom of the Al metal foil and processed to achieve the set temperature in the center of the sample. The temperature in the furnace during all measurements was 163 ± 2°C. The temperature in the furnace and the temperature in the center of the sample were continuously monitored using a dual-channel thermocouples "Testo" and "Hanna" HI 98810, with range from -50°C to +250°C.

Wet heat treatment was carried out in a water bath. Samples were wrapped in thermosetting plastic bags with absence of air. They were heated until reaching the set temperature in the center of the sample. The temperature was continuously monitored using a dual-channel thermocouples "Testo" and "Hanna" HI 98810, with range from -50°C to +250°C.

Physico-chemical analysis

Chemical analyzes were carried out before the heat treatment, i.e. the fresh meat and after thermal treatment at any given temperature in the selected temperature range from 51˚C to 100˚C.

- The water content in meat (determination of mass loss on drying homogenized sample at 105 ± 1° C to constant weight (ISO 1442);
- Ash content in meat (direct combustion at a temperature of 550º C to constant weight (ISO 936);
- Mineral content in meat (A.O.A.C., 1975);
- The total protein content in meat (Kjeldahl method by "Tecator"A.O.A.C., 1975);
- Fat content by Soxhlet method, extraction of fat from the dried sample by petroleum, distillation and drying at 105 ± 1°C to constant weight (JUS ISO 1443).

The results were statistically analyzed by using the ANOVA, MS Excel.

Results and Discussion

Results of chemical parameters for pork meat quality have been separately presented for fresh, frozen and thawed meat, which was later subjected to thermal treatment (Table 1), for meat processed by wet heat treatment, or cooking (Table 2), and meat that has been processed by dry heat treatment, or by roasting (Table 3). In all cases of heat treatment, the treatment of meat lasted until the temperature in the center of the sample reached 51˚C, 61˚C, 71˚C, 81˚C, 91˚C and 100˚C. The results of examination of the chemical composition of fresh, frozen and thawed meat are shown in Table 1. As shown in Table 1, it can be seen that the average water content of frozen meat was (68.83 ± 2.76%), and was significantly higher ($P<0.05$) than the average water content in fresh thawed meat (60.23 ± 1.59%). Because of loss of water during the thaw, the content of other analyzed parameters is increased, and the average fat content was (3.95 ± 0.45%) and was significantly higher (P<0.05) than the average fat content in frozen meat (2.12 ± 0.59%). The average protein content was (24.98 ± 1.31%), and was significantly higher (P<0.05) than the average protein content of frozen meat (21,.6 ± 1.47%). The average content of ash, phosphorus and iron, after thawing the sample, is significantly different (P<0.05) from the average content in fresh frozen samples, while the calcium and magnesium content was not statistically different in these samples.

Table 1: Analysis of the chemical composition of fresh pork (M. Longissimus dorsi)

Meat sample	Moisture%	Ash %	Fat %	Proteins %	P %	Fe mg/100g	Ca mg/100g	Mg mg/100g
Fresh frozen meat, before heat treatment	68,83[a] ±2,76	3,16[a] ±0,63	2,12[a] ±0,59	21,46[a] ±1,47	0,25[a] ±0,32	0,90[a] ±0,24	3,87[a] ±0,17	6,60[a] ±0,09
Fresh thawed meat, before heat treatment	60,23[b] ±1,59	4,93[b] ±0,92	3,95[b] ±0,45	24,98[b] ±1,31	0,37[b] ±0,05	1,51[b] ±0,37	4,33[a] ±0,54	7,72[a] ±0,22

a, b - different letters in superscript indicate statistical significance (P<0,05)

The summary results of the chemical analysis of meat (with a standard deviation of samples) after heat treatment, roasting and cooking heat treatment, are shown in the following tables (Table 2 and Table 3).

Table 2: Analysis of the chemical composition of fresh pork (M.longissimus dorsi) after dry heat treatment „roasting“in the temperature range from 51 ˚C to 100 ˚C.

Temp. in centre t_c˚C	*Moisture %*	*Ash %*	*Fat %*	*Proteins %*	*P %*	*Fe mg/100g*	*Ca mg/100g*	*Mg mg/100g*
51	41,48[a] ±1,22	6,88[a] ±0,95	4,83[a] ±0,87	29,84[a] ±1,37	0,59[a] ±0,12	1,92[a] ±0,51	4,81[a] ±0,82	8,94[a] ±0,32
61	38,71[a] ±1,94	7,17[a] ±1,73	4,96[a] ±0,22	32,52[b] ±1,31	0,62[a] ±0,28	2,13[a] ±0,44	4,95[a] ±0,42	9,28[b] ±0,39
71	32,62[b] ±2,12	7,71[a] ±0,51	5,28[a] ±0,26	37,98[c] ±1,54	0,63[a] ±0,33	2,24[a] ±0,32	5,14[a] ±0,21	9,73[b] ±0,28
81	29,84[c] ±1,83	8,21[a] ±1,02	5,58[a] ±0,57	38,51[c] ±2,12	0,66[a] ±0,13	2,30[a] ±0,21	5,38[a] ±0,34	9,79[b] ±0,81
91	23,69[d] ±1,92	9,22[b] ±0,81	6,41[b] ±0,97	41,94[d] ±2,32	0,72[a] ±0,34	2,46[a] ±0,61	5,74[a] ±0,41	9,94[b] ±0,37
100	18,81[e] ±0,83	9,95[b] ±0,99	7,83[c] ±0,61	44,59[e] ±2,72	0,78[a] ±0,17	2,87[b] ±0,56	5,86[a] ±0,35	10,04[b] ±0,41

a, b, c - different letters in superscript indicate statistical significance (P<0,05)

For thermal processing of meat we chose the temperature intervals from 51˚C to 100˚C because these temperatures occur in significant changes of proteins (sarcoplasmic proteins, myosin, actin, protein of connective tissue). These changes (denaturation, coagulation, hydrolysis) are changing the relationship between protein and water that is found in meat, causing disruption between the protein and the water molecules and the release of water from the sample. The greater are the changes in the proteins, the greater is the number of molecules of water that will be released and the more intense is the water loss during heat treatment. Together with the loose water from the meat during heat treatment and other matter soluble in water loose (soluble proteins, minerals and vitamins) (Leo & Toldrá, 2009) (Kazemi et al., 2009).

Table 3: Analysis of the chemical composition of fresh pork (M.longissimus dorsi) after wet heat treatment „cooking“ in the temperature range from 51 ˚C to 100 ˚C.

Temp. in centre t_c˚C	*Moisture %*	*Ash %*	*Fat %*	*Proteins %*	*P %*	*Fe mg/100g*	*Ca mg/100g*	*Mg mg/100g*
51	44,44^{a} ±1,87	5,77^{a} ±0,63	4,53^{a} ±0,49	29,81^{a} ±1,98	0,53^{a} ±0,07	1,63^{a} ±0,32	4,59^{a} ±0,81	8,83^{a} ±0,24
61	41,59^{a} ±2,22	6,38^{a} ±1,11	4,57^{a} ±0,71	31,35^{b} ±1,28	0,58^{a} ±0,21	1,92^{a} ±0,52	4,88^{a} ±0,28	9,15^{b} ±0,31
71	36,16^{b} ±1,29	7,27^{a} ±0,63	5,04^{a} ±0,71	34,44^{c} ±1,89	0,59^{a} ±0,32	2,13^{a} ±0,27	5,06^{a} ±0,71	9,48^{c} ±0,19
81	32,14^{c} ±1,74	7,84^{a} ±0,93	5,51^{a} ±0,54	36,28^{c} ±0,98	0,63^{a} ±0,12	2,14^{a} ±0,23	5,32^{a} ±0,29	9,72^{c} ±0,32
91	28,74^{d} ±2,13	8,66^{b} ±0,77	5,87^{a} ±0,42	38,85^{c} ±1,94	0,64^{a} ±0,23	2,35^{a} ±0,27	5,44^{a} ±0,31	9,83^{c} ±0,72
100	23,95^{e} ±1,62	8,84^{b} ±0,69	6,45^{b} ±0,81	42,15^{d} ±2,52	0,71^{a} ±0,17	2,56^{b} ±0,36	5,51^{a} ±0,44	9,88^{c} ±0,61

a, b, c - different letters in superscript indicate statistical significance (P<0,05)

The loss of water from the meat causes an increase in dry matter content and ingredients that make the dry matter (protein, fat, minerals) (Table 2 and Table 3). At different temperatures, the heat treatment causes various changes in the protein, which causes the amount of water discharged, and thus the concentration of other substances (Meinert et al., 2007) (Kazemi et el., 2009) (Oroszvári et al., 2005) (Meinert et al., 2009).

From the tables (Table 2 and Table 3), in which the results of analysis of variance of analyzed meat component in the observed temperature range are shown, it can be seen that the average content of all components increases with increasing heat treatment temperature. Comparing the results of changes in chemical constituents during thermal processing of meat obtained in this paper, it can be said that they are quite consistent with the results of previous research (Meinert et al., 2007) (Leo & Toldrá, 2009) (Oroszvári et al., 2005) (Van der Sman, 2007).

Such a high temperature difference, given the fact that the meat has a low thermal conductivity, causes a non-uniform distribution of temperature intervals for the axial direction when viewed from the surface towards the center of the meat sample, which leads to the appearance of a larger number of intervals with higher temperatures than that pursued in the center. At cooked samples there is smaller temperature gradient, and a small number of these intervals. All this results in a greater loss of water in the samples processed by dry heat treatment than those treated by wet heat treatment (Van der Sman, 2007) (Amézquita, 2004) (American Meat Science Association, 1995).

Conclusion

1. Samples were conducted by dry heat treatment “roasting” and wet heat treatment “cooking” of pork meat. Samples were processed to achieve the set temperature in the center of a sample of

51˚C, 61˚C, 71˚C, 81˚C, 91˚C and 100˚C. Heat treatment was performed by roasting in an oven at ambient temperature on the average of (163 ± 2˚C), and cooking at (100 ± 1˚C).

2. Conducted chemical analysis showed that with increasing temperature in the center of the sample during heat treatment due to intense moisture reduction leads to an increase in the content of fat, ash, protein and minerals. The intensity of this increase was generally significantly higher in samples processed by roasting ($P<0.05$) than in samples processed by cooking.
3. The optimum temperature in the center of the sample during the heat treatment of pork is in the range between 71˚C and 81˚C. Temperatures below 71˚C have fairly satisfactory chemical properties, but according to instructions of American Meat Science Association (Research Guidlenes, 1995), thermal treatment is not suitable due to insufficient microbiological safety of processed products. Heat treated products obtained by cooking have uniform and favorable chemical properties on the one hand and on the other hand due to the diffusion of heat more evenly and slightly longer dwell time to achieve the set temperature in the center of the sample with regard to the roasting, get the products with a higher degree of microbiological safety.

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