APARATURA
BADAWCZA I DYDAKTYCZNA

Physical, chemical and sensory quality of meat from greenleg partridge hens subjected to thermal treatment

ANNA AUGUSTYŃSKA-PREJSNAR, MAŁGORZATA ORMIAN, ZOFIA SOKOŁOWICZ
UNIVERSITY OF RZESZÓW, FACULTY OF BIOLOGY AND AGRICULTURE, DEPARTMENT OF ANIMAL PRODUCTION AND POULTRY PRODUCTS EVALUATION

Keywords: thermal treatment, breast muscles, temperature, quality

SUMMARY:

The aim of the study was to evaluate the impacts of thermal treatments and muscles internal temperatures on the meat quality of layers in their post laying periods. The research material consisted of breast muscles, subjected to thermal treatments through baking and boiling. The muscles internal temperatures for the thermal treatments, in the studies conducted, were driven to 75±2ºC and 85±2ºC using a digital thermometer with a probe needle. The impact of applied thermal treatment, including the muscles internal temperature on the protein content was demonstrated using the Kjeldahl method (Foss Tecator, Hőganas, Sweden). The colorimetric assessment, using the Chroma Meter CR-400 (Konica Minolta, Osaka, Japan) indicated that breast meat baked with internal temperature of 75±2ºC were lighter in colour (higher brightness of parameter L* and lower saturation towards yellow). The instrumental evaluation, using the Zwick/Roell BT1-FR1.OTH.D14 resistance machine, and the Warner--Bratzler knife (Zwick GmbH & Co. KG. Ulm, Germany) showed that breast meat subjected to baking was characterized by better brittleness. Both thermal methods indicate that meat brittleness, measured by its sheer force improves with rising temperature. The significant influence of muscles internal temperature on the size of thermal losses was also indicated. Lower thermal losses were observed at 75±2ºC. Consumers opinions have confirmed the effects of thermal treatment methods on the intensity of flavour, including the desirability of its flavour and aroma. Boiled meat was characterized by a significantly higher ($p \leq 0.05$) intensity and desirability of flavour, while baked meat exemplified higher desirability of aroma. Higher brittleness was typical of breast meat with lower muscles internal temperature, a fact that corroborated by instrumental analysis.

Fizykochemiczna i sensoryczna jakość mięsa kur zielononóżka kuropatwiana poddanego obróbce termicznej

Słowa kluczowe: obróbka termiczna, temperatura, mięśnie piersiowe, jakość

STRESZCZENIE:

Celem pracy była ocena wpływu obróbki termicznej i temperatury wewnątrz mięśni na jakość mięsa kur nieśnych po zakończonym okresie nieśności. Surowiec do badań stanowiły mięśnie piersiowe, które poddano obróbce termicznej polegającej na gotowaniu i pieczeniu. W badanych metodach obróbki zabiegi termiczne prowadzono do osiągnięcia temperatury 75±2ºC i 85±2ºC wewnątrz mięśni z wykorzystaniem termometru cyfrowego z sondą igłową. Wykazano zarówno wpływ stosowanej obróbki termicznej, jak i temperatury wewnątrz mięśni na zawartość białka – metoda Kjeldahla (zestaw Foss Tecator, Hőganas, Szwecja). W ocenie kolorymetrycznej – Chroma Meter CR-400 (Konica Minolta, Osaka, Japonia) – jaśniejszą barwą (wyższym parametrem jasności L* oraz niższym stopniem wysycenia w kierunku żółci) charakteryzowały się mięśnie piersiowe pieczone, o temperaturze wewnątrz mięśni 75±2ºC. Ocena instrumentalna – maszyna wytrzymałościowa Zwick/Roell BT1-FR1.OTH.D14, nóż Warnera-Bratzlera (Zwick GmbH & Co. KG. Ulm, Niemcy) – wykazała, że lepszą kruchością charakteryzowały się mięśnie piersiowe poddane procesowi pieczenia. W obu metodach termicznych wraz ze wzrostem temperatury zwiększała się kruchość mierzona siłą cięcia. Wykazano również istotny wpływ temperatury wewnątrz mięśni na wielkość strat termicznych. Niższe straty termiczne uzyskano w temperaturze 75±2ºC. W ocenie konsumenckiej wykazano wpływ metod obróbki termicznej na natężenie smaku oraz pożądalność smaku i zapachu. Istotnie wyższym (p≤0,05) natężeniem i pożądalnością smaku charakteryzowały się mięśnie gotowane, natomiast wyższą pożądalnością zapachu mięśnie pieczone. Wyższą kruchością charakteryzowały się mięśnie piersiowe o niższej temperaturze wewnątrz mięśni, co okazało się zbieżne z analizą instrumentalną.

1. INTRODUCTION

Poland's poultry meat production is dominated by fast growing broilers due to their rapid growth and efficient feed utilization. Native breeds designated for small scaled breeding are predisposed to organic farming [13, 19]. Hens of the native Greenleg Partridge breed intended for use both for egg and meat production are common in Poland's organic farms. Such hens, kept with access to green paddocks, could be good sources of meat. Post egg laying hens are, usually, not good materials for meat production. They do not command high market value, although their meat could serve as excellent raw material for the production of traditional dishes [8]. Poultry meat is subjected to thermal treatment as a way of its preservation prior to its consumption. Treatments in high temperatures result in physical and chemical changes to the protein and fat parameters, hence the meat acquires desirable sensory features such as flavour, aroma, brittleness and succulence. Thermal treatment do, however, result in unfavourable changes such as heat leakages and loss of product's nutritional value. The extent of these unfavourable changes depend on the heating duration and temperature.

The aim of the article was to evaluate the effects of thermal treatment methods on the meat quality of hens in their post laying periods kept in organic farms.

2. MATERIAL AND METHODS OF RESEARCH

The research material was made up of breast meat (n=20) prepared from chicken carcasses of the Greenleg Partridge breed, having past their egg laying cycles. The hens were reared on registered organic farms from May 2015 to June 2016 in similar conditions, fed *ad libitum* on feed mixtures containing 16% crude protein and 11.3 MJ/kg metabolic energy, that were produced from on-farm sourced components. The birds had free access to green paddocks measuring 5 m^2 per bird, sown with grass mixtures. The breeding conditions were consistent with guidelines for the organic production of poultry species as provided for in the EU and national

legislations [16, 17]. 10 hens were randomly chosen for slaughter in their 58th week of life. Both the slaughter and post-slaughter processing were carried out in pre-determined conditions and with similar technologies. The carcasses were, after slaughtering, subjected to cooling processes at +4ºC and were transported in portable refrigerators to the laboratory of the Department of Animal Production and Poultry Evaluation of the University of Rzeszów. A simplified dissection of the carcasses was conducted 24 hours after their slaughter in accordance with Ziołecki and Doruchowski methods [22]. The breast muscles thus prepared constituted the study material for quality evaluation. Before the breast meats were subjected to thermal treatments samples were obtained for chemical analysis namely, nitrogen content using Kjeldahl method (with Foss Tecator set, Hőganas, Sweden), converting the protein using a multiplier factor of 6.25; fat using Soxhlet method (Büchi Extraction System B-811 apparatus, Flawil, Switzerland), samples (5 g ± 0.001 g) dried at 105ºC were subject to Soxhlet extraction using n-hexane as a solvent, while the fat content was determined by weight after removing the solvent. The total ash content was obtained from the complete mineralization of 5 g of the meat sample at 550-650ºC (in a Carbolite AAF1100 muff oven, Hope Valley, UK). Crude protein in the raw meat was 23.65%±0.63, ash 0.64±0.08% and fat 1.18%±0.10. The breast meat was weighed to the accuracy of 0.1 g and then subjected to heat treatment (n=10) through boiling at 98ºC (group A) as well as (n=10) baking at 190ºC (group B). The thermal treatment, in the adopted research processing methods, involved taking the meat internal temperature to 75±2ºC (I); 85±2ºC (II), using a digital thermometer with a probe needle. The crude protein, ash and fat contents were determined for all samples, similar to raw breast meat samples, where the measured internal temperature varied. Measurements of pH were carried out using electrode daggers in combination with a pH-meter HI 99163 (Hann company). Weight loss was calculated based on differences between the weight prior and post thermal treatment. Instrumental colour measurements of meats cross section were done using the reflection colorimeter, Chroma Meter CR-400 (Konica Minolta, Osaka, Japan), with the lighting setting according to porthole D_{65}, and 2^{o} observer. The reading of measurement results and their conversion in real time was achieved using the colorimetric system CIE L*a*b* [4], wherein L* represents lightness, a* red and b* yellow. Three repetitions were performed for each test. The maximum shear force (Fmax in N) was determined using the Zwick/Roell BT1-FR1.OTH.D14 (Zwick GmbH & Co. KG. Ulm, Germany) tester with a Warner-Bratzler V-blade knife (Zwick GmbH & Co. KG) with the head's sweep speed of 100 mm··min^{-1} and initial force of 0.2 N. Meat blocks (5 from each sample) with a cross section of 100 mm^2 and 50 mm in length were cut parallel to the direction of meat fibres. The results of shear force measurements were analysed using the Xpert II test software (Zwick GmbH & Co.KG). The temperature of the samples while determining the texture and conducting the sensory evaluation was 20±1ºC. The sensory evaluation was conducted based on a five point scale, with 1 point denotes least desirable feature and 5 points the highest desirability. The distinguishing features being assessed were desirability and intensity of flavour and aroma, tastefulness and brittleness.

The results obtained were verified statistically using the Statistica 12 software. The result analyses involved the arithmetic mean ($\bar{x}$), standard deviation (SD), standard error of the mean (SEM), while the main effect (a – effect of thermal methods, and b – effects of meat internal temperature) as well as the effect of interaction of the factors (a x b) were determined using the univariate analysis of variance (ANOVA). The significance of differences between mean values in the groups were determined using the Tukey test. The differences accepted as statistically significant were at p≤0.05, while in case of lack of significant differences the symbol NS – not significant was applied.

3. RESULTS AND DISCUSSION

The results of the chemical composition obtained for the raw breast meat were similar to those of Puchała et al. [13], conducted on native green-legged partridge hen breeds that had completed their laying cycle. Changes in various components of the meat as a result of the thermal treatment [9, 14] were also observed. The impact of applied thermal treatment as well as the meat internal temperature on protein content was demonstrated in the study. Significantly (p≤0.05) higher protein content was observed in meat

subjected to baking processes with the meat internal temperature at 85±2ºC (Tab. 1). The results obtained correspond to those obtained by Augustyńska-Prejsnar et al. [2], Ormian et al. [10] in studies conducted on breast meat of broiler chickens. Studies conducted by Kwiecień et al. [9] and Winiarska-Mieczan et al. [20] also indicated varied protein content, depending on the applied thermal treatment. Neither the impact of thermal treatment methods nor that of the meat's internal temperature on ash and fat content was confirmed. Results obtained by Ormian et al. [10] were different as breast meat subjected to baking processes was characterized by higher fat content than those subjected to boiling. Alina et al. [1], Barbanti and Pasquini [3] as well as Winiarska-Mieczan et al. [20] provide varying fat and ash contents, depending on the adopted method of thermal treatment.

The meat colour is altered in course of the thermal treatment [6, 21]. Analysis of the results of instrumental measurements of colour revealed that the applied thermal methods and the meat's internal temperature had significant impacts (p≤0.05) on the differentiation of tests in terms of the brightness parameter (L*) and the colour saturation towards yellow (b*). Breast meat baked with the meat internal temperature of 75±2ºC (Tab. 1) was characterized by a brighter colour (higher brightness parameter L* and lower rate of saturation towards yellow). The results obtained for the colour of boiled meat were similar to those obtained by Fletcher et al. [6]. Results obtained by Chuaynukool et al. [5] from studies conducted on boiled breast meat of chickens in their post egg laying stage, including those by Pizato et al. [12] on broiler chicken breast meat were dissimilar. Studies conducted by Ormian et al. [10] indicated similar dependency both in baking as well as in boiling.

The most significant impact of thermal treatment is the transformation of the meat's brittleness, which is one of the most important distinguishing feature of texture [2, 21]. Significant effects (p≤0.05) have been shown both by the thermal treatment method applied, and the meat's internal temperature, including their interactions (Tab. 1) in the current studies. Lower shear force (better brittleness) was characteristic of breast meat subjected to boiling at 75±2ºC. The results

Table 1 Impacts of thermal treatment and meat's internal temperature on the physical and chemical features of breast meat ($\bar{x}$ ± SD)

Specification	A			B			SEM	Impact		
	I	II	$\bar{x}$	I	II	$\bar{x}$		a	b	a x b
Crude protein (%)	31.82 ±0.90	35.18 ±0.93	33.58 ±1.05	35.24 ±0.86	36.07 ±0.84	35.69 ±0.91	0.38	*	*	ns
Ash (%)	0.86 ±0.11	0.94 ±0.12	0.92 ±0.10	1.10 ±0.20	1.21 ±0.10	1.19 ±0.09	0.01	ns	ns	ns
Fat (%)	1.28 ±0.14	1.25 ±0.16	1.28 ±0.20	1.46 ±0.18	1.36 ±0.20	1.43 ±0.22	0.02	ns	ns	ns
Colour:										
L*	78.45 ±2.14	76.14 ±2.81	77.29 ±2.62	81.20 ±2.01	80.45 ±2.31	80.564 ±2.81	0.20	*	*	ns
a*	2.94 ±0.87	2.61 ±0.90	2.55 ±0.92	3.21 ±0.69	2.98 ±0.48	2.84 0.90	0.06	ns	ns	ns
b*	13.52 ±1.23	14.95 ±1.02	14.42 ±1.28	11.98 ±0.89	13.04 ±1.12	12.56 ±1.09	0.06	*	*	ns
Shear force (N)	30.51 ±2.81	34.98 ±2.72	32.81 ±2.94	33.12 ±2.40	37.12 ±2.12	35.28 ±2.60	0.68	*	*	*
pH	6.02 ±0.05	6.06 ±0.02	6.05 ±0.06	5.92 ±0.04	6.11 ±0.02	6.03 ±0.05	0.02	ns	ns	ns
Weight loss (%)	29.86 ±2.01	33.12 ±1.98	31.51 ±2.10	30.04 ±2.71	34.22 ±2.02	32.31 ±2.82	0.58	ns	*	ns

A – cooking breast muscles; B – baking breast muscles; I – 75ºC; II – 85ºC; a – impact of thermal methods; b – impact of thermal treatments; a x b – impact of thermal methods and thermal treatments methods; *– statistically significant differences p≤0.05; ns – differences statistically insignificant

corroborate those obtained by Rizzi et al. [15] in studies on breast meat of chickens past their laying cycle. Differing results were obtained in studies conducted on broiler chickens breast meat by Augustyńska-Prejsnar et al. [2] and Ormian et al. [10], in which higher brittleness was observed, using baking methods. Saláková et al. [18], however, indicated higher shear force for cooked broiler chickens breast meat. The current studies using both thermal methods have indicated that increasing temperatures resulted in increased brittleness measured as the cutting power. Both Krawczyk and Puchała [8] have reported that meat derived from hens in the post laying periods is marked by less brittleness in comparison to meat from young birds as can be seen in the increased collagen and the thickness of muscle fibres as the bird gets older.

The meat's pH following the thermal treatment have effects on its flavour [7, 14]. The current research did not, however, indicate any impacts of thermal treatment methods and the meat's internal temperature on its pH following the thermal treatment (Tab. 1). The results obtained correspond to those of Qiao et al. [11] carried out on boiled meats. Researches conducted by Chuaynukool et al. [5] showed lower pH values for boiled breast meat of post laying hens. During the heating of breast meat together with its associated protein denaturation, water leakage from the meat along with its soluble protein, salts and vitamins occur. The amount of leakage depends on the meat's water retention capacity prior to its thermal treatment as well as the heating duration and temperature. Studies conducted by Alina et al. [1] and Augustyńska-Prejsnar et al. [2] demonstrated the influence of thermal treatments on the amount of thermal loss although this was not confirmed in the current studies. The studies did, however, indicate significant ($p \leq 0.05$) influence of meat's internal temperature on the level of thermal losses. Lower thermal losses were achieved at 75±2°C.

Thermal treatment is a key factor influencing the development of the specific flavour and aroma profile of meat, which is important to consumers [7]. Such features depend largely on the genotype, age of slaughtered birds, environmental factors, but it, in the case of laying hens, depends mainly on chances of the birds having access to green paddocks and the thermal treatment methods [8]. Table 2 illustrates the effects of thermal treatment and meat's internal temperature on sensory features of breast meat from post egg laying hens. The current studies have demonstrated the impact of thermal treatment methods on the intensity and desirability of flavour and aroma. Significantly higher ($p \leq 0.05$) intensity and desirability of flavour was specific to boiled meat, while a higher desirability of aroma associated with baked meat. Contrary results of studies on the intensity and desirability of flavour

Table 2 Impacts of thermal treatment and meat's internal temperature on the sensory features of breast meat (pts)

Specification	A			B			SEM	Impact		
	I	II	$\bar{x}$	I	II	$\bar{x}$		a	b	a x b
Intensity odour	4.30 ±0.21	4.32 ±0.30	4.32 ±0.32	4.38 ±0.20	4.41 ±0.16	4.40 ±0.22	0.04	ns	ns	ns
Intensity flavour	4.58 ±0.12	4.68 ±0.20	4.64 ±0.22	4.40 ±0.21	4.48 ±0.16	4.46 ±0.20	0.02	*	ns	ns
Desirability odour	4.48 ±0.20	4.40 ±0.16	4.45 ±0.22	4.69 ±0.18	4.64 ±0.20	4.68 0.24	0.04	*	ns	ns
Desirability flavour	4.64 ±0.18	4.42 ±0.23	4.55 ±0.30	4.31 ±0.26	4.35 ±0.23	4.34 ±0.28	0.03	*	ns	ns
Juiciness	4.50 ±0.19	4.40 ±0.21	4.42 ±0.23	4.48 ±0.30	4.41 ±0.29	4.42 ±0.32	0.03	ns	ns	ns
Tenderness	4.60 ±0.20	3.02 ±0.22	4.50 ±0.26	4.48 ±0.18	3.25 ±0.22	3.90 ±0.24	0.03	ns	*	ns

A – cooking breast muscles; B – baking breast muscles; I – 75°C; II – 85°C; a – impact of thermal methods; b – impact of thermal treatments; a x b – impact of thermal methods and thermal treatments methods; * – statistically significant differences $p \leq 0.05$; ns – differences statistically insignificant

were achieved by Augustyńska-Prejsnar et al. [2], Ormian et al. [10] and Kwiecień et al. [9], where baked and grilled meat met with greater acceptability than boiled meat. Studies conducted by Puchała et al. [13] demonstrated that breast meat from hens after their laying periods displayed varying flavour and aroma depending on the genotype. The current study demonstrated the significant influence of meat internal temperature the its brittleness. Higher brittleness was, in consumers opinion, characteristic of breast meats with lower internal temperature, which is consistent with results of the instrumental analysis.

4. SUMMARY

The studies have demonstrated the effect of thermal treatment and meat's internal temperature on protein. Significantly ($p \leq 0.05$) higher protein content was observed in meat subjected to baking to achieve the meat's internal temperature not exceeding 85±2°C.
The applied thermal methods and the meat's internal temperature had significant impacts on the diversity of samples regarding the brightness parameter (L*) as well as colour saturation towards yellow (b*). A brighter colour (higher brightness parameter L* and lower degree of saturation towards yellow) was characteristics of breast meat baked to achieve an internal meat temperature of 75,2°C. The current study also established the significant effects of thermal treatment methods, meat's internal temperature as well as the interaction between both factors on the product's brittleness. The brittleness, measured by the shear force, improved along with rising temperatures in both thermal methods. The significant impact of the meat's internal temperature on the amount of thermal losses was also substantiated. The impact of thermal treatment methods on the intensity of flavour and the desirability of flavour and aroma was, in consumers viewpoint, also demonstrated. Significantly higher ($p \leq 0.05$) intensity and desirability of flavour was characteristic of meat boiled, while a higher desirability of aroma was associated with meat subjected to baking.

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