The selected goose meat quality traits in relation to various types of heat treatment

J. Wołoszyn,* M. Wereńska,*[,1] Z. Goluch,* G. Haraf,* A. Okruszek,* M. Teleszko,* and B. Król†

*Department of Food Technology and Nutrition, Wroclaw University of Economics and Business, Wroclaw 53-345, Poland; and †Department of Animal Nutrition and Feed Management, Wroclaw University of Environmental and Life Sciences, Wroclaw 51-631, Poland

ABSTRACT The effect of water bath cooking (**WBC**), oven convection roasting (**OCR**), grilling (**G**), pan frying (**PF**) on selected physical properties of goose meat was compared in this study. A measurement of cooking loss, texture, color parameters, and sensory evaluation was carried out. The experimental material covered 96 breast muscles cut from carcasses of 17-week-old "Polish oat geese." The kind of goose meat (with and without skin) and the type of heat treatment affected cooking loss, shear force (**SF**), and rheological parameters (hardness, cohesiveness, gumminess, and chewiness). The water bath–cooked and pan-fried samples for both kinds of meat were characterized by lower cooking loss than other ones. Goose meat with skin and subcutaneous fat showed higher cooking loss and lower SF value, hardness, gumminess, and chewiness than that without skin for all methods. The water bath–cooked samples were characterized by the lowest SF value, hardness, and chewiness for both kinds of meat. They had the highest value of L* parameter and were characterized by a lighter color among others, too. Pan-fried meat showed the highest value of a* and lowest of h^o parameters; the color of these samples was redder. Moreover, the lower C values of oven convection-roasted and grilled samples showed that they were brighter. According to the Comission Internationale de l'Eclairage classification, the ΔE parameter only for G and OCR indicated noticeable color differences (<2), whereas other pairs had visible differences. The method of cooking affected sensory descriptors such as the intensity of flavor and aroma, tenderness, juiciness, springiness, cohesiveness, and overall palatability of goose meat. The goose samples of PF, G, and OCR were characterized as very good and WBC as extremely desirable overall palatability. However, in the next stage of research, there is a need to study changes in the chemical composition, the degree of lipid oxidation, and the nutritional value of this meat that underwent different methods of cooking. Only then it will be possibly to clearly determine which method of the heat treatment of goose meat is optimal.

Key words: goose meat, heat treatment, texture, color, sensory evaluation

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INTRODUCTION

Meat is a basic portion of sound and all-round balanced diet due to its nutritional richness. It is a valuable wellspring of high natural-quality protein and also other B complex vitamins, zinc, selenium, iron, and phosphorus. Meat is a complex food with a structured nutritional composition. It is commonly known that waterfowl meat, among others, is very favorable from the nutrition point of view. Although the contribution of waterfowl meat to global poultry meat production is still quite low, it has been on an upward trend for several years and has become increasingly important around the world. The largest producers of goose meat in the world are China and Egypt, whereas in Europe, Poland. Poland exports goose meat to the markets of Germany, Hong Kong, France, Denmark, and Russia (FAO Database http://faostat.fao.org). In Poland, the basic breed used to produce goose meat is White Kołuda geese, which in commercial production makes above 90%. From 14th to 17th wk of age the birds are fattened freely with oats, which is why they are called "Polish oat geese." Fattening with oats results in good meat quality with excellent sensory properties (Buzała et al., 2014).

Generally, meat and meat-based products are cooked before being eaten. Heat treatment of meat guarantees a

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[1]Corresponding author: monika.werenska@ue.wroc.pl

safe product. It affects the main features related to consumer's preferences such as the taste and tenderness of meat, too. The most common heat treatment methods used in cuisine for goose meat are water bath cooking (**WBC**), grilling (**G**), pan frying (**PF**) (with and without fat or oil), deep-fat frying, oven and microwave cooking (Oz and Celik, 2015). Cooking is one of the most important factors that affects the quality of meat due to a series of chemical and physical reactions. During this process, meat undergoes many changes such as weight loss, modifications of water-holding capacity, texture, color, aroma development that are strongly dependent on protein denaturation, and water loss. Protein denaturation during heating causes structural changes in meat, such as the destruction of cell membranes, shrinkage of meat fibers, the aggregation of gel formation of myofibrillar and sarcoplasmic proteins, and shrinkage and solubilization of the connective tissue. Therefore during cooking, the sensory properties of meat and its textural profile change (Tornberg, 2005; Walsh et al., 2010; Omojola et al., 2014; Pathare and Roskilly, 2016). Texture is a key quality attribute used in the fresh and processed food industry to assess the product quality and acceptability. The meat texture includes a variety of characteristics such as hardness, springiness, cohesiveness, gumminess, chewiness. The most widespread method used as an indicator of meat texture is the Warner-Bratzler shear test and texture profile analysis (**TPA**). Hardness is a primary determinant of the meat quality and one of the most important attributes influencing consumer acceptance (Bertram et al., 2004; Grujić et al., 2014; Fabre et al., 2018).

Heat treatment can lead to undesirable modifications of the nutritional value of meat, mainly because of lipid oxidation, changes the protein fraction, and losses of some vitamins and mineral compounds. Cooking instigates water loss in meat, expanding its lipid content, while some fat is lost. The combination of liquid and soluble matters lost from meat during cooking is characterized in food technology as a cooking loss. It is the main factor for the meat industry too because it determines the technological yield of the cooking process (Bertram et al., 2004; Mora et al., 2011; Omojola et al., 2014; Pathare and Roskilly, 2016).

The color measurement in cooked meat can provide reliable information about eating quality attributes. The myoglobin is the main heme pigment responsible for the meat color. The other species contributing to color changes during cooking of meat are deoxymyoglobin, oxymyoglobin, metmyoglobin (**MetMb**), and sulfmyoglobin (Segovia et al., 2007). During cooking 3 forms of myoglobin are converted and degraded through oxygenation, oxidation and reduction reactions, ultimately influencing the appearance of the meat color. The most frequently used instrumental method to determine the color of meat is the measurement of L*, a*, and b* (CIE, 1986) parameters with a chromameter (Liu and Chen, 2001; Mancini and Hunt, 2005).

The quality of cooked meat depends on the heating method, as well as the core temperature, the time and temperature evolution during cooking. Generally, consumers choose a cooking method that makes high-quality meat products having a favorable texture and taste (Mora et al., 2011; Omojola et al., 2014; Pathare and Roskilly, 2016).

In the scientific literature there is insufficient information on the quality of heat-treated goose meat. Therefore, this work has been undertaken to obtain certain information about some properties of breast muscles of "Polish oat geese" subjected to different heat-cooking treatments. The aim of this study was to describe the effect of different heat-cooking treatments on the quality of goose meat by comparing WBC, oven convection roasting (**OCR**), G, and pan-frying methods. Cooking loss, measurement of color parameters (L*, a*, b*), and Warner-Bratzler shear force (**SF**), TPA, and sensory evaluation were used to compare the 4 heat-treatment methods. The comparison of these cooking methods of goose meat is important as it provides information for consumers and industrial practice.

MATERIAL AND METHODS

Meat Samples

The experimental material covered breast (*Pectoralis major*) muscles cut from carcasses of 17-week-old "Polish oat geese." The geese are fed and maintained in a specific way—kept in open-air runs and at pasture. They are reared and fattened up to 17 wk of age according to the standard, Polish fattening technology of White Kołuda geese (Biesiada-Drzazga et al., 2011; Buzała et al., 2014). The birds were fed a complete concentrated diet. The starter mixture (from first to fourth week) was characterized by 19% protein and 11.9 MJ, the grower mixture (from fifth to eighth week) contained 17% protein and 11.7 MJ, and the finisher mixture (from ninth to 13th week) included 14% protein and 11.7 MJ. The main components of commercial mixture were ground wheat, barley, triticale, oat, grass meal, and protein concentrate in varying proportions. From 14th to 17th wk of age, the birds were fattened freely with grass meal and oats (Wojciechowski, 2015, 2016). The geese coming from the same commercial farm were slaughtered industrially. The eviscerated carcasses were placed into a 2°C to 4°C cooler for 24 h, and next, the breast muscles were cut out. To eliminate the effect of heat treatment time on the functional properties of meat, the meat samples were standardized for thickness and weight (thickness = 22 ± 3 mm, the average weight for breast muscles with skin and subcutaneous fat ≈ 480 g, without skin ≈370 g). The experiment was carried out with 96 right breast muscles (48 with skin and 48 without skin and subcutaneous fat) coming from 96 geese carcasses. Before heat treatment, the color parameters L*, a*, b* were measured in raw meat.

Heat Treatments

Water bath–cooking, G, pan-frying (without fat or oil), and OCR methods were chosen as commonly used in domestic preparation of poultry meat. No salt (NaCl), spice, and any food additives were used in the trials. A total of 24 breast muscles (6 samples with skin and 6 samples without skin were investigated twice) of geese were used in each kind of heat treatment. The core temperature for all heat treatments was 75°C.

Oven Convection Roasting

Each breast muscle was placed on a metal rack and roasted in the forced-air convection oven (model EB7551B Fusion, Amica Ltd., Wronki, Poland) connected to a computerized temperature control system (at a constant temperature of T = 200°C; before roasting, the oven was preheated), until the internal temperature of each muscle was 75°C (25 min). The internal temperature in the center of each meat samples was monitored using Teflon-coated thermocouples (Type T, Omega Engineering Inc., Stamford, CT) attached to a Doric multichannel data logger (VAS Engineering Inc., San Diego, CA).

Pan Frying

Pan frying was performed using an electric pan (model 48155, Unold AG, Hockenheim, Germany) coated in Teflon with a plate surface temperature of 160°C. The samples were placed on a preheated pan. The samples were fried and turned when they reached an internal temperature of 40°C. Processing was completed when the temperature in the geometric center of each muscle was 75°C (15 min). The internal temperature was monitored with a handheld thermometer.

Water Bath Cooking

Each breast muscle was placed in thin-wall plastic bags. Next, they were immersed in a water bath (at temperature 90°C) (model SW 22, Julabo GmbH, Seelbach, Germany). The bag opening was above the water surface. Samples were boiled to reach 75°C inside (30 min). The temperature in the geometric center of each sample was monitored with a handheld thermometer.

Grilling

Whole breast muscles were placed between 2 heating plates (heating on the bottom and top plates) of an electric grill (model PD 2020R, Red Fox, Warszawa, Poland) preheated to 200°C. The samples were grilled until a final temperature of 75°C in the geometric center of each muscle was reached (25 min). The internal temperature during cooking was monitored with Teflon-coated thermocouples placed in the geometric center of each sample, whereas the final temperature was confirmed with a handheld thermometer.

After heat processing, muscles were allowed to cool to room temperature for approximately 2 h. Then, the muscles were stored at 4°C for 24 h in the refrigerator, and next, they were allowed to equilibrate to room temperature (21°C, 3 h). Measurements of color (L*, a*, b*), SF, TPA parameters, and sensory evaluation of the meat were carried out.

Cooking Loss

Cooking loss was calculated from differences in the weights before (W_b) and after heat treatment when the sample cooled down to the room temperature (W_t).

$$CL(\%) = (Wb - Wt) / Wb \times 100\%$$

Warner-Bratzler SF and TPA

The 3 (2.54-cm diameter x 1.0-cm height) round cores were obtained from each breast muscle. The cores were collected parallel to the muscle fibers, using a handheld steel cork borer. The measurement of SF was performed at room temperature using an Instron Universal Testing Machine (model 5543, Instron Corp. Canton, Norwood, MA) equipped with a Warner-Bratzler blade. The meat cylinders were sheared in the texturometer (was used to test crosshead speed of 50 mm/min), and the average of 6 readings was used as the final value of SF (expressed in N). An instrumental evaluation of the texture—TPA—was performed using methods published by Bourne (1978, 2002) at room temperature with the Instron Universal Testing Machine (model 5543, Instron Corp. Canton). Three samples (2.54-cm diameter × 1.0 cm height) parallel to the longitudinal orientation of the muscular fibers were taken from each muscle. Then, each sample was immobilized between special stainless-steel plates and then compressed, perpendicular to the muscle fiber orientation, in 2 consecutive cycles of 70% compression with 5 s between cycles, using a cylindrical probe of 5.7-cm diameter. The cross-head moved at a constant speed of 5 mm/min. From the resulting force-time curve, the following parameters were determined (Bluehill 3—testing Software Instron): hardness (the maximum peak force during the first compression); springiness (the height that food recovers during the time between the end of the first compression and the beginning of the second compression); cohesiveness (ratio of the positive force area during the second compression to that during first compression); gumminess—the product of hardness times cohesiveness; and chewiness—the product springiness times gumminess (Bourne, 1978).

Color Measurements

The measurements are presented in the L*, a*, b* color scale (CIE, 1986) using an automated Minolta chromameter (model CR-310, Konica Minolta Co., Ltd., Osaka, Japan) with an illuminant D_{65} and 8-mm viewing port. The L* parameter signifies the lightness of the color, and it is located on a vertical axis in space, and its value ranges from 0 (black) to 100 (white). The coordinates a* and b* represent the values from which saturation and hue of color can be calculated. The value of 0° for +a* represents red, 90° for +b* yellow, 180° for –a*green, and 270° for –b* blue. The C value stands for saturation (chroma), and it has a zero value in the center and increases with the distance from the center, h° is a hue angle expressed in degrees and has its origin on the +a* axis. Before measurement, the apparatus was calibrated according to the white reference standard Y = 94.2; x = 0.313; y = 0.324. The values of L*, a*, and b* were measured across the cut surface of the raw and cooked meat. The means of the reading on 3 random locations of each muscle were determined. Chroma (C) and hue angle (h°) values were obtained from the a* value and b* value using following equations (CIE, 1986):

$$C = \left(a*^2 + b*^2\right)^{1/2}$$

$$h^\circ = tg^{-1}(b*/a*),$$

where h° = 0° for reddish hue and h° = 90° for yellowish hue.

Color space CIE L*, a*, and b* allows to identify, count, and measure objective variances between the different colors. This difference, consisting of deviations ΔL*, Δa*, and Δb*, is best expressed by the term ΔE, which is a square root of the sum of the individual deviation squared. The individual differences (ΔE) in L*, a*, and b* values were calculated from the formula $\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$ (CIE 1986).

Sensory Evaluation

The sensory evaluation of the goose meat subjected to various methods of heat processing was carried out by the quantitative descriptive analysis method with a 10-point scale expressed in conventional units (Stone et al., 1980, 1985; Stone and Sidel, 2004). All sensory work was carried out at the sensory laboratory located in the Department of Food Technology and Nutrition in Wroclaw (Poland), with all requirements according to the international standards (ISO, 1988). A panel of 7 judges, based on previous experience with sensory analysis of meat, was selected. The panel leader led the discussion to come to an agreement on the descriptors present in goose meat. In this step, some terms were removed based on selection criteria. As the panel agreed on descriptors, they began to define and reference each of them. Standard references were chosen taking into account those published in the literature for describing the same specific attribute and some used in our own laboratory. The assessors evaluated the following descriptors: flavor and aroma typical for goose meat, tenderness, juiciness, cohesiveness, springiness, and overall palatability. The samples were analyzed for the intensity of sensory descriptors. Table 1 depicts the attributes used in sensory evaluation and definitions of the points of the scale. The panel members were seated in individual booths in a temperature and light-controlled room. The samples were cut into 1.5 × 1.5 × 1.5-cm cubes (2 replicates for each muscle) and placed into glass ramekins and then coded with 3-digit codes and served to the sensory panel for analysis. Because there were too many samples for one session, the test was conducted in 2 sessions. The sequence of the tasted samples was changed for the second session to rotate them. The opinions expressed by each member of the panel were recorded on an evaluation sheet that had been created during previous tasting sessions, in which all the judges selected and defined the specific attributes of meat. Unsalted crackers and distilled water were provided to clean and refresh the palate between samples.

Statistical Analysis

The results were log-transformed to attain or approach a normal distribution, and subsequently, one-way ANOVA was used in the orthogonal system. Statistical significance of differences between the averages of the groups was calculated using Tukey's multiple comparison test, on the level of significance $P \leq 0.05$, with the use of Statistica 13.1 software (StatSoft Inc., 2019). The tables show average values and their SD.

RESULTS AND DISCUSSION

Cooking Loss

Both the type of goose meat (with and without skin and subcutaneous fat) and the kind of heat treatment

Table 1. Descriptors used in sensory evaluation and definitions of points scale (CU).

Score	Flavor and aroma typical for goose meat	Tenderness	Cohesiveness	Juiciness	Springiness (elasticity)	Overall palatability
0–2	Absence (extremely low intensity)	Extremely tough	Extremely low (extremely easy to fragmentation)	Extremely dry	No elasticity	Unacceptable
3–4	Sufficiently	Moderately tough	Low	Moderately dry	Low elasticity	Sufficient
5–6	Pleasant-good	Moderately tender	Moderately low	Moderately juicy	Moderate elasticity	Good
7–8	Very pleasant	Tender	High	Juicy	Elasticity	Very good
9–10	Excellent (extremely high intensity)	Extremely tender	Extremely high (extremely difficult to fragmentation)	Very juicy	Extreme elasticity	Excellent (extremely desirable)

Abbreviation: CU, conventional units.

Table 2. Cooking loss (%), shear force (N), and TPA parameters of goose meat (n = 12 breast muscles with skin and n = 12 without skin for each kind of heat treatment).

Parameters	Meat	Water bath cooking (WBC)	Grilling (G)	Oven convection roasting (OCR)	Pan frying (PF)	Total	Meat (M)	Heat treatment (T)	M × T
							P-values		
							$P \leq 0.05$		
Cooking loss	Without skin	$^{y}37.13^{b} \pm 2.25$	$^{y}40.80^{a} \pm 3.42$	$^{y}40.50^{a} \pm 1.34$	$^{y}35.71^{b} \pm 3.32$	$^{y}38.53 \pm 3.35$	0.001	0.001	0.518
	With skin	$^{x}42.72^{b} \pm 3.39$	$^{x}47.23^{a} \pm 3.09$	$^{x}47.83^{a} \pm 1.27$	$^{x}44.32^{b} \pm 2.25$	$^{x}45.52 \pm 3.25$			
	Total	$39.91^{b} \pm 3.92$	$44.01^{a} \pm 4.56$	$44.16^{a} \pm 4.01$	$40.01^{b} \pm 5.23$				
Shear force	Without skin	$^{x}68.94^{b} \pm 5.46$	$^{x}76.44^{a} \pm 3.25$	$^{x}72.58^{a,b} \pm 3.55$	$^{x}73.33^{a,b} \pm 3.44$	$^{x}72.82 \pm 6.08$	0.034	0.001	0.001
	With skin	$^{y}59.09^{c} \pm 3.56$	$^{y}69.78^{a} \pm 4.27$	$^{y}63.56^{b} \pm 3.15$	$^{y}63.88^{b} \pm 1.89$	$^{y}63.08 \pm 5.15$			
	Total	$64.02^{b} \pm 7.49$	$73.11^{a} \pm 5.05$	$68.07^{b} \pm 5.69$	$68.61^{b} \pm 7.96$				
Hardness (N)	Without skin	$^{x}252.66^{b} \pm 23.61$	$^{x}317.55^{a} \pm 23.77$	$^{x}325.97^{a} \pm 26.83$	$^{x}323.21^{a} \pm 25.51$	$^{x}304.85 \pm 38.27$	0.001	0.001	0.001
	With skin	$^{y}221.39^{a} \pm 21.04$	$^{y}287.33^{b} \pm 22.52$	$^{y}273.09^{b} \pm 22.45$	$^{y}275.04^{b} \pm 26.75$	$^{y}264.21 \pm 41.19$			
	Total	$231.02^{b} \pm 26.85$	$302.44^{a} \pm 27.14$	$299.53^{a} \pm 36.32$	$299.12^{a} \pm 35.41$				
Cohesiveness	Without skin	$0.55^{a} \pm 0.03$	$^{x}0.53^{a,b} \pm 0.05$	$0.49^{b} \pm 0.02$	$0.53^{a} \pm 0.03$	$^{y}0.52 \pm 0.04$	0.001	0.001	0.500
	With skin	$0.56^{a} \pm 0.03$	$^{y}0.50^{b} \pm 0.02$	$0.51^{b} \pm 0.05$	$0.54^{a,b} \pm 0.02$	$^{x}0.53 \pm 0.04$			
	Total	$0.56^{a} \pm 0.03$	$0.52^{b,c} \pm 0.04$	$0.50^{c} \pm 0.03$	$0.54^{a,b} \pm 0.03$				
Springiness	Without skin	$0.61^{a} \pm 0.04$	$0.61^{a} \pm 0.03$	$0.56^{b} \pm 0.04$	$0.60^{a,b} \pm 0.04$	0.59 ± 0.04	0.950	0.001	0.169
	With skin	0.62 ± 0.03	0.59 ± 0.04	0.58 ± 0.04	0.58 ± 0.03	0.59 ± 0.04			
	Total	$0.61^{a} \pm 0.03$	$0.60^{a} \pm 0.03$	$0.57^{b} \pm 0.04$	$0.59^{a,b} \pm 0.04$				
Gumminess (N)	Without skin	$^{x}129.74^{c} \pm 9.41$	$^{x}158.90^{a} \pm 7.99$	$^{x}151.24^{a,b} \pm 12.07$	$^{x}167.11^{a} \pm 12.24$	$^{x}151.74 \pm 17.78$	0.001	0.001	0.001
	With skin	$^{y}115.05^{b} \pm 7.76$	$^{y}135.40^{a} \pm 10.52$	$^{y}113.77^{b} \pm 7.08$	$^{y}148.20^{a} \pm 14.72$	$^{y}128.10 \pm 22.14$			
	Total	$122.40^{b} \pm 11.24$	$147.15^{a} \pm 15.21$	$132.50^{b} \pm 21.72$	$157.66^{a} \pm 16.30$				
Chewiness (N)	Without skin	$77.19^{c} \pm 6.09$	$^{x}93.85^{b} \pm 7.04$	$^{x}113.84^{a} \pm 5.58$	$^{x}100.23^{a} \pm 6.15$	$^{x}96.27 \pm 16.26$	0.001	0.001	0.001
	With skin	$70.82^{b} \pm 5.31$	$^{y}81.78^{a} \pm 6.32$	$^{y}64.63^{c} \pm 5.22$	$^{y}83.62^{a} \pm 7.13$	$^{y}75.21 \pm 12.71$			
	Total	$74.00^{b} \pm 6.38$	$87.82^{a} \pm 8.92$	$89.23^{a} \pm 26.21$	$91.93^{a} \pm 10.76$				

$^{a–c}$Different letters in rows means statistically significant differences between the group average, including thermal treatment ($P \leq 0.05$).
$^{x,\,y}$Different letter in columns means statistically significant differences between the group average, including the kind of meat ($P \leq 0.05$).
Abbreviation: TPA, texture profile analysis.

affected (P = 0.001) the amount of cooking loss (Table 2), but there was no interaction between the type of meat and heat treatment (P = 0.518). The breast goose meat with skin and subcutaneous fat characterized higher cooking losses (P = 0.001) than that without skin for all 4 cooking methods (WBC, OCR, G, and PF). In meat without skin and subcutaneous fat, the main components lost during cooking are water, water-soluble components, and intramuscular fat. The geese are the waterfowl, which are characterized by a significant amount of the subcutaneous fat. Therefore, in meat with skin an additional component loss during heat treatment is subcutaneous fat, which is why the cooking loss is larger. The oven convection-roasted and grilled goose meat was characterized by higher cooking losses than water bath–cooked and pan-fried (P = 0.001) samples for both kind of meat. Cooking loss is known to proportionally increase with increasing temperature and to depend more significantly on the final temperature at the center, but to be only slightly affected by the processing time. Although in our experiment, the final temperature inside the sample was the same (75°C), the heat treatment method had an impact on the amount of cooking loss. The temperature is determined as core temperature, and the average temperature in the whole muscles at this time could therefore be much higher at a fast heating rate (OCR, G) compared with a slower heating rate (WBC); this may partially explain the higher moisture loss observed. Moreover for oven convection-roasted, grilled, and pan-fried samples the cooking loss was mainly from evaporative and drip losses. However, for the WBC method, because samples cooked in water were surrounded by water, and smaller evaporation occurred, water cooking showed a lower cooking loss (Cheng et al., 2005; Vittadini et al., 2005). In the case of PF, lower cooking loss could also be the result of a fast crust formation that prevents the water from escaping and shorter cooking time. The mean cooking losses obtained in the present study ranged between 35.71 and 40.80% for the geese breast muscles without skin and between 42.72 and 47.83% for muscles with skin, depending on heat treatment. Current results obtained for water bath–cooked goose samples (without skin) were similar and for PF, OCR, and G—higher than those reported by Oz and Celik (2015) for Turkish goose meat. In addition, the cooking loss for grilled goose samples (without skin) was higher (40.80%) than the value stated by Fernandez et al. (2010) for French Landes grey goose meat (20.50%). In addition, Geldenhuys et al. (2013, 2016) established the lower value (28.80–30.31% dependent on sex and season) of cooking loss for oven roasting (at 160°C) game Egyptian goose meat than that of our experiment. Omojola et al. (2014) stated that deep-fried duck meat samples had the highest cooking loss while there were no statistical differences between values obtained for G, PF, and roasting methods. The variation observed in the percentage cooking loss especially for the high value in deep fried meat may be due to high temperature involved in deep frying which might have led to loss of fat and shrinkage in the fried meat. In addition, Lawrence et al. (2001) observed significant differences in cooking loss different beef muscles for 3 kinds of heat treatment (electric belt grill, forced air convection cooking, and electric broiling). Drummond and Sun (2006) indicated that there were no statistically significant differences between the cooking losses from beef muscles that underwent dry heat, moisture heat, and water bath cooking methods. Adam and Abugroun (2015) concluded that the shorter heat treatment time for cooked beef meat resulted in less percentage of cooking loss. Therefore, in the frying method, beef meat was characterized by lower cooking loss than roasting and boiling methods. According to Nimkaram et al. (2011), a statistical analysis of the cooking losses of veal revealed significant differences between cooking treatments (microwave, braising, roasting). In the study conducted by Aaslyng et al. (2003), cooking at an oven temperature of 190°C gave higher cooking loss from pork meat than PF and oven roasting at 90°C.

The differences in cooking losses between the researches could be attributed to the differences in the cooking conditions (e.g. time, temperature and kind of methods, core temperature), material used in the experiment, and various other factors, which are often not reported. Thus, taking into consideration consumer acceptance and economic reasons of producers, better methods of heat treatment for goose meat are PF and WBC.

Warner-Bratzler Shear Force and Texture Profile Analysis

The values for the different textural variables included the TPA analysis are listed in Table 2. Both, the kinds of goose meat (with and without skin and subcutaneous fat, P = 0.034) and the cooking method (P = 0.001) affected the SF value. In our study, we stated significant differences in TPA parameters such as hardness, cohesiveness, gumminess, and chewiness for kinds of meat and cooking methods, too (P = 0.001). There was no significant difference in the springiness value for the kind of meat (P = 0.950), but the cooking methods affected springiness (P = 0.001). The analyzed variables, except cohesiveness and springiness, were affected by the interaction kind of meat × heat treatment (P = 0.001). The examined goose meat with skin and subcutaneous fat was characterized by a lower SF value, hardness, gumminess, and chewiness than samples without skin for all cooking methods. There were no differences in the SF parameter for pan-fried and oven convection-roasted samples for both kinds of meat. The grilled samples were characterized by the highest value of SF and the water bath–cooked meat by the lowest value for SF, hardness, and chewiness parameters in comparison to other cooking methods for both kinds of meat. The faster cooking cycle (for PF, G, OCR), the sharper increase in the temperature gradient between the center and surface temperature might have led to a different thermal denaturative response of the myofibrillar proteins that should play a major role in the observed SF value and TPA parameters of goose meat. The lower SF value and more tender product (for WBC) were probably associated with lower temperature heat processing. In addition, the higher SF value for oven convection-roasted, grilled, and pan-fried samples could be a consequence of surface crust formation and higher dehydration of the center that the samples underwent during heat treatment.

It was previously stated that the cooking methods, kind of muscles, cooking rate, temperature, and time of cooking caused different rheological traits of beef meat (Lawrence et al., 2001; McKenna et al., 2003; Segovia et al., 2007; Yancey et al., 2011; Fabre et al., 2018; Gök et al., 2018). Similar to our results, in an experiment of Drummond and Sun (2006), water-cooked beef muscles had lower SF values than dry heat–cooked samples, indicating that the latter was less tender, whereas Kerth et al. (2003) who conducted research in the range of heat treatment times from 7 to 23 min did not find differences in the mean SF values of beef *longissimus* steaks cooked with different methods. Vittadini et al. (2005) showed that among natural convection (**NC**), forced convection (**FC**), forced/steam convection combined treatment (**FC/S**), no significant differences were found in the SF value, and therefore, all pork samples had comparable hardness. In addition, Nimkaram et al. (2011) stated the same for veal meat subjected to microwave, roasting, and braising treatment. In the studies of Cheng et al. (2005) with pork ham subjected to water cooking, dry cooking, and wet air cooking, the SF values were similar, but TPA parameters (hardness, chewing, and cohesiveness) differed. In the study of Grujić et al. (2014), it was established that SF and the TPA parameters such as hardness, springiness, gumminess, and chewiness for oven-roasted pork meat and water bath samples differed significantly. They concluded that water bath heat treatment gave products with more balanced and favorable rheological properties, considered in relation to oven roasting methods. Mora et al. (2011) observed that the breast turkey samples cooked at 100°C under forced air circulation at 3 different (dry air, low steam injection, high steam injection) cooking conditions differed in the SF parameter. Dry air samples require significantly higher SF than the steam cooked ones. The same regularity was also found by Apata et al. (2012) for rabbit meat subjected to 4 types of cooking. The results revealed that the lowest SF value characterized the samples that underwent stewing, denoted by the best tenderness. Omojola et al. (2014) reported that pan-fried and deep-fried duck samples had the highest SF in comparison with grilled and roasted meat.

The literature review shows that the results obtained by different authors varied significantly, regardless of the tested meat species. The transformation processes of connective tissue and denaturation of myofibrillar protein in the heat treatment of meat samples are very complicated and depend on many factors (among others methods of cooking, times, temperature of heat treatment, end-point temperature, kinds of meat and muscle). The degree of protein denaturation, which implies the change in their structure, is mainly related to the rate of heat flux penetration to the surface of the meat portion, as well as the heat conduction inside the product during thermal treatment. This thermal conductivity inside is very different depending on the type of meat and its size, too (Vittadini et al., 2005; Drummond and Sun, 2006; Panea et al., 2008; Yancey et al., 2011).

Considering consumer satisfaction and beneficial rheological properties of heat-treated examined goose meat, the most appropriate type seems to be WBC.

Color Parameters

Table 3 displays the obtained instrumental color parameters of lightness (L*), redness (a*), and yellowness (b*), as well as the calculated hue angle (h°) and chroma (C) for goose breast muscles cooked under different experimental conditions. There were significant differences ($P = 0.001$, $P = 0.005$) between color parameters L*, a*, b*, C, h° of raw and cooked meat. The color analysis suggested that the cooked geese breast muscles were generally lighter (higher L*) and more yellowy (higher b*), whereas less redness (a*) than raw meat. With cooking of meat occurs the discoloration of meats because of the oxidation of pigment heme groups. Heating treatments affected by meat pigments and temperature caused a lighter color. An increase in the cooking temperature means a reduction of deoxymyoglobin and oxymyoglobin and an increase of MetMb and sulfmyoglobin. The formation of MetMb and denaturation of this molecule by heat treatment lead to a brown color that is expressed by an increased b* value (Segovia et al., 2007; Roldán et al., 2013). In our study the color parameters were affected by the cooking method ($P = 0.001$, $P = 0.005$). There were no differences between grilled, oven convection-roasted, and pan-fried samples for L* parameter. The water bath–cooked goose meat showed the highest value of L*, and this suggested that these samples were characterized by lighter color among others. According to Ressurección (2003), a lighter color is desirable to ensure that the meat products will have high consumer acceptance. The water bath–cooked and pan-fried meat caused a higher value of a* and C parameters than G and OCR methods. The PF method was characterized by the highest value of a* ($P = 0.001$) and lowest of h° ($P = 0.005$) parameters. This means that the color of these samples (PF) was more red (closer to the a* axis of the CIE color space). Redness (a*) intensity in cooked meat is inversely related to the degree of denatured myoglobin, a denaturing process starting at 60°C and rising with a higher heating temperature (Gašperlin et al., 2001; Del Pulgar et al., 2012). Accordingly, the water bath–cooked and pan-fried samples revealed a more intense red color (higher a* values) than those cooked at higher temperature. This may testify more myoglobin degradation in the G and OCR methods. Moreover, the lower C values of the oven convection-roasted and grilled samples showed that they were brighter (less distant to the L*

Table 3. CIE Lab–color parameters of goose meat (n = 96 breast muscles—raw meat; n = 24—cooked breast muscles for each kind of heat treatment).

Parameters	Raw meat (R)	Heat treatment				Total	Heat treatment $P \leq 0.05$
		Water bath cooking (WBC)	Grilling (G)	Oven convection roasting (OCR)	Pan frying (PF)		
L*	$37.87^{c} \pm 2.14$	$58.41^{a} \pm 1.78$	$54.47^{b} \pm 1.09$	$54.06^{b} \pm 1.39$	$53.89^{b} \pm 2.11$	55.21 ± 2.45	0.001
a*	$19.30^{a} \pm 1.05$	$14.52^{c} \pm 1.00$	$12.27^{d} \pm 1.09$	$12.58^{d} \pm 0.39$	$16.04^{b} \pm 0.88$	13.85 ± 1.72	0.001
b*	$1.33^{c} \pm 0.23$	$4.07^{a} \pm 0.22$	$3.48^{b} \pm 0.34$	$3.47^{b} \pm 0.25$	$3.54^{b} \pm 0.34$	3.64 ± 0.38	0.001
C	$19.41^{a} \pm 1.04$	$15.01^{c} \pm 1.03$	$12.77^{d} \pm 1.09$	$13.03^{d} \pm 0.40$	$16.51^{b} \pm 0.86$	14.33 ± 1.72	0.001
h°	$3.91^{c} \pm 0.70$	$15.61^{a} \pm 1.27$	$16.36^{a} \pm 1.43$	$15.21^{a,b} \pm 1.27$	$13.73^{b} \pm 1.23$	15.23 ± 1.54	0.005

[a–d]Different letters in the rows mean statistically significant differences between the group average, including thermal treatment ($P \leq 0.05$).
[x, y]Different letters in the columns mean statistically significant differences between the group average, including the kind of meat ($P \leq 0.05$).

axis of the CIEL system) than the water bath–cooked and pan-fried ones.

Oz and Celik (2015) reported that the cooking method had only significant effect on a* and b* value for geese breast muscles. They stated that the cooking process caused a reduction in L* and a* values, whereas it increased the b* value. In our study the L* and b* values for cooked samples increased and a* decreased compared with raw meat. Vittadini et al. (2005) showed that among the different cooking treatments (NC and FC/S), the color of the pork meat that underwent the FC/S treatment was always significantly different from those samples cooked in NC and FC conditions. The FC/S samples were brighter (higher L*), less red (lower a*), and less yellow (lower b*) than the meat that underwent NC and FC heating. In addition, the lower h° values for the NC and FC samples indicated that the color of these samples was redder than the FC/S samples. However, the higher C values of the NC and FC samples indicated that they were less bright than the FC/S samples. Segovia et al. (2007) observed that the beef steaks cooked at the cook-vide system had higher L* values than samples cooked at atmospheric or sous-vide conditions. The a* and b* values were higher for the sous-vide steaks than for those cooked at an atmospheric pressure and the cook-vide system, indicating more myoglobin degradation than in other conditions. Yancey et al. (2011) demonstrated the differences in L*, a*, b*, h°, and C color parameters of beef steaks cooked with 5 kinds of heat treatments. They stated that these parameters differ depending on the cooking methods and the end-point temperature. The treatment in forced air convection oven make steaks redder inside (the highest a*), whereas clam-shell grill makes steaks less red in color (the lowest a*). The steaks cooked on an open-hearth charbroiler had a greater C value than those cooked on electric counter-top griddles and an electric clam-shell grill. Wyrwisz et al. (2012) stated that G resulted in products with the highest redness a* value in beef muscles in comparison with frying and roasting. On the contrary to roasting, both at 180°C and in the ΔT program, there was a significant reduction in red color saturation of beef muscles when compared with grilled samples.

After analyzing the value of the ΔE parameter in our experiment (Table 4), it may be concluded that the color of the cooked samples changed a lot in comparison with raw meat. The value of ΔE for raw and heat treatment samples ranged between 16.50 (PF) and 21.30 (WBC). The biggest differences in color compared with fresh meat were observed for WBC and the smallest for the PF methods. It means that water bath–cooked samples changed in color more and pan-fried ones less than other raw samples. In studies of Segovia et al. (2007), ΔE parameters for raw and heat-treated beef meat oscillated between 15 (sous-vide and atmospheric cooking treatment) and 23 (cook-vide system) and were similar to our results for geese breast muscles. According to the scale stated by Třešňák (1999) and indicating the degree of disagreement between 2 colors, the values of parameter ΔE calculated in our studies showed disturbing color differences for all methods. The calculated values of the ΔE parameter (Table 4) showing the differences in color between the tested cooking methods were as follows: G and OCR > OCR and PF > PF and G > WBC and G > WBC and PF = WBC and OCR. The lowest difference of the ΔE parameter (0.51) was calculated in pair grilled and oven convection-roasted samples and indicated minute or perceptible color differences. The pairs PF and OCR (3.46) and PF and G (3.81) characterized by not yet discordant or medium color differences. The higher differences of the ΔE parameter (4.61, 4.84, and 4.84, respectively) were established between water

Table 4. Color differences (ΔE) in goose meat.

Parameters	Raw meat (R)	Heat treatment			
		Water bath cooking (WBC)	Grilling (G)	Oven convection roasting (OCR)	Pan frying (PF)
Raw meat (R)		21.30	18.15	17.66	16.50
Water bath cooking (WBC)	21.30		4.61	4.84	4.84
Grilling (G)	18.15	4.61		0.51	3.81
Oven convection roasting (OCR)	17.66	4.84	0.51		3.46
Pan frying (PF)	16.50	4.84	3.81	3.46	

Table 5. Sensory evaluation of goose meat (CU) (n = 12 breast muscles with skin and n = 12 without skin for each kind of heat treatment).

Parameters	Meat	Water bath cooking (WBC)	Grilling (G)	Oven convection roasting (OCR)	Pan frying (PF)	Total	Significant: Meat (M)	Significant: Heat treatment (T)	Significant: M × T
							$P \leq 0.05$		
Flavor and aroma typical for goose meat	Without skin	$^{y}6.22^{c} \pm 0.44$	$^{y}6.78^{b,c} \pm 0.67$	$7.56^{b} \pm 0.53$	$^{y}8.44^{a} \pm 0.53$	$^{y}7.25 \pm 0.99$	0.001	0.001	0.126
	With skin	$^{x}7.22^{c} \pm 0.67$	$^{x}8.00^{b} \pm 0.71$	$8.11^{b} \pm 0.60$	$^{x}9.00^{a} \pm 0.50$	$^{x}8.08 \pm 0.87$			
	Total	$6.72^{c} \pm 0.75$	$7.39^{b} \pm 0.92$	$7.83^{b} \pm 0.62$	$8.72^{a} \pm 0.57$				
Tenderness	Without skin	$^{y}7.89^{b} \pm 0.60$	$^{y}6.33^{b} \pm 0.50$	$^{y}6.67^{b} \pm 0.50$	$^{y}6.44^{b} \pm 0.53$	$^{y}6.83 \pm 0.81$	0.001	0.001	0.005
	With skin	$^{x}8.78^{a} \pm 0.67$	$^{x}6.89^{c} \pm 0.60$	$^{x}7.78^{b} \pm 0.67$	$^{x}8.78^{a} \pm 0.83$	$^{x}8.06 \pm 1.04$			
	Total	$8.33^{a} \pm 0.77$	$6.61^{c} \pm 0.71$	$7.22^{b} \pm 0.81$	$7.61^{b} \pm 1.38$				
Juiciness	Without skin	$7.67^{a} \pm 0.71$	$^{y}5.89^{b} \pm 0.61$	$^{y}6.11^{b} \pm 0.33$	$^{y}6.22^{b} \pm 0.44$	$^{y}6.47 \pm 0.87$	0.001	0.001	0.038
	With skin	$8.00^{a} \pm 0.71$	$^{x}6.78^{b} \pm 0.67$	$^{x}7.33^{a,b} \pm 0.71$	$^{x}7.67^{a,b} \pm 0.71$	$^{x}7.44 \pm 0.81$			
	Total	$7.83^{a} \pm 0.71$	$6.33^{c} \pm 0.77$	$6.72^{b,c} \pm 0.82$	$6.94^{b} \pm 0.94$				
Cohesiveness	Without skin	$8.00^{a} \pm 0.50$	$7.39^{a} \pm 0.49$	$7.89^{a} \pm 0.78$	$7.56^{a} \pm 0.73$	7.71 ± 0.66	0.925	0.003	0.818
	With skin	$8.11^{a} \pm 0.60$	$7.44^{a,b} \pm 0.53$	$8.00^{a,b} \pm 0.50$	$7.33^{b} \pm 0.71$	7.72 ± 0.66			
	Total	$8.06^{a} \pm 0.53$	$7.42^{b} \pm 0.49$	$7.94^{a,b} \pm 0.64$	$7.44^{b} \pm 0.70$				
Springiness (elasticity)	Without skin	$8.78^{a} \pm 0.67$	$6.56^{c} \pm 0.53$	$7.44^{b} \pm 0.73$	$^{y}6.78^{b,c} \pm 0.67$	$^{y}7.39 \pm 1.08$	0.004	0.001	0.100
	With skin	$8.78^{a} \pm 0.67$	$7.11^{b} \pm 0.60$	$7.67^{b} \pm 0.71$	$^{x}7.78^{b} \pm 0.67$	$^{x}7.83 \pm 0.89$			
	Total	$8.78^{a} \pm 0.65$	$6.83^{c} \pm 0.62$	$7.55^{b} \pm 0.71$	$7.28^{b,c} \pm 0.83$				
Overall palatability	Without skin	$9.33^{a} \pm 0.87$	$7.00^{c} \pm 0.50$	$^{y}7.44^{b,c} \pm 0.53$	$^{y}7.89^{b} \pm 0.60$	$^{y}7.92 \pm 1.08$	0.001	0.001	0.242
	With skin	$9.44^{a} \pm 0.73$	$7.33^{c} \pm 0.50$	$^{x}8.11^{b,c} \pm 0.78$	$^{x}8.83^{a,b} \pm 0.50$	$^{x}8.43 \pm 1.01$			
	Total	$9.39^{a} \pm 0.78$	$7.17^{d} \pm 0.52$	$7.78^{c} \pm 0.73$	$8.36^{b} \pm 0.72$				

$^{a–d}$Different letters in the rows mean statistically significant differences between the group average, including thermal treatment ($P \leq 0.05$).
$^{x, y}$Different letters in the columns mean statistically significant differences between the group average, including the kind of meat ($P \leq 0.05$).
Abbreviation: CU, conventional units.

bath–cooked and grilled, oven convection-roasted, and pan-fried samples and it showed medium color differences. According to the CIE classification, the ΔE parameter only for G and OCR indicated noticeable color differences (<2), whereas other pairs had visible differences. We can conclude that the differences in the color of meat subjected to different types of heat treatments in our investigation were large. This is very important for both the consumer and the plants producing fast ready meals from geese meat.

Sensory Evaluation

The results concerning the sensory evaluation are presented in Table 5. The kind of goose meat (with and without skin and subcutaneous fat) affected sensory descriptors such as typical flavor and aroma, tenderness, juiciness, overall palatability (P = 0.001), and springiness (P = 0.004) of goose meat. The kind of goose meat did not affect sensory cohesiveness (P = 0.925). The samples with skin and subcutaneous fat were characterized by higher intensity of typical flavor and aroma, tenderness, juiciness, and springiness of goose meat and a higher score for overall palatability than the skinless ones. The method of cooking had an influence on the intensity of typical flavor and aroma, tenderness, juiciness, springiness, overall palatability (P = 0.001), and cohesiveness (P = 0.003) of goose meat. Only the tenderness (P = 0.005) and juiciness (P = 0.038) affected by the kind of meat × heat treatment interaction. The highest intensity of flavor and aroma typical for goose meat was established for pan-fried goose meat (with skin and skinless) and the lowest for water bath–cooked samples. Despite this fact, the panelists evaluated water bath–cooked samples' overall palatability as excellent because other scores of sensory descriptors such as tenderness, juiciness, and elasticity were higher than those of pan-fried, oven convection-roasted, and grilled goose meat. The water bath–cooked samples were given the higher scores for tenderness and juiciness, and this can be related to lower SF, hardness, and cooking loss of water bath–cooked samples in comparison with other ones. As described in Table 1, the panelists evaluated the flavor and aroma (typical for goose meat) of water bath–cooked samples as highly intensive and the meat texture as tender, juicy, and elastic. The pan-fried, oven convection-roasted, and grilled samples were characterized by very good overall palatability. Savkovic et al. (2006) used roasting and stewing (combined method) for chicken meat. It was obvious that tenderness was affected by the applied treatment, and roasted chicken meat received a higher score and was more tender than stewed breast muscles. Juiciness, flavor, and aroma were not affected by the cooking methods. Meat samples were scored as moderately juicy and of excellent flavor and aroma. In the report of Apata et al. (2012) the color, flavor, and overall acceptability scores were higher in fried rabbit meat than in broiled, roasted, and stewed samples. However, tenderness and juiciness scores were higher in stewed rabbit meat than roasted, broiled, and fried ones. In addition, Adam and Abugroun (2015) reported that the best flavor and aroma were presented by beef samples roasted and then fried, and the last one with the low mean value for the boiling method. The boiled beef samples had higher tenderness than fried and roasted meat but lower juiciness than roasted and fried ones. Roldán et al. (2015) showed that sous-vide preparation of lamb loins led to a less-bright color, chewiness, and juiciness and less intense flavor as compared with roasted lamb loins. Peñaranda et al. (2017) stated that fried pork meat had the highest intensity of flavor in comparison with water-boiled, oven-roasted, and grilled samples. There were significant differences between heating methods for sensory attributes such as juiciness, hardness, and chewiness. Frying obtained the highest score for juiciness, followed by WBC, oven roasting, and G methods. The effects of cooking methods (oven roasting, sous-vide) on taste, juiciness, and acceptability of beef meat were presented by Gök et al. (2018). The cooking of meat by the oven roasting method led to higher taste, juiciness, and acceptability scores. In an experiment of Tanganyika and Webb (2019) the panelists stated that pan-fried and grilled duck meat was more juicier than boiled ones, but no significant differences were noted in tenderness and overall palatability between all cooking methods. Considering all tested sensory features in our research, the overall palatability of water bath–cooked goose samples was rated as excellent, and pan-fried, oven convection-roasted, and grilled samples as very good.

CONCLUSION

The results of our experiment revealed that the different heating treatments (WBC, OCR, G, and PF without fat or oil, to an internal temperature of 75°C) led to different physical and sensory properties of cooked goose breast muscles (with and without skin and subcutaneous fat). Based on the obtained results, it is very difficult to clearly determine which of the investigated heat treatment methods for this meat is optimal. Taking into consideration the amount of cooking loss, rheological and color parameters, as well as sensory evaluation, the best methods of heat treatment of goose breast muscles seems to be WBC. However, in the next stage of research there is a need to study changes in the chemical composition and the degree of lipid oxidation and the nutritional value of the meat that underwent different methods of cooking. Only then it will be possible to clearly determine which method of the heat treatment of goose meat is optimal.

DISCLOSURES

The authors declare no conflicts of interest.

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