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Meat quality characteristics of chickens raised organically and intensively

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The aim of the study was to evaluate selected physical and chemical characteristics of the breast muscles of organically and intensively raised chickens. The parameters determined are important to consumers in assessing meat quality. The experimental material consisted of crossbred chickens obtained from crossing a white broiler cock from Ross 308 parent stock with a brown dual-purpose Rhode Island Red R-66 hen (group E) and Ross 308 commercial crossbred broiler hens (group K). Chickens from group E were reared over 84 days in accordance with the requirements of organic farming, while the group K chickens were reared conventionally over 42 days. The results indicate differences in post mortem changes in the breast muscles of the organically and intensively raised chickens. The muscles of broiler chickens from organic farming were characterized by good nutritional value (1.73 pp more protein and 0.46 pp less fat) and a darker colour (L* 49.65), which may be a desirable feature for many consumers. However, the high pH_{24} level of the breast muscles of organic chickens indicates that the meat may be susceptible to microbiological contamination and can only be stored for a short period. Furthermore, it requires a greater shear force (54.12 N raw and 46.66 N cooked), which may indicate that the meat needs to be cooked longer.

KEY WORDS: chickens / broiler / ecology / meat / quality

Poultry meat production worldwide has shown a clear upward trend for several years – the highest among all types of meat obtained from livestock. Analysis of world meat production in recent years reveals a 0.8% increase in total meat production and a 2.2% increase in poultry meat production. In Poland, poultry meat production in 2016 showed an intensive growth rate of over 10% per annum and reached 2.5 million tonnes. However, this intensive increase in production was not equal among all species and poultry farming systems. The meat of broiler chickens, i.e. intensively reared crossbreds of meat chickens, accounts for about 82% of domestic poultry meat [29].

Due to dynamic changes in the human diet and in consumer demand regarding quality and health safety, consumers increasingly seek out animal products from organic farming. In terms of the number of certified organic producers, Poland ranks between 6th and 9th in Europe. In terms of the value of the organic food market (EUR 50 million), however, Poland is near the bottom (0.3% of the market). Organic production of livestock for meat accounts for an estimated 4.0% of all livestock production in the country, with the rearing of calves occupying the most important position [12]. Organic poultry production remains marginal in the country, accounting for less than 1% of total poultry production. In contrast, in the wealthy countries of Western Europe this type of production accounts for an estimated 8-10% [13, 14].

The quality of poultry meat is an important factor for consumers. Defects in chicken meat appear as a set of traits referred to as PSE or DFD, in contrast to RFN meat of good technological quality. The changes are most frequently noted in the most valuable part of the carcass, i.e. the breast muscles, and involve PSE characteristics, i.e. substantial wateriness, a soft consistency, and a pale, greyish-white colour [6, 5]. The results of many studies indicate that the physical characteristics of meat immediately after slaughter allow for a preliminary assessment of its susceptibility to microbial contamination and losses during storage, refrigeration, and cooking [10, 24].

The objective of the study was to evaluate selected physical and chemical characteristics of the breast muscles of meat chickens from organic and intensive farming. Parameters which are important for consumers in their assessment of meat quality were evaluated.

Material and methods

The experimental material consisted of chickens obtained by crossing a white broiler cock from Ross 308 parent stock with a brown dual-purpose Rhode Island Red R-66 hen (group E) and Ross 308 crossbred broiler hens (group K). The experiment was conducted on 80 chickens, 40 in each group with an equal sex ratio of 1:1.

The group E chickens were reared for 84 days according to the requirements of organic farming as defined by EU [25, 27] and national [26, 30] legislation. The chickens were kept in housing with bedding and access to a chicken run with vegetation in accordance with these regulations.

The group K birds were reared for 42 days in buildings without runs or windows, with a floor covered in straw. Technological and environmental conditions were in accordance with the recommendations of the producer of the Ross breeding material [2].

The birds in each stage of growth received compound feeds with basic nutrient content appropriate for the rearing period (Table 1) and produced from raw materials currently available and in compliance with applicable legislation on organic and intensive production of slaughter chickens. All experimental chickens had constant access to feed and water.

Table 1

Content of basic nutrients in compound feeds for chickens raised organically (group E) and intensively (group K)

Ingredient	Group E		Group K		
	period of application of feed (days of life)				
	1 – 42	43 – 84	1 – 14	15 – 35	36 – 42
Total protein (%)	20.72	17.53	22.86	21.38	19.42
Crude fibre (%)	3.48	3.96	3.26	3.84	3.88
Lysine (%)	0.96	0.71	1.42	1.26	1.06
Methionine (%)	0.41	0.31	0.56	0.50	0.50
Calcium (%)	0.95	0.90	0.98	0.90	0.98
Available P (%)	0.43	0.35	0.48	0.45	0.48
Metabolizable energy (MJ)	11.28	11.84	12.52	12.94	13.26

In group E, two types of compound feeds were used, based on organic, on-farm cereals with supplementary mixtures and additives. All feeds and additives came from organic sources (farms or companies) and were in compliance with the list of additives accepted for organic farming [31]. In addition, from the 22nd day, the birds had constant access to a run with vegetation of varying botanical composition. The stocking density was 10 chickens/m^2, assuming a maximum 21 kg live weight/m^2, and the area of the chicken run was 4 m^2/chicken.

In group K, three types of compound feeds were used, prepared by a commercial feed manufacturing plant according to accepted formulas for intensively reared Ross 308 broiler chickens. The birds were kept in a closed room all times at a stocking density of 16 chickens/m^2, assuming a maximum 39 kg live weight/m^2.

At the end of the rearing period, all birds were weighed and slaughtered, following 12-hour fasting with constant access to drinking water. Then the chickens were subjected to post-slaughter processing according to industrial practice. All birds were individually marked.

All measurements of physical characteristics were performed in the *m. pectoralis superficialis* and *m. pectoralis profundus*, located on the left side of the carcass. The hydrogen ion concentration was measured 15 minutes (pH_{15}) and 24 hours (pH_{24}) post-slaughter with a Mettler-Toledo MP 125 DE/ Inlab 427 pH meter. Instrumental colour measurement in the CIE L*a*b* colour system [4] was performed on the inner side of the raw muscle 48 hours after slaughter (L^*_{48}, a^*_{48} and b^*_{48}) using a Minolta Chroma Meter C580 trichromatic colorimeter (D65 light source, 10º observer, 8 mm measurement aperture, white standard calibration: L* – 99.18, a* – 0.07, b* – 0.05). In this system L* denotes lightness, which is a spatial vector, while a* and b* are trichromatic coordinates, where positive values of a* correspond to red colour, negative to green colour, positive b* to yellow colour, and negative b* to blue colour.

The proximate chemical composition of the muscles was determined according to Polish Standards [18, 19, 20]. The water content was determined by drying to a constant weight at 103 ±2°C [19] and fat content using a B-810 extraction system from Buchi (Switzerland) [20]. Protein content was determined by the Kjeldahl method (2200 Kjeltec Auto Distillation Foss Tecator) and nitrogen was converted to protein using a conversion factor of 6.25 [18].

The water holding capacity (WHC) was determined using a modification of Grau and Hamm's method [8, 21], and the cooking loss (CL) was measured by Pikul's method [17].

To determine selected texture parameters of raw and cooked meat, 48 hours after slaughter samples 1.5 cm in length with a 1 x 1 cm cross section were taken from the *pectoralis superficialis* muscle, cut along the muscle fibres, from the chilled carcasses [9]. Two thirds of the samples were boiled in hermetically sealed zip-lock bags immersed in water at 80°C for 40 minutes under cover. Measurements were made with a TA.XT plus Stable Micro Systems analyser. A Warner-Bratzler flat blade was used to measure the total force required to cut the sample (CF2) and Volodkevich bite jaws were used to measure the total force required to bite the sample (GF2).

Calculations were made using Statistica 10 software [28]. The statistical analysis included the arithmetic mean ($\bar{x}$) and standard deviation (SD). The significance of the differences between means was estimated by Student's t-test. Differences between parameters were considered to be highly statistically significant at $p \leq 0.01$ and statistically significant at $p \leq 0.05$.

Results and discussion

The average carcass weight of the organically reared chickens (710.2 g) was significantly ($p \leq 0.01$) lower than that of broiler chickens, which was 1,660 g (Table 2). The body weight of the chickens, and hence the carcass weight, depends mainly on nutritional and genetic factors [6, 16, 23]. The compound feed prepared according to organic farming criteria was poorer in terms of basic nutrients. Most of all, it contained less protein, on average by 2.09 pp, and less metabolic energy by 1.35 MJ (see Table 1). In addition, the chickens from group E, as a result eating feed of poorer nutritional value, consumed more energy for their living needs, using the greater available space in the henhouse and spending time on the runs. This is consistent with the idea of rearing in compliance the requirements of organic farming, which should meet the behavioural needs of animals to the fullest possible extent and take into account their wellbeing. The priority here is not to achieve a high body weight in the shortest possible time [13], as is the case with intensive fattening. Another important factor determining carcass weight is the selection of genetic material [7]. In the present study, the crossbreds in group E were reared according to the conditions of organic production [26] and as slow-growing birds their carcass weight was 57.2% lower than that of the Ross 308 broiler chickens (group K) at the completion of the rearing period.

Measurement of the hydrogen ion concentrations (Table 2) in the breast muscles 15 minutes after slaughter (pH_{15}) showed a relatively high level for both groups (E 6.67, K 6.55). The next pH measurement (pH_{24}) showed a decrease to 6.11 in group K, which is indicative of normal post-mortem glycogenolysis. This means that these muscles can be considered to be normal meat, as numerous studies have shown that the average pH_{24} values of chicken breast muscles are between 5.6 and 6.1 [10, 16]. On the other hand, the higher values obtained for the group E muscles, i.e. 6.48 for pH_{24}, indicate that the meat has DFD (dark, firm and dry) traits. At both measurement times, the pH of the breast muscles of groups E and K was significantly statistically different – at $p \leq 0.05$ at 15 minutes after slaughter and at $p \leq 0.01$ after 24 hours. The acidity of meat is an important indicator of meat quality, as it determines properties such water-holding capacity, tenderness and colour [1, 22]. Furthermore, low post-mortem acidity of breast muscles has been shown to be conducive to the growth of unfavourable microflora on the surface of the fillet. A pH of 6.4 is believed to be a critical value for the suitability of meat for storage [11].

Indicators of the technological quality of meat include its water-holding capacity (WHC) and cooking loss, which indicate the possible loss of meat mass through the loss of water during storage and processing [24]. Both parameters were more favourable in the case of the organically reared chickens (Table 2). The muscles had a significantly ($p \leq 0.05$) higher water-holding capacity (2.06 mg%) and lower ($p \leq 0.01$) cooking loss (by 14.17 pp) as compared to the muscles of the intensively reared crossbreds. Similar correlations were demonstrated by Pietrzak et al. [16]. The breast muscles of slow-growing chickens (Hubbard JA 957) were found to have a significantly ($p \leq 0.05$) higher water-holding capacity (6.8 cm^2/g) and at the same time lower cooking losses (16.2%) than fast-growing chickens (Hubbard Flex).

The pH results indicated that the breast muscles of the group E chickens may show traits of DFD meat. This was confirmed by the analysis of the colour components of these muscles (Table. 2), which revealed that the group E chickens had significantly ($p \leq 0.01$)

Table 2
Mean ($\bar{x}$) and standard deviation (SD) of selected quality traits of the breast muscle of chickens raised organically (group E) and intensively (group K)

Trait	Group E	Group K
	$\bar{x}$ ±SD	$\bar{x}$ ±SD
Carcass weight (g)	710.2^{A}±58.59	1660^{B}±32.00
Water holding capacity; WHC (mg%)	28.40^{a} ±3.72	30.46^{b} ±3.31
Cooking loss (%)	10.6^{A}±4.67	24.77^{B} ±9.95
pH_{15}	6.67^{a} ±0.28	6.55^{b} ±0.22
pH_{24}	6.48^{A} ± 0.21	6.11^{B} ±0.17
Colour components:		
L^{*}_{48}	49.65^{A} ±2.54	60.88^{B} ±2.57
a^{*}_{48}	7.08^{a} ±0.97	5.21^{b} ±0.93
b^{*}_{48}	9.44 ±1.05	9.28 ±1.07
Total protein content (%)	23.17^{a} ±1.31	21.44^{b}±1.18
Water content (%)	75.86 ±0.84	76.09 ±0.76
Crude fat content (%)	0.09^{A} ±0.01	0.55^{B} ±0.29
CF2 raw muscle (N)	54.12^{A} ±7.18	21.86^{B} ±6.11
CF2 cooked muscle (N)	$46,66^{A}$ ±7,43	23.14^{B} ±13.49
GF2 cooked muscle (N)	18.22^{A} ±5.36	9.95^{B} ±4.11

CF2 – force required to cut through sample
GF2 – force required to bite through sample
a, b – different lower-case letters in a row differ significantly p≤0.05
A, B – different capital letters in a row differ significantly p≤0.01

darker (L*=49.65) and more (p≤0.05) intensively red (a*=7.08) breast muscles than the group K chickens (L*=60.88, a*=5.21). A study of Polish consumer preferences showed that colour is the most important feature among visual determinants of meat of various animal species, influencing the choice of 89% of respondents [15]. The meat of organically reared chickens, having a darker colour similar to that of pork meat, satisfies consumer expectations. Chmiel et al. [3] demonstrated that pork classified as meat of normal quality (RFN - reddish-pink, firm, normal, non-exudative) was characterised by colour lightness L* of 49.8, and this colour component was the primary determinant of the quality assessment. The authors found no significant differences in the physical parameters a* and b* in different meat quality groups.

The breast muscles of the group E crossbreds had a high protein content of 23.17% and a low fat content of 0.09%. For the second group of chickens the corresponding values were 21.44% and 0.55%, respectively ($p \leq 0.01$). The differences in these chemical parameters were statistically significant at $p \leq 0.05$ for protein content and $p \leq 0.01$ for fat content. No differences were shown in the water content in the *m. pectoralis superficialis* of the two groups of chickens. The percentage of basic chemical constituents determines the culinary and technological value of meat. The meat of organically reared chickens, due to their low intramuscular fat content and high protein content, is suitable for the production of dietetic food. Augustyńska-Preisner and Sokołowicz [1] have shown that the amount of intramuscular fat influences the palatability and juiciness of broiler chicken meat.

Among the texture characteristics of meat measured instrumentally, tenderness/toughness seems to be the most important. The texture characteristics of raw meat depend on a number of factors during the life of the animal and after slaughter, such as species, breed, crossing scheme, sex, age, individual characteristics, housing or feeding systems, and anatomical location [3]. During curing and preparation of meat for consumption (usually by heating), thermal denaturation of proteins results in certain changes in the microstructure of the muscle fibres and connective tissue, which affects the texture of meat after heat treatment [1]. In our study, the force required to cut both raw and cooked muscles and to bite cooked muscles was twice as great (significant difference at $p \leq 0.01$) in the E chickens. The largest difference ($p \leq 0.01$) was found for the raw meat, as the force needed to cut completely through the sample was 54.12 N for the group E meat and 21.86 N for group K.

The study shows that the muscles of organic chickens have good nutritional value (more protein and less fat) and are darker in colour, which may be a desirable trait for many consumers. However, the high pH_{24} of the breast muscles of organically reared chickens indicates that the meat may be susceptible to microbial contamination and can only be stored for short periods. In addition, it requires more force to cut it, which may indicate that it should be cooked longer.

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