Application of the support sensory system and principal component analysis to compare meat of chickens of two genotypes

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**ABSTRACT**
Sensory quality of roasted breast muscles of two genotypes of chickens kept for 9 weeks of life in an outdoor or indoor system was tested by Quantitative Descriptive Analysis (QDA). After roasting in a convective-steam oven, 72 individual pectoral muscles of cocks (36 from each genetic group, 18 from outdoor and 18 from indoor system) were subjected to the sensory evaluation. There was a significant effect of genotype on fat odor (fatty flavor, *P* = 0.007), color (*P* = 0.007), and texture parameters: juiciness (*P* = 0.046) and greasy feel (*P* = 0.027). The rearing system had a significant effect only on meat juiciness (*P* = 0.015). Significant genotype × rearing system interactions were found for juiciness (*P* = 0.015) and different taste (*P* = 0.05). Principal component analysis showed distinct differences in the sensory traits of roasted breast muscle of two chicken genotypes produced in different rearing systems.

**RESUMEN**
El presente estudio utilizó el análisis cuantitativo descriptivo (QDA) para evaluar la calidad sensorial de músculos de pechuga asados provenientes de pollos de dos genotipos, los cuales fueron criados durante nueve semanas en sistemas exteriores e interiores. Después de asar 72 músculos pectorales de gallos (36 de cada grupo genético, 18 provenientes del sistema exterior y 18 del sistema interior) en un horno de vapor con convección, se los sometió a una evaluación sensorial. El genotipo produjo un efecto significativo en el olor a grasa (sabor graso, *P* = 0.007), el color (*P* = 0.007) y los parámetros de textura: jugosidad (*P* = 0.046) y sensación grasosa (*P* = 0.027), mientras que el sistema de cría solo incidió significativamente en la jugosidad de la carne (*P* = 0.015). Asimismo, se comprobó la existencia de interacciones significativas entre el genotipo y el sistema de cría para la jugosidad (*P* = 0.015) y gustos diferenciados (*P* = 0.05). El análisis de componentes principales (PCA) dio cuenta de diferencias claras en los rasgos sensoriales de músculo de pechuga asado proveniente de dos genotipos de pollos producidos en diferentes sistemas de cría.

**Introduction**
The nutritional value of poultry meat, its high protein content, and low fat content as well as its flavor make it attractive to consumers, who increasingly declare their preference for meat of chickens that have been produced in the system taking the greatest possible care of birds’ welfare (Damaziak, Michalczuk, & Kurek, 2012; Marcinkowska-Lesiak et al., 2016; Michalczuk, Łukasiewicz, Zdanowska-Sasiadek, & Niemiec, 2014; Popova, Ignatova, Petkov, & Stanić, 2016; Puchala, Krawczyk, Sokolowicz, & Utnik-Banaś, 2015). Studies have shown that more than half of Britons polled assessed the animals’ welfare as very important, and more than 70% of the surveyed citizens of the United States reported concern about the welfare of farm animals (Norwood & Lusk, 2011). Also, a survey of German consumers showed that 56% of the respondents were interested in the welfare of birds, and 82% of them would pay a higher price for products coming from less intensive production (Makdisi & Marggraf, 2011). However, the study of Hall and Sandilands (2007) showed that most consumers had no knowledge about methods of broiler chickens production, and only a few paid attention to the specific factors, e.g. 40% of the respondents were aware of stocking density of birds.

The sensory properties of meat are affected by many factors: the genetic origin of birds (Michalczuk, Damaziak, & Goryl, 2016), the production system (Michalczuk et al., 2014), the age at slaughter (Poltowicz & Doktor, 2012), and animal nutrition (Al-Marzooqi, Al-Farsi, Kadim, Mahgoub, & Goddard, 2010; Zdunczyk & Jankowski, 2013). Most of these studies involved the comparison of meat quality of slow- and fast-growing chickens considering the structure of their pectoral muscles. Previously conducted studies showed that differences between the slow- and fast-growing chickens differ (Horsted, Allesen-Holm, Hermansen, & Kongsted, 2012), especially in terms of their meat texture. The duration of birds rearing is determined by their rapid growth rate. Overgrowth of the connective tissue, which may affect meat tenderness, is typical of the fast-growing birds. With age, their meat is characterized by more intense aroma and...
flavor, as flavor precursors are deposited in muscles (Fanatico et al., 2007).

Palatability of meat is a combination of two sensory experiences: taste and smell (Augustyńska-Prejsnar, Ormian, & Gajdek, 2014). It has been observed that consumers perceive pectoral muscles from fast-growing birds as being more salty than those derived from the slow-growing birds. Consumers found that meat from the medium-growing genotype was more tender than meat from the fast-growing genotypes and that meat of birds raised with outdoor access was less tender than of those raised indoors (Fanatico et al., 2006). Many consumers prefer to buy products from chickens raised outdoors (free range) because they believe that these products have superior sensory qualities or, in other words, taste better (Yang et al., 2015).

The effect of indoor rearing of poultry (Ying, Chenglong, Wang, & Fuyou, 2017) on the sensory quality of their pectoral muscles is well known. The outdoor system became popular in most European countries. On the Polish market, there is only one genotype of medium-growing chickens – Hubbard JA 957 – that is most frequently used for the outdoor production. This fact highly curbs the development of less intensive production, and therefore researchers are in a constant search for new genetic material characterized by health-promoting meat properties. The aim of this study was to evaluate the sensory quality of roasted pectoral muscles of cocks of different genotypes kept in two rearing systems by employing the QDA methods.

Material and methods
All procedures were performed according to the guiding principles for the care and use of research animals and were approved by the Local Ethics Commission.

Birds and their treatment
The experiment was conducted with slow-growing experimental line (E) chickens: the second generation of crossing Polish native Greenleg Partridge and fast-growing commercial chickens (2015; Batkowska, Brodacki, Knaga, & Florek, 2014) and medium-growing Hubbard JA957 (H) chickens. The study was conducted on 480 cocks (240 slow- and 240 medium-growing chicks) which were reared for 9 weeks of life. Birds in each genotype were divided into two groups and kept in two rearing systems: indoor (I) and outdoor (O). The four treatments consisted of slow-growing birds provided outdoor access (EO), slow-growing birds that were confined indoors (EI), medium-growing birds provided outdoor access (HO), and medium-growing birds that were confined indoors (HI). Birds in all treatments were kept in three replicate pens (40 chickens each).

Outdoor chicken groups (HO and EO) had access to free range from the fourth week of life. All birds were fed ad libitum with wheat–corn–soy-based diets. At 9 weeks of age, 18 cocks (6 per pen) with an average body weight of the group were selected from each treatment and slaughtered. The carcasses (72 pieces) were cooled at 4°C for 12 h and transported to the laboratory where dissection was performed (24 h after slaughter), and breast muscle samples were collected for further analyses (Michalczuk, Jóźwik, et al., 2016).

Methods of sensory testing
Preparation of raw materials
After cooling, the carcasses were portioned. The right pectoral muscle was separated, then packed in a labelled bag and refrigerated for 24 h. Fresh pectoral muscles (48 h after slaughter) after heat treatment were subjected to sensory analysis.

Preparation and presentation of individual samples
The pectoral whole muscles were roasted in the CPE-110 convective-steam oven (Küppersbusch, Germany) at 180 ± 2°C. The heat treatment was carried out until reaching a temperature of 75 ± 1°C in the geometric center of the muscle. The temperature of the heat treatment was monitored by an electronic thermometer.

Individual samples of pectoral muscles (~20 g each) were placed in coded plastic boxes (250 mL) closed with a lid. The sensory evaluation of the samples was conducted at ~45°C. To purge the palate of sample residues, each panelist was provided with water between tastings. Sets of samples for each evaluation were individually coded and presented in a random order to avoid the so-called carry-over effect.

Analytical profile evaluation
Sensory evaluation was performed in an accredited Sensory Analysis Laboratory operating under Food Evaluation and Diagnostics Health Sciences Department, Faculty of Human Nutrition and Consumption, WULS-SGGW, which is a member of the European Sensory Network. The laboratory meets all requirements of ISO 8589 standard (ISO, 2010a).

A computerized support system for sensory analysis ANALSENS NT was used to plan evaluation sessions, to generate random numbers to code the samples, to record individual results, and to pre-process them.

Detailed sensory assessment of pectoral muscle samples was carried out by Quantitative Descriptive Analysis (QDA) according to Stone and Sidel (1985), using the analytical procedure described in ISO standard 13299 (ISO, 2010b).

Under this procedure, in the preliminary proceedings, the panelists were acquainted with samples and determined individually the attributes of meat color, aroma, texture, and taste; in order to achieve uniformity of their understanding by all evaluators, to adjust their terminology and definitions as well as to conduct preliminary assessment sessions. The list of traits, their definitions, and the relevant boundaries determining the linear scale are shown in Table 1.

A continuous non-structured 10-cm long scale with the left end corresponding to the lowest intensity (value 0) and the right end to the highest intensity (value 10) of the evaluated sensory trait was used. Moreover, the overall sensory quality was assessed as not harmonized (value 0) and very harmonized (value 10). Sensory evaluation of meat was carried out according to ISO 8586-2 standard (ISO, 2008) by nine qualified panelists having relevant methodological preparation (theoretical and practical) on sensory methods and extensive experience in carrying out evaluations by QDA.

Each sample was analyzed in two independent replicates; the basis of the average results was 18 individual ratings.
Table 1. Sensory properties of pectoral muscle and their definitions.

| Sensory properties | Definition | Boundary determinants |
|--------------------|------------|-----------------------|
| **Aroma**          |            |                       |
| Chickeny flavor    | Aroma characteristic for roasted poultry meat | Imperceptible–very intense |
| Poultry flavor     | Characteristic for cooked poultry meat | Imperceptible–very intense |
| Fatty flavor       | Characteristic for animal (poultry) fat | Imperceptible–very intense |
| Liver flavor       | Characteristic for heat-treated animal liver | Imperceptible–very intense |
| Other flavor       | Aroma different than the other characteristics | Imperceptible–very intense |
| **Texture**        |            |                       |
| Softness           | Degree of softness, resistance of the sample at biting, and grinding the sample in the mouth | Hard–soft |
| Fibrosity          | Presence of fibers, difficulty in biting | Low–high |
| Juiciness          | The impression of meat juice during chewing | Dry–juicy |
| Greasy feel        | Characteristic for fatty poultry meat | Low–high |
| **Taste**          |            |                       |
| Toasted flavor     | Taste characteristic for roasted poultry meat | Imperceptible–very intense |
| Taste of poultry meat | Taste characteristic for cooked poultry meat | Imperceptible–very intense |
| Sour taste         | Basic taste, does not require definition | Imperceptible–very intense |
| Salty taste        | Basic taste, does not require definition | Imperceptible–very intense |
| Diffuse taste      | Taste different than those differentiators | Imperceptible–very intense |
| **Overall meat quality** | Sensory overall impression based on all quality parameters, their intensity, and harmonization | Low–high |

**Statistical analysis**

The results were then subjected to the two-way analysis of variance with genotype and rearing system treated as fixed effects. Treatment means were separated by Fisher’s protected least significant differences (NIR). The verification was carried out at a significance level of $P < 0.05$. Principal component analysis (PCA) was used to summarize correlations in sensory properties of roasted pectoral muscle between two different genotypes of cocks and two rearing systems. Calculations were performed in Statistica ver. 10 software (StatSoft Polska Sp. z o.o., Krakow, Poland).

**Results and discussion**

Sensory properties of the roasted pectoral muscles of cocks are summarized in Table 2. The highest point score for odor characteristic of roasted poultry meat (chickeny flavor) and statistically the lowest score for odor characteristic of poultry fat (fatty flavor) were given to the roasted pectoral muscles derived from HO cocks. At the same time, pectoral muscles derived from HO roosters received the lowest scores for the color, which means that the roasted meat was characterized by the brightest color (Figure 1). Color is one of the most important quality attributes of poultry meat, being of great significance to consumers. It is also an important indicator of the technological usability of meat as a raw material which may be intended either for direct sale or for further processing (Michalczuk et al., 2014). Genotype significantly affected the color of roasted muscles (Table 2). The resulting correlations are different from those described by Laszczyk-Legendre (1999), who showed that the greater juiciness as well as darker and more intense flavor were typical of meat from birds from the free-range system (Label Rouge). Pectoral muscles of E1 cocks were characterized by a better texture and the highest scores for juiciness (Table 2). In the sensory analysis, juiciness is defined as the presence of a meat juice during sample chewing, whereas greasy feel (texture characteristic for fat poultry meat) depends significantly on the genotype of birds.

In the case of juiciness, an interaction was also found between the genotype and the rearing system of birds (Table 2). Texture is one of the key attributes of the sensory quality of meat. It is determined by fiber structure of meat used and the processes (events) occurring during processing, as well as by contents of fat and water. In the case of

Table 2. Influence of genotype (G) and production system (PS) on the sensory properties of roasted breast muscles.

| Sensory properties | Hubbard JA 957 | Experimental line | Genotype | Production System | Interaction Genotype x Production System | $P$ values |
|--------------------|----------------|------------------|----------|-------------------|----------------------------------------|------------|
| Chickery flavor    | 4.6            | 5.2              | 4.8      | 4.9               | 0.99                                  | 0.537      |
| Poultry flavor     | 4.7            | 5.0              | 5.2      | 4.9               | 1.68                                  | 0.565      |
| Fatty flavor       | 1.1            | 0.9              | 1.6      | 1.3               | 0.47                                  | 0.007*     |
| Liver flavor       | 0.2            | 0.1              | 0.2      | 0.3               | 0.06                                  | 0.095      |
| Other flavor       | 0.2            | 0.1              | 0.1      | 0.1               | 0.07                                  | 0.608      |
| Color              | 1.9            | 1.6              | 2.2      | 2.0               | 0.36                                  | 0.007*     |
| Softness           | 6.1            | 6.3              | 6.2      | 6.3               | 0.58                                  | 0.892      |
| Fibrosity          | 2.9            | 3.0              | 3.2      | 3.3               | 1.18                                  | 0.222      |
| Juiciness          | 2.6            | 3.1              | 3.7      | 3.0               | 1.06                                  | 0.046*     |
| Greasy feel        | 0.9            | 0.9              | 1.4      | 1.1               | 0.54                                  | 0.027*     |
| Toasted flavor     | 4.2            | 4.2              | 4.1      | 4.1               | 1.30                                  | 0.767      |
| Taste of poultry meat | 5.1            | 5.4              | 5.7      | 5.1               | 1.34                                  | 0.617      |
| Sour taste         | 0.6            | 0.4              | 0.7      | 0.5               | 0.28                                  | 0.537      |
| Salty taste        | 0.8            | 1.1              | 1.1      | 0.9               | 0.28                                  | 0.459      |
| Different taste    | 0.1            | 0.1              | 0.1      | 0.4               | 0.11                                  | 0.141      |
| Overall meat quality | 6.3            | 6.5              | 6.5      | 6.4               | 0.61                                  | 0.816      |

*P values < 0.05 for difference in mean score.
turkeys, it has been proved that conditions of their rearing may affect the quality of the produced slaughter material. As reported by Damaziak et al. (2016, 2017), muscles of turkeys produced in the free-range system had heavier vascularization, a higher content of connective tissue, and a higher content of glycoprotein post-slaughter.

According to Fanatico, Cavitt, Pillai, Emmert, and Owens (2005), pectoral muscle of slow-growing birds is smaller and thinner as compared with the pectoral muscle of commercial broiler chickens. Probably, the greater juiciness and greasy feel of pectoral muscles of the El cocks observed in this study could also be caused by muscle structure. EO pectoral muscles stand out thanks to a noticeable, intense different taste. No effect of genotype on the taste of the pectoral muscles was noticed in the study. Among the analyzed sensory attributes of roasted pectoral muscles, the genotype of cocks significantly affected the fatty flavor ($P = 0.007$), color ($P = 0.007$), juiciness ($P = 0.046$), and greasy feel ($P = 0.027$), while the rearing system influenced only the different taste ($P = 0.049$) (Table 2).

Similar results were demonstrated by Puchala et al. (2015) in their work on the use of different genotypes for the free-range production. In the sensory assessment, the taste panel tended to give higher scores to the meat and broth from hens reared with free-range access (especially with regard to flavor). However, interactions were found between the genotype and the rearing system and their impact on the sensory quality of the roasted pectoral muscles for texture discriminant: juiciness ($P = 0.015$) and different taste ($P = 0.050$) (Table 2).

The data presented in Figure 1 were analyzed statistically using the PCA to select the most important sensory characteristics affecting the perception of the quality of the investigated pectoral muscles of cocks. The sensory quality of the tested pectoral muscles can be described by two components PC1 and PC2. The two main components (PC1 and PC2) together explained about 75% of the variability (Figure 1). The first component PC1 explained 44.8% of the sensory variability of roasted breast muscle of cocks and was created by such descriptors as follows: the aroma of chicken (poultry flavor), juiciness, the feeling of greasiness (greasy feel), toasted flavor, salty taste, and overall meat quality.

The second component (PC2) explained 30.0% of the variability and was created by the following descriptors: chickeny flavor, fatty flavor, color, softness, and sour taste (Figure 1). There were correlations between the scores given to the particular sensory traits and overall meat quality. According to Szterk and Jesionkowska (2015), the overall quality expressed by sensory descriptors is very useful for rapid and objective assessment of meat quality.

The PCA analysis showed that roasted pectoral muscle of cocks, an important role was played by aroma and flavor characteristic for roasted and cooked poultry meat, its color, and texture.

Placing samples on PCA biplot showed that the sensory quality of the roasted breast muscles differed between cocks of genotype H and E from the maintenance system outdoor and indoor (Figure 1).

Both the production system and genotype of birds affected the sensory quality of breast muscle samples of cocks (Figure 1). However, the samples of breast muscles of cocks from the indoor system El and Hi had various PC1, but the same PC2. This indicates that they differed in chickeny (poultry flavor), juiciness, the feeling of greasiness (greasy feel), toasted flavor, salty taste, and overall meat quality. In turn, these samples did not differ in chickeny flavor, fatty flavor, color, softness, and sour taste. Roasted Hi pectoral muscles were characterized by a weakly perceptible odor and taste of poultry meat and wereless juicy than El and EO.

In the case of the outdoor system, the EO and HO samples differed in both their PC1 and PC2, which proves a greater role and effect of the genotype on sensory quality of breast muscles of cocks produced in the outdoor than in the indoor system (Figure 1).

Conclusion
The use of QDA can be useful for the sensory comparative analysis of meat of chicken with different growth rates and from different rearing systems.

The results showed the impact of the genetic line of chickens on odor descriptors of poultry fat, color, and textural features such as juiciness and greasy feel of roasted pectoral muscles. The housing system had a significant effect only on meat juiciness. Interactions were found between genotype and the production system of cocks and their effect on juiciness was confirmed.

PCA showed that in sensory evaluation of roasted pectoral muscle of cocks, the most important are the aroma and flavor being characteristic for roasted and cooked poultry meat, as well as its color and texture. The correlations between overall quality and the aroma of poultry meat (chicken flavor), its color, and salty taste confirm that the overall meat quality descriptors can be used for quick assessment of the sensory quality of roasted chicken breast muscles.

Disclosure statement
No potential conflict of interest was reported by the authors.
Funding
Research was realized within the project ‘BIOFOOD – Innovative, functional products of animal origin’ no. POIG.01.01.02-14-090/09 co-financed by the European Union from the European Regional Development Fund within the Innovative Economy Operational Programme 2007 – 2013; BIOFOOD (Innovative, functional products of animal origin);

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