DYNAMICS OF SMOKE INGREDIENTS PENETRATION INTO THE INTERIOR OF CHICKEN MEAT PRODUCTS DURING BOILING/SMOKING AND DRYING

ORIGINAL SCIENTIFIC PAPER

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ABSTRACT:

During processing in meat, numerous activities occur. Those activities can have a positive or negative impact on the properties of aw materials and finished products. The aim of this study was to determine the dynamics of smoke components penetration (total phenols and organic acids) during boiling/smoking and drying of chicken meat at different thermal regimes. The dynamics of total phenol and total organic acids penetration into meat samples was monitored during all stages of production (cooking/smoking, drying and storage). Eight experimental groups were analyzed. Samples in four experimental groups (EG I-IV) were subjected to boiling and smoking, and other four groups (EG V-VIII) to drying with different parameter values: boiling/smoking temperature 55-75°C, process duration 80-110 minutes, drying temperature 14-18°C, with air circulation 40-50 m^3/min and relative humidity 85-88% in appropriate conditions. Based on the obtained results, the statistically significant influence of different heat treatments and their technological parameters on the dynamics of phenol and organic acid penetration was established ($p<0.05$). Temperature stood out as an important technological parameter with the greatest impact. The results show that due to elevated temperatures during heat treatments there is an increase in the concentration of total phenols and organic acids. Furthermore, it was concluded that the investigated processing procedures of chicken meat had an impact on the dynamics of penetration of smoke components.

KEYWORDS: phenols, organic acids, boiling, smoking, drying

INTRODUCTION

Scientific research in the field of food safety has recently increasingly included research related to operations and processes of heat treatment, smoking and drying of meat in order to obtain a high quality safe product, with greater nutritional value and better sensory properties.

Heat treatment is a critical degree of meat processing. Three main factors are especially important: the temperature on the surface of the meat, the temperature in the center of the product and the method of heat transfer (contact, air or steam) [1], [2].

Smoking is a process in which the volatile components of smoke and steam from wood, which is not completely burned, penetrate the meat and act on certain ingredients of the meat. Smoking achieves specific sensory properties, primarily color and aroma [3], [4]. After smoking, the products have a pleasant, characteristic smell and taste of smoke and a light pink hue on the surface of the product [5], [6]. Sikorski and Kolakowski [8] and Roseiro et al. [8] state that 40-60% of meat products are smoked during production. The volatile components formed during incomplete burning of wood give a smoke preserving effect [4].

Smoke, which is created in the process of woodburning, contains several thousand different chemical compounds, some of which have a negative impact on human health. About 600 smoke constituents are known, which can be classified into different groups of organic compounds: aliphatic, ketone and aromatic acids, aldehydes, dialdehydes, aromatic aldehydes, alcohols, phenols, amines, aromatic hydrocarbons and others [9], [10].

Drying meat is a technological process, which aims to obtain quality products with a specific aroma and taste. Drying of meat leads to the formation of products with altered properties [9].

For the process of smoking/drying meat, the most important components of smoke are phenols, carbonyl compounds (aldehydes and ketones), organic acids and alcohols, which are formed at different temperatures. Of the phenols (formed at temperatures between 300°C and 550°C), cresols and creosote are important. Organic acids are formed at a temperature of 160°C to 250°C (the most important for changes in

smoked meat are: formic, acetic, propionic, butyl, benzoic) [8], [10]. During smoking process, the components that produce smoke are deposited on the surface of the product and diffuse to different depths in the products [11]. Typical sensory characteristics of smoked products were found to be associated with the presence of phenols and odoriferous substances resulting from various chemical and biochemical reactions in food [11], [12].

Several authors have examined the influence of heat treatment on the presence and content of phenols and organic acids in meat and meat products, but no research based on this kind of the meat and this kind of the processing [2], [4], [13], [14]. As mentioned, phenols are the main compounds associated with the desirable characteristics of the obtained products in various technological processes (dyeing, preservation and formation of flavors). The production of chicken meat is constantly increasing, so the production of smoked products from this type of meat is an opportunity to process surplus meat and better supply the population with specific products.

The aim of this work was to determine the dynamics of smoke penetration during boiling/smoking and drying of chicken meat with different heat regimes. Also, the impact of these heat treatments and processing time on the total phenols and organic acids concentrations.

MATERIALS AND METHODS

Chickens used during the experiment, were raised on the family farm in conditions of intensive breeding. Intensive breeding took place in two phases with appropriate feed mixtures (starter and finisher). The main ingredient in the feed mixtures that the animals were fed was predominantly corn. In addition to corn, toasted soybeans, sunflower and dehydrated alfalfa were added to the chicken mixes. The feeding of the chickens lasted 42 days. During the research, 48 hens were used. The breast meat (96 pieces divided in eight experimental groups) used for further research was shaped (6-7 cm wide and 12-13 cm long sample) and cooled for 24 hours at a temperature of about 1°C. After cooling (temperature <4°C was reached in the center of the piece), the pieces of meat were pickled (table salt 2.5%, nitrite salt 0.3%, pepper and garlic). The pickling process was carried out under controlled conditions: temperature 2-4°C, duration 10 days. After pickling, the samples were subjected to boiling (temperature between 55°C and 75°C, process time from 80 minutes to 110 minutes) and drying (temperature between 14°C and 18°C, with air circulation of 40 m^3/min up to 50 m^3/min and relative humidity from 85% to 88%) in appropriate conditions.

Experimental groups are divided based on changes in smoking/boiling parameters (EG I-IV) and drying (EG V-VIII). Twelve samples from each experimental group was treated by boiling (thermodynamic chamber for drying, smoking, baking and cooking by Atmnos Maurer Germany), and twelve (12) at low temperature were smoked and dried in a fermentation chamber (Universal thermodynamic chamber Doleschal, Austria) [4].

The values for the temperature and processing time for the experimental groups are as follows: EG I (temperature 70°C, time 90 minutes), EG II (temperature 65°C, time 100 minutes), EG III (temperature 60°C, time 100 minutes)), EG IV (temperature 55°C, time 107 minutes), EG V (temperature 17.5°C, time 300 minutes), EG VI (temperature 14.5°C, time 360 minutes), EG VII (temperature 14.5°C, time 240 minutes), EG VIII (temperature 14.5°C, time 300 minutes).

CHEMICAL ANALYSIS

Phenol penetration dynamics

Phenol penetration dynamics in chicken meat samples was monitored during the all phases of production (fresh samples, boiling/smoking and storage).The Folin Ciocalteu method as described in Naveena et al. [15] was used to determine the content of total phenols in chicken meat samples, 2008. In brief, 5 g of sample was homogenized with 25 mL of 70% acetone and kept overnight for extraction at 4°C. Aliquots of extracts were transferred in a test tubes and the volume was made to 0.5 mL with distilled water followed by the addition of 0.25 mL Folin–Ciocalteu reagent and 1.25 mL sodium carbonate solution (20%). The tubes were analyzed measuring the absorbance at 725 nm (WTW UV-Vis) after 40 min. The total phenolics were calculated as galic acid equivalent from the calibration curve using standard galic acid solution (0.1 mg/mL).

During the production of boiled products, the analysis of phenol content was performed on the first day (fresh meat), on the eleventh day (after first and second smoking) and on the twentieth day (storage). During the production of dried products, the determination of phenol content was performed on the first day (fresh meat), on the fifth and tenth (smoking) and on the twentieth day (storage). From each piece of meat, 15 pieces measuring 5 cm x 5 cm were cut (5 pieces from the surface, 5 from the line that forms the border between the zones of meat different in color shade and 5 from the center of the piece). Pieces from the same position were joined, chopped and a sample was taken for analysis. Phenol concentration was measured three times on each sample.

Organic acid penetration dynamics

The dynamics of organic acids penetration into chicken meat samples was monitored during all stages of production (fresh samples, boiling/smoking and storage) [16]. Meat samples were prepared in the same way as described in the previous section.

The content of total organic acids in chicken meat samples was determined by the method of neutralization with 0,1 M NaOH solution. Neutralization lasted until the indicator changed color after the addition of the first excess drop of alkali. During the production of boiled products, the analysis of organic acid content was performed on the first day (fresh meat), on the eleventh day (after I and II smoking) and on the twentieth day (storage). In dried products, the analysis of the organic acids concentration was performed on the first day (fresh meat), on the fifth and tenth day (smoking) and on the twentieth day (storage).

STATISTICAL ANALYSIS

The results of this study are presented as the mean values accompanied with their standard deviations. One factor analysis of variance (ANOVA) was performed using statistical software SPSS (VER.20). When the main impact was significant, averages were split by Tukey's test of the smallest significant deviations at 5% level. Level of significance ($p<0.05$) was used for comparison and discussion of the obtained results.

RESULTS AND DISCUSSION

Dynamics of phenol penetration in chicken meat samples

Tables 1 and 2 show the results of the phenol content in four experimental groups of chicken meat products during the technological production and during storage. The results of total phenols in samples of fresh chicken meat during the boiling process showed the highest concentration in EG I (131.62 mg/kg), and the lowest in EG IV (88.47 mg/kg). During the boiling process on the eleventh day (after I smoking) the highest phenol content was measured in EG I (212.64 mg/kg) and the lowest in EG IV (156.80 mg/kg). On the eleventh day (after II smoking), the highest phenol content was determined in EG I (173.14 mg/kg), and the lowest in the EG IV (142.53 mg/kg). On the twentieth day after storage of boiled chicken meat products, the highest mean value of the measured phenol content was in EG I (173.01 mg/kg) and the lowest in EG IV (144.00 mg/kg) (Table 1).

Table 1. Dynamics of phenol penetration in chicken meat samples during the technological processing (fresh meat, boiling/smoking) and after storage

Experimental group/Phenol concentration (g/kg)	Fresh meat	Boiling/Smoking		Storage
		First smoking	Second smoking	
	1. day	11. day	11. day	20. day
EG I	131.62±10.09	212.64±4.37	173.14±1.10	173.01±1.10
EG II	116.17±5.79	196.70±0.94	142.73±2.72	147.11±1.15
EG III	96.05±3.88	211.75±1.96	162.40±5.10	163.89±2.10
EG IV	88.47±1.37	156.80±1.45	142.53±3.15	144.00±7.08

* Data are presented as mean ± standard error from 6 samples (n = 6)

EG (I-IV)-Experimental group: EG I: 70°C, 90 min, 7.1 m^3/min, 74 -76 %; EG II: 65°C, 100 min, 9.7 m^3/min, 78-82 %; EG III: 60°C, 100 min, 9.7 m^3/min, 78-82 %; EG IV: 55°C, 107 min, 12.7 m^3/min, 82-86%

Using the t-test of paired samples with each other, the mean values of phenol content measured in different time periods (day 1, day 11, day 20) in all groups were compared. Statistically significant difference between the phenol content in EG I and EG II (t =5.90, Sig.=0.010), as well as the phenol content in EG IV (t=6.34, Sig.=0.008) was found, while the differences in phenol content in boiled chicken meat among other experimental groups were not statistically significant (Table 2).

Table 2. Results of phenol content comparison between experimental groups in chicken meat samples during the technological processing (fresh meat, boiling/smoking) and storage

Treatment	Test Value = 0					t	$\bar{X}_{dif}$	Sig.
	$\bar{X} \pm SD$	S.D.	Std.Error	95% CI differences Lower limit	95% CI differences Upper limit			
EGI - EGII	21.92	7.42	3.71	10.10	33.74	5.90	3	0.010
EGI - EGIII	14.08	14.96	7.48	-9.72	37.88	1.88	3	0.156
EGI - EGIV	39.65	12.50	6.25	19.75	59.55	6.34	3	0.008
EGII – EGIV	17.72	19.25	9.62	-12.90	48.36	1.84	3	0.163
EGIII - EGIV	25.57	20.42	10.21	-6.92	58.07	2.50	3	0.087

EG (I-IV)- experimental group, $\bar{X}$ – average value, S.D.-standard deviation CI (interval of trust), Sig. (p<0.05)

The results of determining the mean values of total phenol content in samples of fresh chicken meat used during drying showed that the highest phenol concentration in EG VII (113.34 mg/kg) and the lowest in EG VI (68.17 mg/kg). During the drying process on the fifth day of drying, the highest phenol content was measured in EG VII (194.25 mg/kg) and the lowest in EG V (128.44 mg/kg). After the tenth day of drying, the highest phenol content was determined in the samples from EG VII (202.15 mg/kg), and the lowest in the sample from EG V (138.11 mg/kg). On the twentieth day after storage of cooked chicken meat products, the highest mean value of the measured phenol content was in EG VII (201.11 mg/kg, and the lowest in EG V (141.17 mg/kg) (Table 3).

Table 3. Dynamics of phenol penetration in chicken meat samples during the technological processing (fresh meat, drying) and storage

Experimental group/Phenol concentration (mg/kg)	Fresh meat	Boiling/Drying		Storage
	1.day	5. day	10. day	20. day
EG V	70.69±3.22	128.44±1.48	138.11±9.00	141.17±1.10
EG VI	68.17±15.09	155.52±2.30	159.90±3.21	157.93±1.20
EG VII	113.34±10.40	194.25±1.07	202.15±5.10	201.11±3.45
EG VIII	108.96±2.53	174.56±5.77	186.23±4.11	187.16±1.10

*Data are presented as mean ± standard error from 6 samples (n = 6)

EG (V-VIII)-Experimental group: EG V: 17.5°C, 300 min, 40 m^3/min, 85-86 %; EG VI: 14.5°C, 360 min, 40 m^3/min, 85-86 %; EG VII: 14.5°C, 240 min, 40 m^3/min, 85-86 %; EG VIII: 14.5°C, 300 min, 40 m^3/min, 85-86 %

Using the t-test of the paired samples, the mean values of the phenol content measured in different time periods (day 1, day 5, day 10 and day 20) were compared. The obtained results showed a statistically significant difference in phenol content between dried chicken meat products during which different treatments were applied. The difference in phenol content in EG V and EG VI was not statistically significant (t=-2.44, Sig.=0.092), while the difference in phenol content in other treatments was statistically significant (Table 4).

Table 4. Results of phenol content comparison between experimental groups in chicken meat samples during the technological processing (fresh meat, drying/smoking) and storage

Treatments	Test Value = 0					t	$\bar{X}_{dif}$	Sig.
	$\bar{X} \pm SD$	S.D.	Std.Error	95% CI differences Lower limit	95% CI differences Upper limit			
EGV-EGVI	-15.77	12.90	6.45	-36.31	4.75	-2.44	3	0.092
EGV-EGVII	-58.11	10.59	5.29	-74.97	-41.25	-10.96	3	0.002
EGV-EGVIII	-44.62	4.34	2.17	-51.54	-37.70	-20.53	3	0.000
EGVI-EGVII	-42.33	2.69	1.34	-46.61	-38.04	-31.44	3	0.000
EGVI-EGVIII	-28.84	9.04	4.52	-43.23	-14.45	-6.38	3	0.008
EGVII-EGVIII	13.48	6.52	3.26	3.10	23.86	4.13	3	0.026

*EG (V-VIII) - experimental group , $\bar{X}$ – average value , S.D.-standard deviation CI (interval of trust), Sig. (p<0.05)

Dynamics of organic acid penetration in chicken meat samples

Tables 5 and 6 show the results of determining the organic acid content in four experimental groups of chicken meat products during the processing (in fresh samples, in boiled/smoked and smoked/dried samples) and finished products during storage. The results in the boiling process showed the highest value of organic acids in samples EG III (1.48%) and the lowest in EG IV (1.08%). During the boiling process on the eleventh day (after first smoking), the highest content of organic acids was measured in EG III (1.76%), and the lowest in EG I (1.56%). On the eleventh day (after second smoking) the highest content of organic acids was determined in EG II (1.62%), and the lowest in EG IV (1.38%). On the twentieth day after storage, the highest mean value of the measured organic acid content was in EG IV (1.00%) and the lowest in EG I (0.88%).

Table 5. Dynamics of organic acids penetration in chicken meat samples during the technological processing (fresh meat, boiling/smoking) and storage

Experimental group/ organic acid concentration (%)	Fresh meat	Boiling/Smoking		Storage
		First smoking	Second smoking	
	1.day	11. day	11. day	20. day
EG I	1.28±0.15	1.56±0.11	1.38±0.14	0.88±0.12
EG II	1.16±0.17	1.69±0.10	1.62±0.11	0.96±0.18
EG III	1.48±0.07	1.76±0.15	1.42±0.15	0.96±0.11
EG IV	1.08±0.13	1.71±0.22	1.40±0.10	1.00±0.15

*Data are presented as mean ± standard error from 6 samples (n = 6) EG (I-IV)-Experimental group: EG I: 70°C, 90 min, 7.1 m^3/min, 74 -76 %; EG II: 65°C, 100 min, 9.7 m^3/min, 78-82 %; EG III: 60°C, 100 min, 9.7 m^3/min, 78-82 %; EG IV: 55°C, 107 min, 12.7 m^3/min, 82-86%

Using the t-test of paired samples, the mean values of organic acid content measured in different time periods (day 1, day 11, day 20) in all experimental groups were compared. The obtained values were not statistically significant (Table 6).

Table 6. Results of organic acid comparison between experimental groups in chicken meat samples during the technological processing (fresh meat, boiling/smoking) and storage

Treatments	Test Value = 0							
	$\bar{X} \pm SD$	S.D.	Std.Error	95% CI differences		t	$\bar{X}_{dif}$	Sig.
				Lower limit	Upper limit			
EGI-EGII	-0.08	0.15	0.07	-0.32	0.15	-1.09	3	0.353
EGI-EGIII	-0.13	0.08	0.04	-0.26	0.00	-3.15	3	0.051
EGI-EGIV	-0.02	0.15	0.07	-0.27	0.22	-0.28	3	0.795
EGII-EGIII	-0.04	0.21	0.10	-0.38	0.29	-0.44	3	0.688
EGII-EGIV	0.06	0.11	0.05	-0.12	0.24	1.00	3	0.387
EGIII-EGIV	0.10	0.19	0.09	-0.20	0.42	1.08	3	0.358

*EG (I-IV) - experimental group , $\bar{X}$ – average value , S.D.-standard deviation CI (interval of trust), Sig. (p<0.05)

The results of measuring the mean values of organic acid content in samples of fresh chicken meat used during the drying process showed the highest content in EG V, and the lowest in EG VIII.

During the drying process on the fifth day, the highest content of organic acids was measured in EG V, and the lowest in EG VII. After the tenth day of drying, the highest content of organic acids was determined in the samples from EG VI, and the lowest in the sample from EG VII. On the twentieth day after storage, the highest mean value of the measured organic acid content was in EG VI and the lowest in EG VII (Table 7).

Table 7. Dynamics of organic acids penetration in chicken meat samples during the technological processing (fresh meat, drying) and storage

Experimental group/Organic acid concentration (%)	Fresh meat	Smoking/Drying		Storage
	1.day	5. day	10. day	20. day
EG V	1.48±0.21	1.51 ±0.05	1.76±0.15	1.77±0.17
EG VI	1.26±0.07	1.40±0.14	1.91±0.13	2.01±0.14
EG VII	1.35±0.16	1.36±0.17	1.44±0.05	1.44±0.43
EG VIII	1.03±0.16	1.51±0.10	1.82±0.19	1.98±0.19

*Data are presented as mean ± standard error from 6 samples (n = 6)EG (V-VIII)-Experimental group: EG V: 17.5°C, 300 min, 40 m^3/min, 85-86 %; EG VI: 14.5°C, 360 min, 40 m^3/min, 85-86 %; EG VII: 14.5°C, 240 min, 40 m^3/min, 85-86 %; EG VIII: 14.5°C, 300 min, 40 m^3/min, 85-86 %

Using the t-test of the paired samples, the mean values of the organic acid content measured in different time periods (day 1, day 5, day 10 and day 20) were compared. The obtained results showed that there is a statistically significant difference in organic acid content between treatments in dried chicken meat in EG V and EG VII (t=4.33, Sig.=0.027), while in other treatments there is no statistical significance (Table 8).

Table 8. Results of organic acid comparison between experimental groups in chicken meat samples during the technological processing (fresh meat, drying/smoking) and storage

Treatments	Test Value = 0					t	$\bar{X}_{dif}$	Sig.
				95% CI differences				
	$\bar{X} \pm SD$	S.D.	Std.Error	Lower limit	Upper limit			
EGV - EGVI	-0.01	0.21	0.10	-0.35	0.32	-0.13	3	0.898
EGV -EGVII	0.23	0.10	0.05	0.06	0.40	4.33	3	0.023
EGV - EGVIII	0.04	0.28	0.14	-0.40	0.49	0.31	3	0.772
EGVI - EGVII	0.24	0.32	0.16	-0.26	0.75	1.53	3	0.221
EGVI-EGVIII	0.06	0.14	0.07	-0.16	0.28	0.85	3	0.457
EGVII-EGVIII	-0.18	0.37	0.18	-0.78	0.40	-1.00	3	0.390

EG (V-VIII)-experimental group , $\bar{X}$ – average value , S.D.-standard deviation CI (interval of trust), Sig. (p<0.05)

The values of phenol content in fresh samples of chicken meat show an increase in the mean values of phenol content in all groups and a decrease on the eleventh day (second smoking) during boiling/smoking process. The value of phenol content in the tested samples during drying remained similar to the values obtained after the completion of the boiling/smoking process. The obtained values of phenol content in both processes of boiling/smoking and drying in the analyzed samples of final products increase during the process, the value of which after storage remained mostly similar. The obtained results are much higher in relation to the values (46.97%) obtained by Krvavica et al. [17], Nadia and Amal [14] (38, 87%), and Valø et al. [18]. The reason may be the formation of phenol and deposition on the surface due to elevated temperatures and longer boiling/smoking and drying.

Sérot et al. [19] found that the content of phenolic compounds in products increases with processing time and the applied temperature (55 minutes, 50°C), but the relative percentage of these compounds is constant for a given process and independent of process parameters, with which the results presented in this paper can be related.

The obtained results of the content of organic acids indicate an increase during the technological process. During storage obtained values remain unchanged, which is similar to the values presented in the paper Rekanović [2]. In fresh samples, the values of organic acids were lower compared to the values obtained after first smoking, where there was an increase in the mean values of organic acids. After the second smoke, there is a slight decrease in the average values of organic acids concentration, and the tendency to decrease continues during storage. During the smoking process on the fifth and tenth day, as well as during storage, there is a slight increase in organic acids in chicken meat products. The obtained results are similar to the values presented in their research by the authors: Rekanović, [2]; Rekanović et al. [20]; Nadia and Amal [14].

Furthermore, when the obtained values for the phenol and organic acids concentration in chicken

meat are taken into account, in the boiling process (after first smoking) there was an increase in the content of both phenol and organic acids. As the process went (after second smoking) there is a slight decrease in the share of these parameters whose value during and after storage remains approximately the same. The values obtained are similar to the values mentioned in the study of Rekanović [2].

During the entire process of drying and all stages of processing, the content of phenol and organic acids increases, and during storage no significant changes occur and the value remains approximately the same as the values obtained after the process. Both processes affect the obtained values, which means that the movement and penetration of smoke particles leads to a lesser extent into the final products. The reason may be prolonged exposure to smoke at elevated temperatures. Both processes affect the obtained values, which means that the movement and penetration of smoke particles lead to a lesser extent into the final products. The dynamics of penetration in all phases of processing has a slight tendency to increase the share of these components that are in line with the values of other research [14], [17], [18], [21], [22], [23], [24].

CONCLUSION

After the obtained and presented results, it can be concluded that the examined procedures of boiling/smoking and drying of meat affect (p<0.05) the penetration dynamics of smoke ingredients into the interior of meat sample by monitoring phenol concentration during processing and storage. Due to elevated temperatures, the concentration of total phenols increases. Furthermore, it can be said that the investigated procedures of boiling/smoking and drying meat affect (p<0.05) the dynamics of penetration of smoke ingredients into the interior of meat by monitoring the concentration of organic acids during processing and storage. Due to elevated temperatures, the concentration of organic acids increases. Temperature was singled out as an important technological parameter during the boiling/smoking and drying process with the greatest impact. The results show that due to elevated temperatures during heat treatments there is an increase in the concentration of total phenols and organic acids. During the storage process, the obtained values remain unchanged.

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