

## Comparison of Selected Quality Attributes of Chicken Meat as Affected by Rearing Systems

Monika Michalczuk\*, Monika Łukasiewicz, Żaneta Zdanowska-Sąsiadek, Jan Niemiec

Department of Poultry Breeding and Production, Faculty of Animal Science, Warsaw, Poland  
University of Life Sciences, ul. Ciszewskiego 8, 02–786 Warsaw, Poland

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The objective of this study was to establish the effect of rearing conditions of slowly-growing Hubbard JA 957 chickens on selected quality attributes of their meat. Birds from the control group (C) were kept on litter over the entire rearing period, whereas these from the experimental group (E) – with access to free range since the 4th week of life. The birds were slaughtered on day 63, and collected samples of breast muscles were assayed for proximate chemical composition, technological properties, and fatty acid profile in intramuscular fat. The study demonstrated no significant differences in the chemical composition of muscles depending on rearing systems. Meat of chickens using free range was characterized by higher shear force ( $P \leq 0.01$ ), which shows that it is tougher than the meat of chickens which do not use the free range. No significant differences were seen in physicochemical values when it comes to different systems of rearing. The access to free range has no influence on fatty acid formation either. The lack of significant differences indicates that the system of rearing has a minor effect on the quality of poultry meat.

### INTRODUCTION

Many consumers claim that products from ecological rearing are characterized by a higher nutritive quality and better taste [Midmore *et al.*, 2005; Andree *et al.*, 2010; Horsted *et al.*, 2010]. It was confirmed in a research by Fanatico *et al.* [2006], who was explaining higher sensory values of meat of chickens reared with the access to free range by a decrease of stress factor resulting from high birds density per area unit. Other authors [Horsted *et al.*, 2010] emphasize the significance of selecting appropriate birds to be suitable for alternative rearing systems. In the systems of less intensive production, the slow-growing birds prove well since their lower growth rate and lower body weight are factors facilitating better health status and lesser mortality [Fanatico *et al.*, 2008; Mikulski *et al.*, 2011]. In addition, it is worth emphasizing that in the unconventional rearing systems the birds are reared for a longer period of time, which allows their meat to attain desirable sensory values [Horsted *et al.*, 2012]. Consumers are searching for bioproducts originating from birds that are fed appropriately and allowed to use free ranges and satisfy their natural behaviors [Dawkins *et al.*, 2003; Aksoy *et al.*, 2010].

The quality of meat is determined by many factors estimated in the laboratory. However, consumers' opinion about meat's appearance plays important role as well [Florkowski *et al.*, 2002]. The feeding of poultry not only determines the basic parameters of production results and nutritive value, but

also significantly models the taste and odor of meat. One of the key aspects of the quality of food, including poultry meat, is its nutritive value. Poultry meat, breast muscles in particular, are characterized by high nutritive values. Consumers expect meat and meat products to show, most of all, appropriate flavor values, high nutritive value, low fat content but at the same time high concentrations of vitamins and minerals. The chemical composition of muscles is modified by genetic and environmental factors [Grabowski, 1993].

Consumers express an increasing interest in food products which they perceive as having been produced with natural methods and being environment friendly, that assure a high nutritive value, are characterized by good taste and are manufactured with respect for birds welfare [Fanatico *et al.*, 2007].

The objective of this research was to determine the impact of rearing system of slow-growing birds on selected quality traits of poultry meat.

### MATERIAL AND METHODS

The experiment was conducted at the experimental station of the Warsaw University of Life Sciences (RZD Wilanów – Obory) in the springtime of 2010. Experimental procedures were approved by the Ethical Commission (approval no. 27/2009 of the 16 April 2009). The experimental material were slowly-growing Hubbard JA – 957 chickens. The birds were reared in two systems: control group (C) kept on litter over the entire rearing period, whereas these from the experimental group (E) – with access to pasture since the 4<sup>th</sup> week of life. In both groups, stock density in a pen

\* Corresponding Author: Tel. + 48 22 5936555;  
E-mail: [monika\\_michalczuk@sggw.pl](mailto:monika_michalczuk@sggw.pl) (Dr. Monika Michalczuk)

reached 11 birds per m<sup>2</sup> of the experimental poultry house. Starting from the first week, weekly measurements were made of husbandry conditions in the facility the birds were reared in, including: in-house temperature, air relative humidity and concentration of gases (CO<sub>2</sub>, NH<sub>3</sub> and H<sub>2</sub>S). The chickens from the experimental group had, additionally, access to free range with sizes of 3x5m (2 birds/m<sup>2</sup>). The chickens were reared until 63 days of age, and fed in a three-stage system according to recommendations of the Hubbard company (starter 1 – 24 day, grower 25 – 42 day, and finisher 43 – 63 day of life). Table 1 presents the nutritive value of feed used in the study. The chickens using free ranges had also the possibility of ingesting green forage that included the following grasses: ryegrass (40%), red fescue (50%), and common meadow-grass (10%). The proximate composition and fatty acid composition of green forage were presented in Table 2.

On day 63 of birds life, 48 chickens from each group with body weights approximating the mean body weight in a group, were fasted for 12 h. The chickens were electrically stunned in a water bath (120 mA, 50 Hz) for 2 s. Next, they were slaughtered by the method of cutting the cervical blood vessels, and bled out for *ca.* 7–10 min. After scalding in water with a temperature of 56–58°C for *ca.* 60 s, the birds were manually plucked, eviscerated, and their carcasses were placed in a cold store at a temperature of 4°C for 24 h.

TABLE 1. Composition and nutritive value of basal diet in broiler feeding.

Item (%)	Starter (1–24)	Grower (25–42)	Finisher (43–63)
Maize	10.00	10.00	10.00
Wheat	49.56	53.76	60.26
Wheat middlings P 16	5.00	7.00	8.00
Sunflower meal	4.70	7.00	8.00
Soybean meal (46.5)	25.30	17.10	9.30
Limestone Ca39	1.00	1.10	0.87
Sodium bicarbonate	0.24	0.24	0.25
NaCl	0.24	0.21	0.22
Phosphate 2-Ca	1.31	0.96	0.74
Soybean oil	1.30	1.30	1.30
MHA Methionine 84%	0.32	0.28	0.19
Lysine	0.36	0.38	0.28
Threonine	0.12	0.12	0.04
Premix Rovimix DSM <sup>3</sup>	0.55	0.55	0.55
Nutritive value			
EM (kcal/kg)	2849	2857	2902
Total protein (%)	21.68	19.50	16.98
Crude fibre (%)	3.60	3.96	4.07
Crude fat (%)	3.00	3.03	3.04
Crude ash (%)	5.85	5.40	4.69

<sup>3</sup>Supplied the following per kg of feed: 11.000 IU vit A, 3.000 IU vit D<sub>3</sub>, 40 mg vit E, 2 mg vit K<sub>3</sub>, 2 mg vit B<sub>1</sub>, 7 mg vitB<sub>2</sub>, 4 mg vit B<sub>6</sub>, 0.02 mg vit B<sub>12</sub>, 70 mg niacin, 16 mg pantothenic acid, 1.5 mg folic acid, 400 mg choline, 0.2 mg biotin, 110 mg Mn, 80 mg Zn, 45 mg Fe, 20 mg Cu, 0.7 mg J, 0.3 mg Se.

TABLE 2. Chemical composition and fatty acid profile of grass (%).

Chemical composition	
Dry matter	24.79
Total protein	7.90
Crude fat	0.33
Crude ash	3.73
Crude fibre	9.34
Fatty acid profile	
SFA	33.25
MUFA	24.44
PUFA	42.31
PUFA <i>n</i> -3	27.27
PUFA <i>n</i> -6	15.04
PUFA <i>n</i> -6/ <i>n</i> -3	0.55

Afterwards, breast muscles were sampled and homogenized. One breast muscle was used directly for analyses of the chemical composition, physicochemical parameters and fatty acids profile, whereas the other one was divided into two parts – one was stored under refrigerating conditions at a temperature of -18°C for one week and the other for nine weeks in order to determine TBA.

### Chemical composition

Proximate chemical composition of meat was analyzed using standard procedures [AOAC, 1995]: water content – by drying at 105°C for 4 h; protein content – by Kjeldahl method; fat content – by Soxhlet extraction; and ash content – by combustion.

### Physical properties

The pH value of meat samples was assayed according to the Polish Standard [PN-ISO 2917:2001] with a CP-411 pH-meter (Elmetron, Zabrze, Poland), using a combined glass-calomel electrode. The electrode was calibrated against buffers of pH 4.0 and 7.0.

The breast muscle was disintegrated twice in a meat grinder with a hole diameter of 3 mm and thoroughly mixed to assure homogeneity of the sample. In thus prepared sample, pH value was measured.

Water holding capacity (WHC) was determined according to Grau & Hamm [1953], three replications of muscle were tested and the average value was taken as the result.

Color parameters (a\*, b\*, L\*) were analyzed with a Minolta CR-410 chroma meter using ground meat. Each measurement was carried out in five replications, taking their average value as the result. Parameter L\* (color brightness) can assume values from 0 to 100. Parameters a\* – redness and b\* – yellowness are tri-chromaticity coordinates. They can assume positive and negative values; +a\* corresponds to red, -a\* to green, +b\* to yellow, and -b\* to blue.

To determine cooking loss, breast muscles were weighed to the nearest 0.01 g (m<sub>1</sub>), and heated in a water bath at 90°C for about 30 min (until the internal temperature reached 75±2°C in the geometric center). Cooked meat was cooled at room temperature for about 1 h and moved to a cold store

room (4–6°C) for 24 h, after which it was weighed again ( $m_2$ ). Cooking loss (%) was calculated using the formula:

$$\text{Cooking loss} = [(m_1 - m_2) : m_1] \times 100$$

Shear force was measured with the tensile tester ZWICK 1120 using a Warner-Bratzler blade. Maximum shear force ( $F_{\text{max}}$ ) was measured at a cross-head speed of 50 mm/min. The meat sample was cut perpendicular to the muscle fibres. The test was finished when shear force after cutting the sample decreased to 75% of maximum force. Shear force was measured in five replications and their average value was taken as the result. The samples to be tested were prepared by excising cuboids (1 cm × 1 cm × approx. 5 cm) from the previously cooked breast muscles along the fibers.

Fatty acid profile was determined according to the Polish Standard [PN-EN ISO 5509:2001]. Fatty acids were separated using a gas chromatograph (Hewlett Packard 6890 Series GC System) with a FID detector and a capillary column BPX 70 (50 m × 0.25 mm × 0.25 μm film) by SGE Inc. Austin. Injection temperature was 220°C, column temperature was programmed to 1 min at 140°C, 1.5 min at 140/210°C, and 8 min at 210°C, and the samples were injected using the split ratio of 30:1. Helium was used as a carrier gas. Chromatograms were compared with Sigma standards, and fatty acid content was expressed as percentage in relation to the total amount of fatty acids determined.

TBA in breast muscles was determined twice: after the first week of meat storage under freezing conditions at a temperature of -18°C and after 9 weeks. TBA was determined by the extraction method according to Shahidi [1990], which involved measuring the absorbance of color solution, the color of which developed as a result of reaction between fat oxidation products (mainly malondialdehyde) and 2-thiobarbituric acid (TBA). Approximately 2 g of ground meat was weighed into a centrifuge tube to the nearest 0.01 g, to which 5 mL of 10% trichloroacetic acid was added and triturated for 2 min with a glass rod. Next, 5 mL of 0.02 molar TBA solution was added, the sample was triturated again for 2 min and centrifuged for 10 min at 4,000 rpm. After centrifugation, the solution was filtered into a glass tube and after the opening was sealed with polythene sheeting, the color was developed for 24 h at room temperature. After this time, samples were collected for colorimetric determination. The absorbance was measured using a Hitachi U-1100 spectrophotometer at 532 nm against reagent blank. The reagent blank was prepared by adding 5 mL of 10% trichloroacetic acid and 5 mL of 0.02 molar TBA solution to a glass tube. The determination result was expressed as absorbance units per g of fat sample.

### Statistical analysis

The results were analyzed statistically by one-way analysis of variance using SPSS 19.0 PL for Windows [SPSS, 2010].

## RESULTS AND DISCUSSION

### Chemical composition

An important parameter determining meat quality is its proximate chemical composition (Table 3). Irrespective

TABLE 3. Chemical composition of chicken breast muscles depending on the type of rearing system (%).

Item	Outdoor	SE	Indoor	SE
Dry matter	25.47	0.081	25.60	0.080
Total protein	23.22	0.067	23.24	0.086
Crude fat	0.96	0.089	1.16	0.082
Crude ash	1.08	0.025	1.05	0.023

of the rearing system, dry matter content of breast muscles was at a level of 25%. Analyses showed also very equalized contents of protein (*ca.* 23%) and crude ash (*ca.* 1%). The study did not demonstrate any significant effect of the rearing system on fat level in muscles. Similar findings were reported in many other works [Fanatico *et al.*, 2007; Dou *et al.*, 2009; Wang *et al.*, 2009]. The lack of differences and very high stability of the chemical composition of breast muscles point to a minor effect of rearing systems on changes in these parameters [Bogosavljevic-Boskovic *et al.*, 2010]. According to investigations by Gornowicz [2008] and Gornowicz & Pietrzak [2008], the factor inducing the greatest differences in the chemical composition of muscles is genotype.

### Physicochemical properties

The physical properties describe the quality of poultry meat and determine its usability for processing [Czaja & Gornowicz, 2004]. Results of measurements of the physicochemical properties of breast muscles depending on the rearing system were presented in Table 4.

The parameter being a direct indicator of meat quality is active acidity (pH). In the conducted experiment, a higher pH value was assayed in the muscles of birds using free range, however differences were not significant ( $p \geq 0.05$ ). In the case of breast muscles, the pH value of 5.8 indicates the proper acidity and fits within the range of values corresponding to quality standards for non-defective meat. The rate of pH decrease depends on glycogen reserves in muscles. Only sufficiently high reserves assure the proper course of meat maturation and pH decrease. Many studies confirm the impact of growth rate of poultry on the final level of pH [Fernandez

TABLE 4. Selected quality traits of breast muscles of chickens depending on the type of rearing system.

Item	Outdoor	SE	Indoor	SE
pH	5.80	0.020	5.77	0.007
Cooking loss (%)	19.98	0.409	20.22	0.372
WHC (cm <sup>2</sup> /g)	10.94	0.428	10.43	0.446
Shear force (N)	28.95 <sup>A</sup>	0.369	26.64 <sup>B</sup>	0.577
Colour parameters				
L*	54.48	0.749	53.78	0.431
a*	0.53	0.116	0.56	0.106
b*	8.99	0.236	9.00	0.170
TBA <sub>1 week</sub>	0.036 <sup>a</sup>	0.005	0.023 <sup>b</sup>	0.004
TBA <sub>9 week</sub>	0.041 <sup>a</sup>	0.005	0.033 <sup>b</sup>	0.005

A, B – means with different superscripts differ significantly at  $P \leq 0.01$ ; a,b – means with different superscripts differ significantly at  $P \leq 0.05$ .

*et al.*, 2001; Berri *et al.*, 2005]. Authors determined a higher level of glycogen reserves in muscles of slowly-growing birds, hence a lower *post-mortem* pH value was observed in these birds. The effect of the rearing system on the level of active acidity of meat was, however, not confirmed [Dou *et al.*, 2009; Wang *et al.*, 2009].

An important factor that may have adverse effects on sensory perception by consumers is cooking loss which indicates the quantity of meat juices lost during thermal treatment. The high value of cooking loss may intensify the sensation of a lack of juiciness or even dryness of meat, which significantly affects the overall sensory acceptability of meat. In the conducted experiment, insignificantly higher losses upon heat treatment were observed in muscles of the chickens reared with no access to free range (Table 4). Fanatico *et al.* [2005] observed an opposite tendency. They determined a higher cooking loss from breast muscles of slow-growing chickens that were using free range, compared to the birds reared only indoors. In addition, these authors emphasize that the discussed parameter is significantly affected by genotype. According to Fanatico *et al.* [2005], breast muscles of slow-growing birds are characterized by higher cooking loss than those of the fast-growing ones, which was also confirmed in a research by Debut *et al.* [2003].

A significant physicochemical parameter is water ability to bind with meat. A high water holding capacity (WHC) value can positively influence meat juiciness. The lack of significant differences in the discussed parameter shows that the system of rearing has a limited influence. This may result in the lack of differences in sensory assessment of meat from different rearing systems.

Wang *et al.* [2009] observed a similar tendency as that reported in our study. They also did not confirm statistical significance of their results ( $P > 0.05$ ). Opposite results were described by Castellini *et al.* [2002] who noted a significantly lower WHC in muscles of chickens allowed to use free ranges.

The sensory evaluation of meat is also directly influenced by tenderness. Under laboratory conditions, it is determined by measurement of shear force. In the conducted experiment, a higher ( $p \leq 0.01$ ) shear force of breast muscles was assayed in the chickens using free range (Table 4).

Another criterion of meat quality perceptible by consumers is meat color. Consumers assess freshness and often also quality of meat by visual impression. In this study, no effect was found of the rearing system of birds on color parameters of their breast muscles (Table 4).

Meat color is one of the key parameters to consumers as it indicates product's quality. It is determined mainly by genetic factors and is linked with the synthesis of melanin in skin and epidermis [Fletcher *et al.*, 2000]. Ponte *et al.* [2008] demonstrated that chickens using free ranges were characterized by a brighter color of meat and a higher contribution of yellow color in muscles, which according to those authors is due to the content of natural carotenoids in green forage ingested by the birds using free ranges. Fanatico *et al.* [2007] claim meat color to be one of the most significant criteria of carcass selection at purchase. The rearing system may, therefore, affect the physical parameters of muscles, but may also significantly affect consumers' choice preferences.

Owing to the frequent use of cold and freeze storage of meat products, it is important to determine processes of transformations that may proceed during storage. Of key significance in determining the quality of long-stored products is lipids oxidation. A higher value of TBA was reported in breast muscles of chickens using free ranges both after one week and nine weeks of meat storage under freezing conditions ( $-18^{\circ}\text{C}$ ), (Table 4).

Oxidation of meat lipids proceeding during its storage, processing, heating and further storage is one of the main processes leading to quality deterioration or even spoilage. Lipids oxidation results in the synthesis of compounds like low molecular weight volatile substances such as aldehydes, that are responsible for the generation of rancid, undesirable taste and aroma, that are unacceptable to consumers [Skolimowska *et al.*, 2009].

Apart from taste and aroma deterioration, the oxidation of fatty acids has an adverse effect on the color, texture and nutritive value of meat [Hugo *et al.*, 2009].

A higher TBA value in chickens using free ranges was noted by Castellini *et al.* [2002]. It results from birds' diet supplementation with green forage that is a rich source of unsaturated fatty acids, linolenic acid in particular, which in turn leads to increasing concentrations of polyenoic fatty acids in meat, thus increasing its susceptibility to oxidation. Processes of oxidative rancidification in meat and meat products may be effectively controlled and minimized by the application of both natural and synthetic compounds with antioxidative properties [Botsoglou *et al.*, 2004; Smet *et al.*, 2008; Marcinčák *et al.*, 2011; Miezeliene *et al.*, 2011].

### Fatty acid profile

The rearing of chickens under various conditions, *i.e.* with and without access to free range, had a significant effect on fatty acid profile in fat of their breast muscles (Table 5). The analysis of the fatty acid composition of lipids of chicken breast muscles demonstrated that the percentage content of monoenoic fatty acids (MUFAs) was significantly higher and that of polyenoic fatty acids (PUFAs) was lower.

The study showed also a slightly lower *n-6:n-3* ratio in the group of birds allowed to use free range, it was however not confirmed statistically (Table 5).

When analyzing the quality of poultry meat and fat, Pietrzak *et al.* [2006] demonstrated a significantly higher content of monoenoic fatty acids (MUFAs) than of the polyenoic ones (PUFAs). Generally, poultry fat is characterized by more desirable composition than other animal fats, which facilitates its absorption in the body. It contains *ca.* 60–70% of polyunsaturated fatty acids. In turn, the MUFAs (the level of which in poultry meat reaches *ca.* 45–50% [Diaw *et al.*, 2010] includ-

TABLE 5. Fatty acid profile in chicken breast muscle depending on the type of rearing system (g/100 g).

Item	SFA	MUFA	PUFA	PUFA <i>n-3</i>	PUFA <i>n-6</i>	PUFA <i>n-6/n-3</i>
Outdoor	31.28	44.83	23.90	2.54	21.36	8.40
Indoor	31.56	44.68	23.75	2.24	21.51	9.60
SE	0.38	0.63	0.60	0.05	0.56	0.28

ing *e.g.* oleic acid, are desirable from the dietetic point of view. Poultry may synthesize saturated and monoenoic fatty acids from non-fat feed mixtures. These include mainly: palmitic, stearic, palmitoleic and oleic acids. In contrast, polyenoic acids like linoleic acid (*n*-6) and linolenic acid (*n*-3) are not synthesized by poultry and ought to be provided to birds with feed mixtures.

A high content of polyenoic fatty acids in poultry meat and fat increases its nutritive value compared to pork or beef. Compared to these meats, poultry meat is characterized by a lower calorific value as it contains less fat which is rich in unsaturated fatty acids [Grześkowiak *et al.*, 2001]. Especially significant are *n*-3 PUFAs. It has been demonstrated that their daily intake at a level of 0.3–1.0 g in a man's diet protects against ischemic heart disease. In addition, they exhibit therapeutic and prophylactic effects on such diseases as arthritis as well as breast and pancreas cancers [Lopez-Ferrer *et al.*, 2001]. According to Koreleski [2002], in a man's diet the ratio of unsaturated to saturated fatty acids should be reached at least 1, and the *n*-6:*n*-3 ratio should not exceed 10.

It ought to be emphasized that the high level of unsaturated fatty acids in poultry fat may have adverse effects on its stability. Rapid oxidative changes of lipids and the resultant oxidation products may deteriorate the quality of poultry meat and meat products and considerably shorten their shelf-life [Pikul, 1996].

## SUMMARY

The conducted study showed that the rearing system does not affect the proximate chemical composition and physicochemical properties of breast muscles. The access to free range did not have any influence on fatty acids profile formation. The lack of significant differences in the examined parameters can indicate that the rearing system has a minor importance when it comes to the quality of poultry meat. The analyses determined the quality of meat but only in terms of laboratory measurements. Summary of the received results and sensory analysis of meat could fully determine its quality and consumer acceptability.

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