Influence of husbandry systems and thermal processing methods on the results of instrumental colour assessment and shear force of broiler chicken meat

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Keywords: raising system, thermal processing, breast muscles, leg muscles, colour, shear force

ABSTRACT:

The objective of the study was to assess the impact of raising systems and thermal processing methods on colour parameters and shear force. The study was conducted on the breast and leg muscles of Ross 308 broiler chickens from two different raising systems, with chickens from group A being held on littered indoor, while those in group B were on free-range with access to paddocks. The muscles were put through thermal processing, involving boiling (I) and baking (II) until the meat internal temperature achieved 82ºC. The influence of the raising system on the colour of the raw muscle was observed. It was found that both the breast and leg muscles of chickens held in free-range had characteristically darker colour, as evidenced by the significantly higher ($p<0.05$) colour saturation of red (a*) and yellow (b*). Lower mechanical resistance, measured by cutting force ($p<0.05$), had breast muscles (16.25 N) and leg muscles (19.21 N) from chickens kept without access to free-range compared to the breast muscles (14.37 N) and leg muscles (17.77 N) from chickens with access to free-range. Raising system and thermal processing methods had impact on the varied colouration of the breast and leg muscles. Breast muscles from chickens held in indoor system but subjected to boiling processes were characterized by brighter colour. The thermal processing methods applied had significant impact ($p<0.05$) on the maximal shear force of the investigated muscles. Boiling muscles were characterized by lower shear force, which is better texture. It has been shown ($p<0.05$) the impact of the raising system on the value of the maximum shear force of breast muscles.

Wpływ systemu chowu i metody termicznej na wyniki instrumentalnej oceny barwy i siłę cięcia mięsa kurcząt brojlerów

Słowa kluczowe: system chowu, obróbka termiczna, mięśnie piersiowe, mięśnie nóg, barwa, siła cięcia

STRESZCZENIE:

Celem badań była ocena wpływu systemu utrzymania i metod obróbki termicznej na parametry barwy i siłę cięcia. Badania przeprowadzono na mięśniach piersiowych i mięśniach nóg kurcząt brojlerów Ross 308, pochodzących z dwóch różnych systemów chowu: kurczęta z grupy A utrzymywano na ściółce bez dostępu do wybiegu, kurczęta z grupy B z dostępem do wybiegu. Mięśnie poddano obróbce termicznej polegającej na gotowaniu (I) i pieczeniu (II) do osiągnięcia wewnątrz mięśnia temperatury 82ºC. Stwierdzono wpływ systemu utrzymania na barwę surowych mięśni. Zarówno piersiowe, jak i mięśnie nóg kurcząt mających dostęp do wybiegów cechowały się ciemniejszą barwą, o czym świadczy istotnie wyższe ($p<0,05$) wysycenie barwy w kierunku czerwieni (a*) i żółci (b*). Niższą opornością mechaniczną, mierzoną siłą cięcia ($p<0,05$), charakteryzowały się mięśnie piersiowe (16,25 N) i nóg (19,21 N) kurcząt utrzymywanych bez dostępu do wybiegu w porównaniu do mięśni piersiowych (14,37 N) i nóg (17,77 N) kurcząt z dostępem do wybiegów. System utrzymania i stosowane metody termiczne miały wpływ ($p<0,05$) na zróżnicowanie barwy mięśni piersiowych i mięśni nóg. Jaśniejszą barwą charakteryzowały się mięśnie piersiowe i mięśnie nóg kurcząt utrzymywanych bez dostępu do wybiegów poddane procesowi gotowania. Zastosowane metody termiczne miały istotny wpływ ($p<0,05$) na wartość maksymalnej siły cięcia badanych mięśni. Mniejszą siłą cięcia, czyli większą kruchością, charakteryzowały się mięśnie gotowane. Wykazano ($p<0,05$) wpływ systemu utrzymania na wartość maksymalnej siły cięcia mięśni piersiowych.

1. INTRODUCTION

While the consumption of poultry meat has steadily increased in Poland, its most commonly chosen parts by consumers have remained the breast and leg muscles. The leading system of raising broiler chickens is their being kept in littered indoor facilities [8]. An alternative to the intensive raising system is the littered free--range rearing with access to green paddocks [2]. Researches on the alternative system have indicated that a smaller stocking rate, freedom of movement and being outdoors, including the possibility of pecking green plants can contribute to improving the quality of poultry meat [14, 18]. The scale of poultry meat production for slaughter from alternative raising systems have been insignificant. Given the growing consumer interest in meat from chicken raised in free-range the question that arises is whether and to what extent should the quality of poultry meat depend on the type of raising system?

Thermal processing is not only a method of food preservation, but also a link between the raw material and the consumable product. The purpose of the process is to extend the product's life, increase the digestibility and assimilability of proteins, and more-so to give the product a suitable brittleness, flavour, aroma and colour [9, 12]. Consumers' preferred method of preparing dishes with poultry meat is boiling and baking.

Instrumental methods of measuring colour and brittleness are characterized by high level objectivism and they enhance measurements. Measurements undertaken using instrumental test, in comparison with sensory analysis are faster and ensure better repeatability of results [10]. The huge access to meat colour evaluation has contributed to the emergence of objective measurement methods, one of which is the direct method of measuring the colour reflection of components using the „Hunter Lab" scale expressed as L*a*b*. Studies have shown the existence of links between the L*and*b* colour components of poultry meat and its quality [7, 8, 13, 14, 17, 18, 19]. The most commonly applied parameter in the instrumental assessment of meat texture is the interdependency between meat's brittleness and the maximum value of its shear force [10].

The objective of the study was to assess the impact of raising systems and methods of thermal processing on the colour parameter and shear force of meat.

2. MATERIAL AND METHODS

The studies were conducted on breast and leg muscles of Ross 308 broiler chickens from two separate groups. The group A chickens were raised indoors on litter, while the group B were also raised on litter, but with access to green paddocks with grass mixtures. The outdoor surface area per bird was 4 m^2. The paddocks were fitted with nipples and canopies to protect the birds against the sun. The chickens were, over the raising period, fed at will on fully rationed mixes of starter, grower and finisher with concentrated feed components tailored to the dietary needs of the broilers and with unlimited access to water. The stocking rate for chickens in both groups was 4/m^2. 30 chickens with body weights close to the group average were randomly taken from each in order to assess the meat quality. The birds were slaughtered on their 42nd day of age. Having been slaughtered and dressed the carcasses were subjected to chilling process at a temperature of +4ºC through 24 hours, followed by a simplified analysis by dissection in accordance with Ziołecki and Doruchowski [22]. The breast and leg (thigh and tibia) muscles were subjected to superficial and deep dissections.

10 pieces, each of breast and leg muscles of similar weight, approximated to 1 g, were selected for the thermal treatment. The thermal treatment involved using the boiling method (I) in water at 96ºC at a ratio of water to meat of 3:1 as well as baking process (II) at 180ºC. The methods of thermal treatments applied led to the attainment of meat's internal temperature of 82ºC. The in-meat temperature was monitored using a digital thermometer with a probe needle.

The instrumental measurement of the colour of the breast and leg muscles was carried out using a meat colour assessing kit (Minolta's reflective colorimeter with a CR-400 head with a computerized kit and the Spectra Magic NX software). The colour parameters were set for lighting in accordance with the D_{65} illuminator. The colour of the raw meat was assessed from the interior side directly after its extraction from the bones. The colour evaluation of the thermally treated muscle was carried out on its cross-section. The measurement was taken by placing the measuring head to the surface (5 readings of the colour parameter from the meat's entire surface at points with characteristic uniform colour representation of the analyzed surface). The reading of results of measurements and their conversions in real time was achieved using the CIE L*a*b* colorimeter system [3], wherein L* represent brightness, (a*) red and (b*) yellow. Two repetitions were performed for each sample.

The instrumental measurement of the breast and leg muscle texture was conducted using a universal single-column testing system for toughness, the Zwick Z1.0 TH Roell 1 kN with a fast data transfer interface to a PC with a Xpetll testing software for toughness. The shearing test was undertaken using a Warner-Bratzler single-knife slicing system (a single flat blade, 1.2 mm thick, having a triangular notch of 60º), whose inner edge serves as the working edge. The test was performed at a crosshead speed of 100 mm/min and an initial strength of 0.2 N on chilled samples (4ºC) prepared from raw and pre-thermally treated meat of 10x10x50 mm in size, sliced parallel to the course of muscle fibre. Two repetitions were performed for each sample.

The results obtained were subjected to statistical analysis using the STATISTICA 12 software. The mean value for groups and the standard deviation (SD) were determined. In order to analyse the impact of raising system on the quality features of raw breast muscle, a one-factorial analysis of variance (ANOVA) and in particular the Tukey test at a level of significance of $p<0.05$ was conducted. The impact of raising systems and thermal methods was statistically verified using a two-factor analysis of variance (ANOVA) at a level of significance of $p<0.05$.

3. RESULTS AND DISCUSSIONS

Colour is an indicator of the quality of poultry meat and it is the first feature consumers assess at point of purchase [1, 5, 17]. The impact of raising system on the colour of raw breast and leg muscles (Tab. 1) was observed in the current study. Analyses of the L*a*b* values have shown that the tested breast meat differed in their brightness of colour. Higher value of the L* parameter was displayed in the breast meat of chickens held indoors ($p<0.05$). Broiler chickens with access to paddocks were characterized with decisively higher ($p<0.05$) colour saturation of their breast and leg muscles towards the red (a*) and the yellow (b*), in comparison to birds held without access to paddocks. Similar findings were obtained by Chen et al. [4], Fanatico et al. [5] and Sales [15].

Table 1 Results of evaluation of colour and shear force parameters in raw breast and leg muscles of broiler chickens ($\bar{x}$ ± SD)

Details	breast muscles		SEM	leg muscles		SEM
	A	B		A	B	
Colour:						
L*	56.81[a] ±3.01	54.44[b] ±2.61	0.59	51.87 ±3.22	48.76 ±2.95	0.44
a*	2.42[a] ±0.53	3.61[b] ±0.64	0.18	10.72[a] ±0.85	12.02[b] ±1.06	0.18
b*	3.58[a] ±0.95	4.68[b] ±1.31	0.34	6.02[a] ±1.60	7.88[b] ±1.68	0.12
Shear force (N)	14.37[a] ±3.01	16.25[b] ±2.61	1.52	17.77[a] ±2.82	19.21[b] ±2.65	0.35

a, b – the averages for the assigned letters in rows differ significantly ($p<0.05$)
A – indoor raising system; B – free-range system

Different findings relating to the saturation of the yellow colour for both the breast and leg muscles were obtained by Skomoruch and Sosnówka-Czajka [18]. Tong et al. [21], on the contrary, did not observe any differences between the meat colour of chickens raised indoors and those with access to paddocks. Higher saturation of yellow colour may be associated with the pecking of carotenoid rich plant material, while higher saturation in favour of red can be due to greater motor activity [2, 14, 18, 20].

The current study has also demonstrated the impact of raising systems on the brittleness of raw breast and leg muscles (Tab. 1). Smaller shear force ($p<0.05$), that is, greater brittleness was typical of both breast and leg muscles of chickens held indoors without access to paddocks. Similar findings namely, higher shear force of meat from chickens held in free-range were observed by Santos et al. [16] as well as Połtowicz and Doktor [14].

In analyzing the results of the instrumental measure of colour, it was observed that the raising system and the thermal method applied impacted on the colour variation of the breast and leg muscles (Tab. 2 and 3). Lower L* parameter for brightness, i.e., darker colouration and higher colour saturation towards the red (a*) was typical of breast and leg muscles of chicken held in free-range and subjected to baking process. Additionally, the impact of thermal methods on the yellow (b*) parameter on breast muscle was also demonstrated. Higher colour saturation towards yellow was observed in muscles subjected to baking treatment. The results obtained corroborates those from studies by Ormian et al. [12]. A darker colour was, on the other hand, observed in the process of boiling in studies conducted by [6] and

Table 2 Impacts of raising system and thermal methods on the colour and shear force of breast muscles ($\bar{x}$ ± SD)

Tested features	A		B		SEM	Impact		
	I	II	I	II		a	b	a x b
Colour								
L*	84.04 ±1.31	80.71 ±0.87	86.88 ±1.67	82.49 ±0.98	0.48	*	*	ns
a*	2.76 ±0.42	2.98 ±0.29	2.43 ±0.38	2.69 ±0.39	0.06	*	*	ns
b*	10.26 ±1.81	12.97 ±0.92	11.81 ±1.52	13.36 ±1.18	0.13	ns	*	ns
Shear force (N)	15.04 ±1.92	18.98 ±1.89	16.98 ±1.65	20.97 ±1.69	0.54	*	*	*

A – indoor raising system; B – free-range system; I – boiling method, II – baking method; a – impact of raising system; b – impact of thermal methods; a x b – impact of raising system and thermal methods; * – statistically significant differences $p<0.05$; ns – differences statistically insignificant

Qiao et al. [13]. Colour changes in meat in course of thermal treatments depend on the degree of denaturation of the protein component of myoglobin [11].

The brittleness of poultry meat is one of the most sought after quality features of meat after thermal treatment. Brittleness is conditioned by several factors, especially the bird's age, raising system, method of feeding and type of thermal treatment [1, 11]. The current study has demonstrated the impact of raising system and thermal methods of the shear force of breast muscles (Tab. 2). Lower shear force at ($p<0.05$), greater brittleness, is typical of breast muscles from chickens held indoors and subjected to boiling processes. The findings correspond to those obtained in studies by Ormian et al. [12] and Michalczuk et al. [8]. No impacts of the raising system on the maximum value of the shear force of leg muscles was demonstrated in the current study (Tab. 3). Leg muscles subjected to boiling processes had typically less mechanical resistance (shear force) at ($p<0.05$) when compared to muscles subjected to baking processes.

4. CONCLUSIONS

It has been confirmed, relying on the study, that breast and leg muscles of chickens raised in free-range were typically darker in colour, as evidenced by the lower value of the L* component as well as higher values of (a*) and (b*) colour component. Higher brittleness, i.e., less shear force, was observed with raw breast and leg muscles of chickens raised indoors without access to paddocks.

Raising systems as well as applied thermal processing methods had impacts on the diversity of colouration of breast and leg muscles. The lower L* brightness parameter and higher colour saturation towards (a)* red (darker colouration) was displayed by breast and leg muscles of chickens raised in free-range, subjected to baking process. The impact of raising system and thermal processing methods on the value of breast muscles shear force was indicated. Less shear force was characteristic of breast muscles of chickens raised indoors and subjected to boiling processes. The thermal treatment methods applied had impacts on the shear force of leg muscles.

Table 3 Impact of raising system and thermal methods on colour and shear force of leg muscles ($\bar{x} \pm$ SD)

Tested features	A		B		SEM	Impact		
	I	II	I	II		a	b	a x b
Colour								
L*	70.58 ±1.80	72.32 ±1.54	72.84 ±1.11	73.25 ±1.24	0.51	*	*	ns
a*	6.85 ±0.16	6.91 ±0.22	5.86 ±0.16	5.96 ±0.19	0.12	*	*	ns
b*	13.89 ±0.74	14.16 ±1.02	14.14 ±0.71	14.89 ±1.06	0.28	ns	ns	ns
Shear force (N)	12.52 ±1.25	15.63 ±1.62	12.04 ±1.15	16.56 ±1.36	0.89	ns	*	ns

A – indoor raising system; B – free-range system; I – boiling method, II – baking method; a – impact of raising system; b – impact of thermal methods; a x b – impact of raising system and thermal methods; * – statistically significant differences $p<0.05$; ns – differences statistically insignificant

LITERATURE

[1] Augustyńska-Prejsnar A., Sokołowicz Z., Factors affecting the sensory quality of meat from broiler chickens. Wiad. Zoot., R. LII 2, 2014, 108-116.

[2] Castellini C., Berri C., Le Bihan-Duval E., Martino G., Qualitative attributes and consumer perception of organic and free-range poultry meat. Word's Poultry Science. Journal, 64, 4, 2008, 500-512.

[3] CIE. Supplement No 2 to: Recommendations on uniform color spaces – Color difference equations. Psychometric Color Terms. Commission Internationale del'Eclairage (1971) to 1-1. CIE Publication No 15 (E-1.3.1), Paris France, 1976.
[4] Chen X., Jiang W., Tang H. Z., Xu G. F., Zhang X. B., Wei S., Wang Q., Effects of outdoor access on growth performance, carcass composition, and meat characteristics of broiler chickens. Poultry Sci., 92, 2013, 435-443.
[5] Fanatico A. C., Pillai P. B., Emmert J. L., Owens C. M., Meat quality of slow- and fast-growing chicken genotypes fed low- nutrient or standard diets and raised indoors or with outdoor access. Poultry Sci., 86, 2007, 2245-2255.
[6] Latif S. S., Effect of marination on the quality characteristics and microstructure of chicken breast meat cooked by different methods. Lucrări Stiintifice, 54, 2010, 314-324.
[7] Mancini R. A., Hunt M. C., Current research in meat color. Meat Sci., 71, 2005, 100-121.
[8] Michalczuk M., Łukasiewicz M., Zdanowska-Sąsiadek Ż., Niemiec J., Comparison of selected quality attributes of chicken meat as affected by rearing systems. Pol. J. Food Nutr. Sci., 64, 2, 2014, 121-126.
[9] Mikulski D., Celej J., Jankowski J., Majewska T., Mikulska M., Growth performance, carcass traits and meat quality of slower-growing and fast-growing chickens raised with and without outdoor access. Asian-Australas. J. Anim. Sci., 2011, 1407-1416.
[10] Niedźwiedź J., Żmijewski T., Ostoja H., Cierach M., Porównanie wartości maksymalnej siły cięcia wybranych mięśni z tylnej ćwierćtuszy wołowej. Inż. Ap. Chem., 50, 3, 2011, 57-58.
[11] Orkusz A., Czynniki kształtujące jakość mięsa drobiu grzebiącego. NIT, 1 (16), 2015, 48-56.
[12] Ormian M., Augustyńska-Prejsnar A., Sokołowicz Z., Wpływ obróbki termicznej na wybrane cechy jakości mięśni piersiowych kurcząt z chowu wybiegowego. Post. Tech. Przetw. Spoż., 2, 2015, 43-46.
[13] Qiao M., Fletcher D. L., Smith D. P., Northcutt J. K., Effects of raw broiler breast meat color variation on marination and cooked meat quality. Poultry Sci., 81, 2002, 276-280.
[14] Połtowicz K., Doktor J., Effect of free-range raising on performance, carcass attributes and meat quality of broiler chickens. Anim. Sci. Pap. Rep., 29, 2, 2011, 139-149.
[15] Sales J., Effects of access to pasture on performance, carcass composition, and meat quality in broilers: A meta-analysis. Poultry Sci., 93, 2014, 1523-1533.
[16] Santos A. L., Sakomura N. K., Freitas E. R., Fortes C. M. S., Carrilo E. N. V. M., Comparison of free range broiler chicken strains raised in confined or semi-confined systems. Rev. Bras. Cienc. Avicola, 7, 2005, 85-92.
[17] Słowiński M., Florowski T., Adamczak L., Dasiewicz K., Golonko M., Zastosowanie pomiaru barwy do oceny jakości mięsa drobiowego. Post. Tech. Przetw. Spoż., 2, 2005, 41-43.
[18] Skomorucha I., Sosnówka-Czajka E., Wpływ systemu utrzymania kurcząt brojlerów na kształtowanie się wybranych parametrów jakościowych mięsa. Rocz. Nauk. Zoot., 42, 1, 2015, 45-53.
[19] Sman R. G. M., Modeling cooking of chicken meat in industrial tunnel ovens with the Flory-Rehner theory. Meat Sci., 95, 2013, 940-957.
[20] Tong H. B., Cai J., Lu J., Wang Q., Shao D., Zou M., Effects outdoor access days on growth performance, carcass yield meat quality and lymphoid organ index of a local chicken breed. Poult. Sci., 94, 2015, 1115-1121.
[21] Tong H. B., Wang Q., Lu J., Zou J. M., Chang L. L., Fu S. Y., Effect of free-range days on a local chicken breed: Growth performance, carcass field, meat quality, and lymphoid organ index. Poultry Sci., 93, 2014, 1883-1889.
[22] Ziołecki J., Doruchowski W., Metoda oceny wartości rzeźnej drobiu. COBRD Poznań, 1989.