The Effect of Different Level of Air Steam Saturation During Cooking in the Oven and Vacuum Storage on the Quality of Turkey Meat

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The effect of cooking in hot air combined with steam and vacuum storage on the quality of turkey meat was studied. The use of steam during cooking decreased cooking losses of turkey meat, and at the same time caused a greater lipid oxidation. The higher rate of SH groups oxidation was found in meat heated with 20, 50 and 90% steam than in meat heated with 0% and 70% steam. Thermal processing caused a decrease in unsaturated fatty acids and an increase in saturated fatty acids content; the smallest changes were demonstrated in meat heated with 20% steam. After thermal processing meat cooked with higher steam (50, 70, 90%) was characterized by better juiciness and tenderness. During storage samples heated in hot air alone and with 20% steam showed lower content of malondialdehyde and better flavour than others samples.

Keywords: cooking, physicochemical properties, sensory quality, turkey meat, vacuum storage

Introduction

In air convection cooking, convective heat transfer occurs between a solid food and the surrounding air. The heat transfer coefficient varies during the process. Steam introduced during cooking complicates the determination of the heat transfer coefficient and results in an increased heat transfer rate (Murphy *et al.*, 2001). Combination ovens, commonly known as “combi” ovens, have been gaining popularity since their introduction. Combi ovens combine the accurate heat control of a convection oven with the efficiency of steam cooking that can be used individually, sequentially or in combination to give the operator multiple cooking choices in a single piece of equipment. This type of oven is becoming more popular both in food service operations and in home kitchen. These ovens were reported to enhance flavour, taste and tenderness of meat based foods (Vittadini *et al.*, 2005). Murphy *et al.* (2001) studied the cooking process of chicken meat patties in air convection oven where steam was injected to reach different relative humidities (40-95%). They reported that increasing the humidity increased the heat transfer coefficient and consequently reduced cooking time.

An increased product yield was achieved by reducing oven temperature or final internal temperature, and increasing air humidity. Chiavaro *et al.* (2009) found significantly lower cooking time of pork using forced convection with steam (FC/S) than using forced convection (FC) only. These authors showed that cooking pork under relative humidity $\geq 20\%$ did not prevent high cooking loss from product and the development of lower quality attributes (texture and colour) those FC samples, especially at 120 and 140°C. Gardes *et al.* (1995) evaluated the influence of cooking in a superheated steam oven on pork roast quality in comparison with conventional and forced convection ovens finding that cooking time and weigh loss did not significantly differ between forced convection and superheated steam cooked products.

Cooked turkey meat, which has a higher level of oxidatively labile polyunsaturated fatty acids in its membrane phospholipids than most other meats, is particularly susceptible to the development of lipid oxidation during refrigerated storage (Tang *et al.*, 2005). Excessive oxidation of muscle lipids can produce compounds that adversely affect the quality of meat. These compounds are in some cases associated with off-flavours and off-odours, loss of colour and vitamins and lower consumer acceptability, and also affect the safety of meat (Conchillo *et al.*, 2005).

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Storage in vacuum conditions has proved to be a successful technology for extending the shelf life of food products (Higgins *et al.*, 1998). The development of packing can improve the shelf life and prevent chemical deterioration of food products caused by lipid oxidation and pigment autoxidation. Molecular oxygen is an integral part of the lipid peroxidation process. Therefore, vacuum packaging reduces oxidation as it decreases the contact between a product and atmospheric oxygen (Fernandez-Espla and O'Neill, 1993).

The objective of the present study was to compare the effect of different air steam saturation levels during thermal processing in a steam-convection oven on the eating quality of turkey meat and its subsequent storage stability.

Materials and Methods

Sample preparation Turkey breast muscles were bought from the Poultry Plant INDYKPOL S.A. in Olsztyn, Poland. After cleaning and washing, the muscles were cut into 2 ± 0.2 cm thick slices. Three slices were used for raw material analyses whereas the remaining slices were placed on the oven tray (six slices at a time) and cooked in a BECK FCV 4EDS steam-convection oven (BECK GmbH, Jagsthausen-De), using hot air (220°C - sample A) or air saturated with steam. Four steam saturation levels were used: 20% (sample B), 50% (sample C), 70% (sample D) and 90% (sample E). During roasting, temperature was measured at four points of the meat slice: the bottom surface (the slice "presses down" the thermocouple to the perforated tray), directly under the upper surface of the slice, along the side, and inside the slice approximately at its geometric centre. The temperature profile was determined in two slices simultaneously, and temperature readouts were registered every 5 s. The roasting process was continued until the temperature at the coolest point of the turkey breast slice reached 80°C. Temperature was measured using a type K thermocouple in the measuring system Multimeter 2700 with Multiplexer 7710 (Keithley Instruments, Inc, Ohio, USA). After cooking meat slices were allowed to reach the room temperature (24°C) and six slices were used for analyses directly after cooking. The remaining slices were vacuum-packed with a TEPRO TP5 packaging unit, into bags of five-layer PE-LD/adh/PA/ADH/PE-PD film (total thickness 0.08 mm, PA layer thickness 0.024 mm, oxygen permeability $40 \text{ mL m}^{-2}24\text{h}^{-1}\text{bar}^{-1}$, and water vapour permeability $10 \text{ gm}^{-2}24\text{h}^{-1}\text{bar}^{-1}$). Three slices were put into one bag. After packing the samples were stored at $3 \pm 1^\circ\text{C}$ in the dark for 28 days. One package for each kind of samples was randomly selected at sampling days 7, 14, 21 and 28.

Chemical composition The samples were examined for the content of water, protein, fat and ash (AOAC, 1990).

Weight loss determination Weight loss was calculated

as the percent weight difference between the raw and cooked meat relative to the weight of the raw meat. The weight of cooked meat was measured after reaching the room temperature.

SH groups' content The SH groups' content was determined using 5,5'-dithiobis-2-nitrobenzoic acid, and the absorbance was measured at $\lambda = 412 \text{ nm}$ (Sedlak and Lindsay, 1968).

Fatty acids Fat used for fatty acid determination was isolated as described by Folch *et al.* (1957). The content of fatty acid methyl esters was determined by the GC method after methylation with a chloroform/methanol/sulphuric acid (100:100:1) mixture (Peisker, 1964). Analyses were performed on an automated apparatus (HP 6890N, Agilent Technologies, Palo Alto, CA, USA) equipped with flame ionisation detector and a capillary column (30 m $\times$ 0.32 mm ID). Supelcowax 10–0.25 μm was used as a liquid phase. Characteristic operating conditions were as following: injector temperature 250°C, detector temperature 250°C, helium flow 1 mL/min). Fatty acid methyl esters were identified by comparison with retention times of authentic standards (Applied Science Corporation). Results were expressed as a percentage (w/w) of the total fatty acid methyl esters.

Malondialdehyde content The Malondialdehyde (MDA) content was assayed by the method developed by Tarladgis *et al.* (1960) and modified by Pikul *et al.* (1989)

Acid value (AV) The acid value was determined in the fat extracted from the samples in accordance with the Polish Standard PN-EN ISO 660 (2005).

pH value For pH determination 10 g of the sample and 90 mL of distilled water were homogenized in a blender (type MPW-302) for 60 s. The pH of the mixture was measured using a pH-meter; model ATC PICCOLO 2 standardized at pH 4 and pH 7 (Pexara *et al.*, 2002). The pH was measured directly after homogenization and was read after stabilization.

Water activity An adequate amount of ground sample was placed into a measuring container and three measurements were made with a water activity analyser (type AWC 203-C, Novasina, Pfäffikon, Switzerland) after reaching equilibrium at 20°C, according to the manufacturer's instruction. The samples were brought to room temperature prior to evaluation.

Sensory evaluation The sensory evaluation was performed immediately after thermal processing and during storage. The sensory quality was estimated by five trained panellists, in accordance with PN ISO 3972 (1998). Stored samples were heated to approximately 70°C in a microwave oven before serving. The samples were evaluated using a structured graphic scale with five anchor points (ISO 4121,

2003). The following attributes were determined: flavour (typical of poultry meat, aromatic, WOF, sour) intensity (1-undetectable, 5-very -strong), tenderness (1-very tough, 7-very soft) and juiciness (1-very dry, 7-very juicy). All judges were trained in sensory profiling of cooked turkey meat in 6 training sessions. The aim of these training was to develop a common vocabulary for the description of the sensory attributes of turkey meat. Each attribute was extensively described and explained to avoid any doubt. After the session the assessors agreed on a four attributes of flavour, which were relevant to suitable definitions (typical of poultry meat-freshly cooked poultry meat; aromatic-the flavour related to a complex mixture of volatile compounds produced during cooking provided by roasted, fatty and cooked flavour; WOF-characterised by a loss of a freshly cooked meat aroma and a simultaneous increase in undesirable odours commonly described as “stale”, “wet cardboard”, “painty”, “grassy” or “rancid”; sour- flavour associated with meat where excessive amount of lactic acid has been produced by bacteria.

Statistical analysis The data are reported as mean values of three replicates ($n = 3$) of each analytical determination. One-way analysis of variance (ANOVA) was performed in order to study the effect of air steam saturation level during thermal processing on several quality parameters (cooking loss, water, protein, fat, ash, pH, water activity, MDA, LK, SH-groups, fatty acids and sensory quality) of turkey meat. The significance of differences was determined by Tukey's test at $P < 0.05$. Statistical analysis of data was performed using STATISTICA v. 8 PL software (StatSoft, 2007).

Results and Discussion

Effect of thermal processing on the quality of turkey meat

Cooking loss The cooking losses were mainly caused by water losses and differed significantly ($P < 0.05$) depending on the thermal treatment (Table 1). The addition of steam had favourable effect on the cooking yield probably because of the shorter cooking time. The lowest cooking loss were found in the sample heated in hot air saturated with the highest level of steam (90%). This might be explained by the reduced water evaporation from the meat surface thanks to the presence of high amount of steam. This was also because the product had to reach the same final temperature at the center; a longer cooking time was required when cooking at low than at high humidity. These results are in agreement with those reported for chicken patties by Murphy *et al.* (2001), who found that product yield increased on chicken breast patties cooked at 149°C and an air humidity range from 50% to 95%. Danowska-Oziewicz *et al.* (2007) stated that cooking loss in chicken quarters cooked in a steam-convection oven at 180°C with 50% steam was 29.2%. Vitadini *et al.* (2005) showed higher weight loss in pork meat during forced convection than forced convection/steam combined thermal processing.

Proximate composition The chemical composition of raw and cooked turkey meat is shown in Table 1. In the raw samples water, protein and fat content were 74.94%, 23.03% and 1.03%, respectively. Results showed that the cooking method significantly ($P < 0.05$) affected sample composition. The samples cooked in hot air alone contained less water than samples cooked in hot air with different steam levels

Table 1. The effect of the air steam saturation during the thermal processing on quality of the turkey meat.

Specification	Raw meat	Steam saturation of air [%]				
		0 (A)	20 (B)	50 (C)	70 (D)	90 (E)
Cooking loss [%]	—	32.03 ^b ± 2.30	30.60 ^{ab} ± 1.47	30.13 ^{ab} ± 0.76	30.67 ^{ab} ± 0.45	27.87 ^a ± 0.85
Water [%]	74.94 ± 0.06	64.46 ^{a*} ± 0.08	65.01 ^{b*} ± 0.11	65.58 ^{c*} ± 0.10	65.07 ^{b*} ± 0.08	67.72 ^{d*} ± 0.07
Protein [%]	23.03 ± 0.25	33.25 ^{c*} ± 0.08	33.27 ^{c*} ± 0.34	31.89 ^{b*} ± 0.07	32.34 ^{b*} ± 0.47	30.65 ^{a*} ± 0.28
Fat [%]	1.03 ± 0.01	0.99 ^b ± 0.10	0.61 ^{a*} ± 0.02	1.75 ^{c*} ± 0.06	1.17 ^b ± 0.07	1.07 ^b ± 0.12
Ash [%]	1.04 ± 0.02	1.34 ^{b*} ± 0.01	1.29 ^{b*} ± 0.02	1.16 ^{a*} ± 0.03	1.32 ^{b*} ± 0.02	1.16 ^{a*} 0.02
SH groups total [mg /100g]	69.38 ± 1.18	58.16 ^{c*} ± 0.70	39.52 ^{a*} ± 0.34	41.87 ^{a*} ± 1.56	62.01 ^{d*} ± 1.38	45.04 ^{b*} ± 1.32

a, b, c, d – mean values within the row followed by different letters are significantly different at $P < 0.05$,

* – significant change as a result of thermal processing

and more protein than samples heated in hot air combined with 50%, 70% and 90% steam. The changes of protein content were affected by water losses during cooking. The amount of fat decreased significantly ($P < 0.05$) after cooking only in the sample, which was heated in hot air with 20% steam and it increased in the sample heated in hot air with 50% steam. These results agree with researches of other authors (Rodriguez-Estrada *et al.* 1997, Murphy *et al.* 2001, Clause and Ovesen 2001, Conchillo *et al.* 2005, Danowska-Oziewicz *et al.* 2007).

The ash content (Table 1) of raw meat was 1.04% and it increased significantly ($P < 0.05$) in all meat samples after thermal processing. The content of ash in the cooked samples was in the range between 1.16% and 1.34%. Similar results were found by Tang *et al.* (2005) who observed that the ash content was significantly higher in the cooked turkey breast (2.31-2.32%) than in the raw material (1.23%).

SH-groups Thermal processing caused a significant ($P < 0.05$) decrease in total SH groups levels of all samples, however a degree of changes depended on the air steam saturation during thermal processing (Table 1). The biggest changes were observed in the samples heated in hot air combined with 20% and 50% steam and the smallest one in the meat heated in hot air combined with 70% steam. The content of SH groups in cooked meat is a result of their exposure during thermal processing and their participation in reactions with other food components (Hoffman 1978, Apenten and Galani 2000). Presumably meat heating in hot air combined with 70% steam resulted in faster sulfhydryl groups exposure than their participation in reactions with other food components. However, in samples heated in air saturated with 20%, 50% and 90% steam SH groups could have reacted faster with other food components (e.g. aldehydic products of lipid peroxidation) or have been involved in protein-protein interactions. These results partly correspondent with those reported by other authors. Danowska-Oziewicz *et al.* (2007) found that heat treatment caused a significant decrease in total SH groups' levels; a degree of changes was different in various meat products. The smallest changes were observed in fish, while the biggest in chicken. Traditional pan-frying caused a higher reduction of SH groups in pork and fish than cooking in the combi oven. The same authors in an earlier experiment showed a decrease in SH groups' level after cooking in the cyclojet (Danowska-Oziewicz *et al.*, 2002). Borowski and Karpińska (1995a) found that cooking of white and dark turkey meats in convection oven, microwave oven and frying without fat in an acuthermal pot caused a decrease in total SH groups' level. The smallest changes were observed in meat heated in an acuthermal pot. The authors suggested that, despite the long time of that cooking process, it was so

gentle that its interference in protein structure was relatively low. According to Opstvedt *et al.* (2005) SH groups in fish are subjected to oxidation, which increases with temperature and content of pro-oxidants. Oxidation may be reduced by reduction oxygen content, but extremely low levels are needed in order to achieve a significant reduction.

Fatty acids content The fatty acids: C14:0, C14:1, C15:0, C17:0, C17:1, C20:0 and C20:1 were found in the samples at percentages below 1.0% therefore they are not presented in Table 2. On relation to other fatty acids it was observed that turkey meat cooking in the steam-convection oven resulted in changes in the fatty acid composition, that depended on the air steam saturation level during thermal processing. The total saturated fatty acids (SFA) content increased significantly ($P < 0.05$) after cooking in samples heated in hot air alone and combined with 50% and 90% steam. The monounsaturated (MUFA) acids content was reduced ($P < 0.05$) after thermal processing in samples heated in hot air with 20% steam and increased in samples cooked in hot air alone and combined with 50% steam. The total polyunsaturated fatty acids content decreased after thermal processing (except for sample heated with 20% steam). The smallest unfavourable changes in fatty acids were demonstrated in samples treated with hot air saturated with 20% steam. This was probably due to the highest lipid losses after cooking, containing mainly triacyloglycerols of adipose tissues with relatively more SFA than PUFA. The use of higher air steam saturation levels (50%, 70%, 90%) and hot air alone during thermal processing caused the greatest decrease in the polyunsaturated fatty acids content and an increase in the saturated fatty acids content. According to Duckett and Wagner (1998) cooking increased the stearic acid and total saturated fatty acid contents of the beef intramuscular lipid while reducing total PUFA content. Shams El-Din and Ibrahim (1990) found that the total saturated fatty acids increased and unsaturated fatty acids decreased during boiling and roasting chicken meat. According to the authors roasting of chicken muscles caused higher loss in unsaturated fatty acids than boiling. On the other hand, Rodriguez-Estrada *et al.* (1997) found no significant differences in the percentage of saturated and monounsaturated fatty acids between raw and cooked beef hamburger samples, although there were significant differences for the polyunsaturated fatty acids. Scheeder *et al.* (2001), also showed that cooking of beef patties only slightly decreased the proportion of saturated fatty acids in favour of polyunsaturated fatty acids. Gerber *et al.* (2009) found a decrease in the totals of saturated and unsaturated fatty acids due to cooking of beef and pork because of melting fat during this process.

Table 2. The effect of the air steam saturation during thermal processing on the fatty acids composition.

Fatty acids	Raw meat	Meat after thermal processing				
		Steam saturation of air				
		0	20	50	70	90
C16:0	23.97 ± 0.31	23.87 ^{ab} ± 0.26	23.57 ^a ± 0.60	25.68 ^{*b} ± 0.85	23.36 ^a ± 1.03	23.09 ^{*a} ± 1.16
C16:1	4.42 ± 0.10	2.90 ^{*a} ± 0.14	4.09 ^{*c} ± 0.07	4.37 ^c ± 0.06	3.37 ^{*b} ± 0.17	2.86 ^{*a} ± 0.15
C18:0	9.45 ± 0.20	12.72 ^{*b} ± 0.22	10.48 ^{*a} ± 0.12	10.49 ^{*a} ± 0.58	11.73 ^{*b} ± 0.26	12.70 ^{*b} ± 0.51
C18:1	33.26 ± 0.21	36.34 ^{*c} ± 0.15	32.61 ^{*a} ± 0.41	36.27 ^{*c} ± 0.41	34.75 ^{*b} ± 0.82	34.87 ^{*b} ± 0.47
C18:2	21.64 ± 0.16	16.92 ^{*a} ± 0.31	21.57 ^c ± 0.23	16.91 ^{*a} ± 0.85	19.40 ^{*b} ± 0.47	18.37 ^{*b} ± 0.73
C18:3	2.10 ± 0.07	1.47 ^{*a} ± 0.04	1.97 ^{*c} ± 0.04	1.71 ^{*ab} ± 0.17	1.78 ^{*bc} ± 0.05	1.59 ^{*ab} ± 0.09
C20:4	2.96 ± 0.17	3.34 ^b ± 0.21	3.43 ^{*bc} ± 0.19	2.22 ^{*a} ± 0.18	3.64 ^{*bc} ± 0.20	3.95 ^{*c} ± 0.19
Σ saturated	34.86 ± 0.26	38.08 ^{*b} ± 0.52	35.47 ^a ± 0.53	37.66 ^{*ab} ± 1.45	36.44 ^{ab} ± 1.46	37.21 ^{*ab} ± 1.75
Σ monounsaturated	38.43 ± 0.11	40.19 ^{*c} ± 0.17	37.47 ^{*a} ± 0.35	41.50 ^{*d} ± 0.32	39.03 ^b ± 0.74	38.88 ^b ± 0.75
Σ polyunsaturated	26.70 ± 0.16	21.73 ^{*a} ± 0.55	27.06 ^c ± 0.39	20.84 ^{*a} ± 1.20	24.82 ^{*b} ± 0.72	23.91 ^{*b} ± 1.01
Σ unsaturated	65.13 ± 0.26	61.92 ^{*a} ± 0.53	64.58 ^c ± 0.44	62.34 ^{*a} ± 0.61	63.85 ^{*bc} ± 0.48	62.79 ^{*ab} ± 0.60

^{a, b, c} – mean values within the row followed by different letters are significantly different at $P < 0.05$,

* – significant effect of the thermal processing at $P < 0.05$.

Effect of the storage on the quality of cooked turkey meat

pH Heat treatment did not cause significant changes ($P > 0.05$) in pH values of samples (Table 3). During storage the pH values decreased gradually. The most intensive changes were observed in meat heated in hot air saturated with 70% and 90% steam.

After 7 and 28 days of storage the higher pH values were found in meat samples treated with hot air alone than in other samples. After 14 days of storage the sample heated in hot air combined with 50% steam was characterized by the higher pH value than samples treated with hot air saturated with 20% and 90% steam. After 21 days of storage the highest pH values were observed in meat cooked in hot air alone and combined with 50% steam and the lowest values in the sample treated with hot air saturated with 90% steam. This decrease in pH values during storage might have been caused by the increase in quantity of free fatty acids as a result of hydrolytic changes. Pexara *et al.* (2002) observed a decrease

in pH of cured and cooked turkey breast fillets stored for 30 days in vacuum at 4°C, from the initial 6.2 to about 5.8 and 5.0 in fillets stored for 20 days in vacuum at 10°C. This decrease in pH was linear during the first 15 days of storage, and occurred more rapidly in samples stored at 10°C. On the other hand, Smith and Alvarez (1988) found that the pH of vacuum cooked-in-bag turkey breast rolls did not changed significantly ($p < 0.05$) during 87 days of refrigerated storage.

Water activity The water activity of turkey meat (Table 3) decreased significantly ($P > 0.05$) after cooking (except of sample C). During storage water activity showed decreasing tendency in all meat samples heated in hot air combined with steam (B, C, D, E) and an increasing one in sample treated with hot air alone (A), but these changes were significant ($P < 0.05$) only in samples A and B. These results partly correspond to those obtained by Karpińska-Tymoszczyk (2007) who found that water activity in cooked turkey meatballs

Table 3. The effect of cooking and storage time on the pH and water activity of cooked turkey meat.

Specification	Samples	Raw meat	Storage time [days]				
			0	7	14	21	28
pH	A(0)	6.47 ± 0.06	6.56 ^{cC} ± 0.01	6.57 ^{cD} ± 0.01	6.52 ^{bAB} ± 0.01	6.53 ^{bC} ± 0.01	6.49 ^{aC} ± 0.01
	B(20)	6.47 ± 0.06	6.51 ^{bABC} ± 0.05	6.51 ^{bA} ± 0.01	6.49 ^{abA} ± 0.02	6.49 ^{abB} ± 0.01	6.42 ^{aB} ± 0.02
	C(50)	6.47 ± 0.06	6.52 ^{bBC} ± 0.01	6.53 ^{cC} ± 0.01	6.54 ^{cB} ± 0.02	6.52 ^{bcC} ± 0.01	6.44 ^{aB} ± 0.01
	D(70)	6.47 ± 0.06	6.47 ^{bAB} ± 0.01	6.51 ^{cAB} ± 0.01	6.51 ^{cAB} ± 0.01	6.50 ^{cB} ± 0.01	6.39 ^{aA} ± 0.01
	E(90)	6.47 ± 0.06	6.45 ^{bA} ± 0.01	6.53 ^{dBC} ± 0.02	6.49 ^{cA} ± 0.01	6.44 ^{bA} ± 0.01	6.41 ^{aAB} ± 0.01
Water activity	A(0)	0.995 ± 0.001	0.987 ^{aA*} ± 0.001	0.991 ^{bAB} ± 0.002	0.993 ^{bAB} ± 0.002	0.993 ^{bC} ± 0.002	0.993 ^{bB} ± 0.001
	B(20)	0.995 ± 0.001	0.991 ^{cBC*} ± 0.001	0.987 ^{bA} ± 0.001	0.984 ^{aA} ± 0.001	0.985 ^{abA} ± 0.002	0.984 ^{aA} ± 0.001
	C(50)	0.995 ± 0.001	0.992 ^{aC} ± 0.001	0.993 ^{aB} ± 0.002	0.993 ^{aB} ± 0.001	0.992 ^{aC} ± 0.001	0.994 ^{aB} ± 0.001
	D(70)	0.995 ± 0.001	0.989 ^{aABC*} ± 0.002	0.989 ^{aB} ± 0.003	0.987 ^{aAB} ± 0.002	0.986 ^{aAB} ± 0.002	0.985 ^{aA} ± 0.002
	E(90)	0.995 ± 0.001	0.989 ^{aAB*} ± 0.002	0.990 ^{aAB} ± 0.002	0.990 ^{aAB} ± 0.002	0.990 ^{aBC} ± 0.002	0.988 ^{aA} ± 0.003

a, b, c, d – mean values within the row followed by different letters are significantly different at $P < 0.05$,

A, B, C, D – mean values within the same column for the same specification with the different letters are significantly different at $P < 0.05$,

* – significant changes as a result of thermal processing at $P < 0.05$.

0, 20, 50, 70, 90 – steam saturation of air during thermal processing 0%, 20%, 50%, 70%, 90% respectively.

gradually decreased during storage in control sample and in sample with extract of sage.

Acid value The cooking process caused a significant ($P < 0.05$) increase in acid values of all meat samples (Table 4). During storage hydrolytic changes took place in all meat samples. The earliest significant changes in acid values were observed in meat heated in hot air combined with 20% and 50% steam and the latest in samples treated with hot air combined with 70% and 90% steam. This findings agree with those reported by others authors. Shams El-Din and Ibrahim (1990) demonstrated that the acid value increased in chicken muscles after boiling and roasting. According to Borowski and Karpińska (1995b) the intensity of hydrolytic processes in cooked turkey breast meat depended on the cooking method. The higher acid values observed in samples cooked in an acuthermal pot suggest that during thermal processing in a closed chamber the free water contained in meat becomes a factor that hydrolyses esters bonds or activates the separation of free fatty acids from the molecules of glycerides.

Malondialdehyde content The cooking process caused a significant ($P < 0.05$) increase in malondialdehyde (MDA) content (Table 4) of all samples. The higher degree of lipid oxidation was recorded in meat heated in hot air combined with steam than hot air alone. The explanations offered for the cooking effect on the rate and extent of lipid oxidation of meat takes into account factors associated with the thermal treatment itself (cooking methods, final cooking temperature or cooking rate) and with the product composition (amount and type of lipid, antioxidant, etc.; Serrano *et al.* 2007, Broncano *et al.* 2009). The application of steam during cooking caused steam condensation on the surface of meat and presumably increased of heat transfer coefficient. As the air steam saturation level did not affect significantly the times of particular samples cooking (data not shown) it may suggest that the longer time of high temperature influence on the lipids took place in samples cooked with steam. Therefore higher MDA content was noted in meat heated hot air with steam in comparison to samples cooked in hot air alone.

Table 4. The effect of cooking and storage time on acid value and malondialdehyde content of cooked turkey meat.

Specification	Samples	Raw meat	Storage time [days]				
			0	7	14	21	28
Acid value [mgNaOH/1g]	A(0)	15.73 ± 0.44	17.44 ^{aA*} ± 0.84	17.93 ^{aA} ± 0.38	18.08 ^{aA} ± 0.63	23.79 ^{bC} ± 0.85	23.15 ^{bA} ± 0.81
	B(20)	15.73 ± 0.44	17.98 ^{aA*} ± 0.73	18.20 ^{aA} ± 1.51	20.65 ^{bB} ± 0.74	21.56 ^{bBC} ± 0.41	22.73 ^{bA} ± 0.39
	C(50)	15.73 ± 0.44	17.42 ^{aA*} ± 0.82	17.32 ^{aA} ± 0.90	24.02 ^{bC} ± 0.72	22.80 ^{bC} ± 1.54	23.45 ^{bAB} ± 0.66
	D(70)	15.73 ± 0.44	18.85 ^{aA*} ± 0.10	18.29 ^{aA} ± 0.51	18.47 ^{aC} ± 0.39	18.41 ^{aA} ± 1.03	25.00 ^{bB} ± 0.65
	E(90)	15.73 ± 0.44	18.96 ^{aA*} ± 0.64	18.78 ^{aA} ± 0.83	19.73 ^{aAB} ± 0.99	19.13 ^{aAB} ± 0.50	23.42 ^{bAB} ± 0.39
Malondialdehyde [mg/kg]	A(0)	0.22 ± 0.04	1.30 ^{bA*} ± 0.09	0.26 ^{aA} ± 0.06	0.15 ^{aA} ± 0.02	0.25 ^{aA} ± 0.02	0.25 ^{aA} ± 0.06
	B(20)	0.22 ± 0.04	2.43 ^{cB*} ± 0.20	0.74 ^{bB} ± 0.05	0.70 ^{bB} ± 0.04	0.38 ^{aA} ± 0.11	0.68 ^{abA} ± 0.10
	C(50)	0.22 ± 0.04	2.32 ^{cB*} ± 0.06	1.91 ^{cC} ± 0.26	0.61 ^{abB} ± 0.06	0.43 ^{aA} ± 0.04	0.86 ^{bB} ± 0.21
	D(70)	0.22 ± 0.04	2.44 ^{cB*} ± 0.05	2.42 ^{cD} ± 0.02	1.42 ^{bC} ± 0.16	1.44 ^{bB} ± 0.07	0.73 ^{ab} ± 0.09
	E(90)	0.22 ± 0.04	2.46 ^{dB*} ± 0.15	1.96 ^{cC} ± 0.13	1.18 ^{cC} ± 0.13	1.51 ^{bB} ± 0.06	1.32 ^{abC} ± 0.08

a, b, c, d – mean values within the row followed by different letters are significantly different at $P < 0.05$,

A, B, C, D – mean values within the same column for the same specification with the different letters are significantly different at $P < 0.05$,

* – significant changes as a result of thermal processing at $P < 0.05$.

0, 20, 50, 70, 90 – steam saturation of air during thermal processing 0%, 20%, 50%, 70%, 90% respectively.

During storage malondialdehyde content decreased in all samples. It was demonstrated that MDA content was significantly lower in vacuum-stored turkey meat treated with hot air alone compared to other samples. Decrease in the MDA content could be a consequence of interactions between this compound and meat proteins, or the formation of secondary products of lipid oxidation that do not react with TBA. Ulu (2004) reports that malonaldehyde is highly reactive and remains bound to other food ingredient. Lebepe *et al.* (1990) are of the opinion that bacteria can metabolise TBA or malondialdehyde with which it forms colour complexes, resulting in a decrease in the MDA content of meat and meat products. This result agrees with previous findings published by Przysiężna (2005), Smith and Alvarez (1988) and Higgis *et al.* (1998). The authors observed a decrease in TBARS values during refrigerated storage of vacuum-packed turkey meat or meat products.

Sensory quality Directly after cooking turkey meat samples were characterized by similar intensity of typical

of poultry meat flavour (3.8–4.0) – Table 5 and it did not changed significantly ($P > 0.05$) during 28 days of storage. The intensity of aromatic flavour after cooking was similar in all samples (3.4–3.8) and during storage it was reduced significantly ($P > 0.05$) in samples heated in hot air combined with 50%, 70% and 90% steam.

The shelf life and acceptability of processed, ready-to-eat uncured meats is limited because of the rapid onset on rancidity, denoted as WOF. This becomes evidence during the refrigerated storage of cooked meat products within a few days (Jayathilakan *et al.*, 2007). In the presented experiment WOF appeared after 7 days in samples heated with 70% and 90% steam and after 14 days it was detected in meat cooked in hot air combined with 20% and 50% steam and after 21 days in samples treated with hot air alone. Its intensity was described as slightly detectable at the end of storage. Sour flavour was detected in all samples after 14 days at a very week level. After 21 and 28 days of storage it was described as slightly detectable in samples heated in hot air combined

Table 5. The effect of storage time on the sensory quality of cooked turkey meat.

Attributes	Samples	Storage time [days]				
		0	7	14	21	28
Typical of poultry meat	A (0)	4	4	4.2	3.8	3.2
	B (20)	3.8	4	3.4	3.2	3.2
	C (50)	4	3	3.8	3.8	3.4
	D (70)	3.8	4	3.8	3.4	3.6
	E (90)	4	4	3	3.2	3
Aromatic flavour	A (0)	3.4	3.4	3.4	3.2	2.6
	B (20)	3.4	3.2	2.8	3.2	2.6
	C (50)	3.6 ^b	3.2 ^{ab}	3.2 ^{ab}	3.6 ^b	2.4 ^a
	D (70)	3.8 ^b	3.2 ^{ab}	3.2 ^{ab}	2.2 ^a	2.3 ^a
	E (90)	3.8 ^b	3.2 ^{ab}	2.8 ^{ab}	2.8 ^{ab}	2.2 ^a
WOF flavour	A (0)	1 ^a	1 ^a	1 ^a	1.8 ^b	2 ^b
	B (20)	1 ^a	1 ^a	1.8 ^b	1.8 ^b	1.8 ^a
	C (50)	1 ^a	1 ^a	1.8 ^b	1.8 ^b	1.8 ^b
	D (70)	1 ^a	1.8 ^b	1.8 ^b	2 ^b	2 ^b
	E (90)	1 ^a	1.8 ^b	1.8 ^b	2.4 ^b	2.2 ^b
Sour flavour	A (0)	1	1	1.2	1.2	1
	B (20)	1	1	1.2	1.2	1.2
	C (50)	1 ^a	1 ^a	1.2 ^a	1.8 ^b	1.8 ^b
	D (70)	1 ^a	1 ^a	1.2 ^a	2 ^b	2 ^b
	E (90)	1 ^a	1 ^a	1.4 ^a	2 ^b	2 ^b
Juiciness	A (0)	4.8 ^b	4.4 ^b	3.6 ^{ab}	3.2 ^{ab}	2.8 ^a
	B (20)	4.6 ^b	3.8 ^{ab}	3.6 ^{ab}	3 ^{ab}	2.8 ^a
	C (50)	6 ^b	5.2 ^{ab}	4.8 ^{ab}	3.6 ^a	3.2 ^a
	D (70)	5.2	5.2	5	5	4.2
	E (90)	5.8	5.6	5.4	5	4.8
Tenderness	A (0)	4.6	4.6	4.2	4.2	4
	B (20)	5	4.8	4.8	4.8	4.6
	C (50)	6 ^b	5.4 ^{ab}	5.2 ^{ab}	5 ^{ab}	4.8 ^a
	D (70)	6.2 ^b	5.8 ^{ab}	5.6 ^{ab}	5 ^a	5 ^a
	E (90)	5.8	5.2	5.2	4.8	4.8

^{a, b} – mean values within the row followed by different letters are significantly different at $P < 0.05$,

Scale: flavours (1-undetectable, 5- very strong), juiciness (1-very dry, 7- very juicy), tenderness (1-very tough, 7- very tender).

0, 20, 50, 70, 90 – steam saturation of air during thermal processing 0%, 20%, 50%, 70%, 90% respectively.

with 50%, 70% and 90% steam and in meat cooked in hot air alone and combined with 20% steam it was still very week. Meat cooked in hot air combined with 50%, 70% and 90% steam was characterized by better juiciness directly after thermal processing than the samples heated in hot air alone and air saturated with 20% steam. During storage the juiciness decreased gradually in samples A, B and C. After thermal processing samples cooked in hot air combined with the higher steam saturation (C, D, E) were tender, whereas meat heated in hot air alone and the lowest steam level (20%) was rather tender. The significant ($P < 0.05$) changes in respect

of tenderness were recorded during storage only in C and D samples. Barbanti and Pasquini (2005) observed that air/steam-cooked chicken breasts showed reduced shear force, and thus better tenderness, in comparison to only air-cooked muscles. Nevertheless, the higher temperature in the oven was applied, the higher shear force values for meat were noted. Rodríguez-Pérez *et al.* (2003) showed that during the storage at the different temperatures (2.3, 6.5, 10, 13.5, 17.7°C) the smell and taste of vacuum-packed cooked chicken breast deteriorated gradually. According to these authors sensory evaluation based on both smell and taste properties,

may provide a fairly complete idea of the degree of the product spoilage, because these attributes are the most important for the consumer acceptability and a useful tool for estimating the shelf life of the products.

It is concluded that cooking turkey meat under hot air combined with steam caused the lower cooking losses and loss of unsaturated fatty acids, otherwise bigger protein changes (except 70% steam) and lipid oxidation. During storage greater unfavourably changes were observed in samples cooked in hot air combined with steam especially at high saturation level (70%, 90%). These results suggest that the better will be cooking turkey meat with the application an air/steam treatment if it is consuming at once after preparing. If the turkey meat is vacuum storage after thermal process it should be cooking hot air only or with the lowest steam (20%).

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