Animal Science Papers and Reports vol. 29 (2011), no. 2, 139-149
Institute of Genetics and Animal Breeding, Jastrzębiec, Poland

Effect of free-range raising on performance, carcass attributes and meat quality of broiler chickens

Katarzyna Połtowicz*, Joanna Doktor

National Research Institute of Animal Production,
Krakowska 1, 32-083 Balice, Poland

(Received November 19, 2009; accepted January 26, 2011)

The aim of the study was to determine the effect of free-range raising system on production results and carcass and meat quality of broiler chickens aged 42 days, using fast growing Ross 308 line. Day-old chicks were randomly assigned to two groups, 120 birds in each. Group I throughout rearing remained indoors on deep litter while Group II was kept at free range. Production results, carcass quality, physico-chemical traits of breast and leg muscles (pH_{15min} and pH_{24h}, L*a*b* colour space, water-holding capacity, drip loss, thermal loss, and shear force) were determined. Housing system affected the rearing performance of birds. Higher body weight and lower mortality were characteristic of Group I. Rearing system had no effect on dressing percentage, carcass colour and carcass quality. The majority of physico-chemical parameters of breast and leg muscles were similar in both groups.

KEY WORDS: broiler chickens / carcass / free-range / meat quality

Animal welfare is increasingly viewed as a factor affecting the quality of animal products while being an important tool of marketing strategy. The management system used in highly productive farms is often subjected to harsh criticism, one of the reasons being its failure to provide adequate welfare. In many countries, this attitude has led to the development of poultry meat production under less intensive rearing conditions. Currently, there is rapidly growing interest in the potential of specific foods to influence various aspects of the psychological state and well-being. A survey of American consumers showed that they purchase organic foods because of the

*Corresponding author: poltowicz@izoo.krakow.pl

production method [Onyango *et al.* 2006]. Furthermore, consumers believe that the meat of free-range chickens is healthier than that of birds kept in a poultry house only [Fanatico *et al.* 2006]. It is also believed that "natural", less intensive management systems provide chickens with higher welfare levels, resulting in much better product quality [Pavlovski *et al.* 2009]. However, the evaluation of overall welfare is very difficult. In pigs, alternative housing systems allow them to display species-specific behaviour and decrease the occurrence of abnormal behaviours [Millet *et al.* 2005]. Some research findings have also shown improved welfare in chickens having access to free range. This is reflected in the behaviour of free-range chickens, which more often express their natural instincts compared to confined birds [Sosnówka-Czajka *et al.* 2007]. As a result, systems and technologies that ensure access to free range, low stocking density, and natural lighting are attractive increasing interest among poultry producers and consumers. Alternative poultry meat production has been long popular in Europe and the French Label Rouge programme, which requires outdoor access, has gained the widest recognition [Fanatico *et al.* 2005a]. According to Castellini *et al*. [2002b] and Jahan *et al*. [2004] more natural rearing conditions and increased activity of the birds contribute to the lower lipid content in broiler meat, and pasture intake generates their meat with a greater degree of consumer acceptability [Ponte *et al*. 2008]. It is known that fast-growing broiler chickens are not adapted to extensive management systems, but they are commonly used under extensive conditions for economic reasons [Castellini *et al.* 2006]. In the United States, alternative broiler production is based mainly on the same fast-growing birds that are used in the conventional system [Fanatico *et al.* 2005a]. Also in Poland, chicken broilers of fast-growing genetic lines are usually used in alternative systems.

As is generally known, poultry meat quality is a complex issue that can be viewed in different aspects. Bird rearing system is one of many non-genetic factors that can considerably affect meat quality [Bogosavljević-Bosković *et al.* 2006b]. Large discrepancies found in the literature concerning evaluation of the effect of alternative production systems on poultry meat quality probably result from different age and genetic origin of the birds studied.

Facing the above, the aim of the present study was to determine the effect of free-range rearing on performance, carcass quality and meat quality of broiler chickens reared to day 42 of life.

Material and methods

Used were 240 chickens from fast growing Ross 308 line reared over 42 days. After individual weighing and tagging, day-old straight-run chicks were randomly assigned into two groups of 120 (Group I and II) birds in each. Group I over the rearing period was housed indoors only, on deep litter, while Group II was given access to grassy area (0.75 m^2/bird) from the morning (about 7 am.) to the afternoon (about 6 pm.) The initial density in each pen was 12 birds/m^2. All chickens were fed

ad libitum the same complete starter (1-21 days), grower (22-35 days) and finisher (36-42 days) containing 19.0, 18.0 and 18.0% crude protein and 2975, 3025 and 3075 kcal metabolizable energy/kg, respectively. During rearing, body weight, feed intake and mortality were recorded.

At the end of the experiment, *i.e*. on day 42 of life, five males and five females of medium body weight were selected from each of four sex groups and slaughtered. Fifteen minutes *post mortem*, initial pH of breast and leg muscles (pH_{15min}) was measured with a CyberScan10 pH meter equipped with a glass electrode. Twenty-four h *post mortem* the meat pH was measured again **(**pH_{24h}). Carcass colour readings were taken in the L*a*b* colour space (also referred as the CIELAB colour space) where L* refers to lightness, a* refers to redness, and b* refers to yellowness. CIE L*a*b* values were measured on the surface skin of the breast, thighs and lower back after chilling, using a MINOLTA CR310 Chroma meter (Japan). Areas was selected that were free of any obvious blood-related defects, such as bruises, or hemorrhages [Flechter *et al*. 2000].

After determination of L*, a* and b* values chilled carcasses were weighed and subjected to simplified cutting. The data obtained were used to calculate cooling loss percentage, dressing percentage (as a ratio of the weight of chilled carcass to *ante mortem* body weight) and percentage of breast muscles, leg muscles and bones, edible giblets and abdominal fat of carcass in relation to the weight of chilled carcass with giblets. Breast and leg muscles were analysed for some technological parameters. Muscle colour (L*a*b* colour space) was determined using a MINOLTA CR 310 Chroma meter (Japan) on the inner side of *pectoralis superficialis* muscle and thigh muscles, immediately after they were detached from the bone. The entire area of the analysed muscles was measured, with four measurements per muscle and calculation of the mean for individual colour parameters of L* (lightness), a* (redness) and b* (yellowness). Water-holding capacity (WHC) was determined based on the volume of free water squeezed from a ground meat sample using the filter paper method [Grau and Hamm, 1953]. Drip loss was determined from meat weight loss after 24-h cold storage at +4°C. Thermal loss was determined from percentage loss of meat weight as a result of cooking. Samples weighing about 80 g (e=0.001 g) were placed in individual plastic bags and cooked in a water bath at 100°C until a core temperature of 78°C was obtained in the thickest part of the sample. The samples were cooled, weighed for thermal loss determination, and further passed to preparation for the shear force measurements. One 1.27 cm diameter core was removed from each sample parallel to the fibre orientation through the thickest portion of the cooked muscle. Shear force was determined as maximum force (N) perpendicular to the fibres using INSTRON 5542 equipped with a Warner-Bratzler blade.

The results were verified statistically using two-way analysis of variance and significant differences were determined using Duncan's test (STATGRAPHICS Plus 6.0).

Results and discussion

During the 42 days of rearing, chickens from Group I and II achieved the mean body weight of 1.71 and 1.65 kg, respectively (Tab. 1). These figures as well as the other production indicators of investigated broilers should be regarded as poor. The experiment was carried out during summer heat which could affect the birds' performance. Detrimental effect of high temperature on the performance of broiler chickens is already well documented, principally through reducing feed intake, growth rate and feed conversion [Har *et al.* 2000, Öskan *et al.* 2003, Abu-Dieyeh *et al*. 2006]. Like in the study by Baeza *et al.* [2001], free-range access caused a reduction in body weight which together with increased mortality (Tab. 1) reduced production efficiency

Table 1. Performance of 42-days old broiler chickens (x±SD)

Trait	Group I		Group II	
	♂	♀	♂	♀
Body weight (kg)	1.77±0.25[a]	1.64±0.22 [b]	1.64±0.22[b]	1.65±0.23
Feed conversion (kg feed/kg gain)	1.94		1.99	
Mortality (%)	0		4.17	
EPP (pts)	210		188	

[ab]Means in rows with different letters differ at P≤0.05.

in this group. However, the differences in body weight occurred in cockerels only, while the mean body weights of pullets from both rearing systems were almost identical. Literature data suggest that the effect of free-range production system on the body weight of broilers is inconclusive. According to Warad *et al*. [2001] the 40-days old broiler-reared Ross pullets were significantly heavier than free-range birds at the same age (1.94 *vs*. 1.28 kg). According to Pavlovski *et al.* [2009] chickens reared in the building achieved considerably higher body weight (1.82 kg) compared to free-range chickens (1.67 kg). These data are also in accordance with Bogosavljević-Bošković *et al.* [2003a,] Milošević *et al.* [2005], Skomorucha *et al.* [2008]. In turn, Knust *et al.* [1995] reported that free-range Peking ducks achieved lower body weight compared to ducks reared indoors. In the case of moulards, free-range rearing contributed to an increase in their body weight. Similar relations were reported by Muriel and Pascual [1995] for 81-day old Redstar Shaver cockerels. Likewise, Santos *et al.* [2005] and Ponte *et al.* [2008] showed significantly higher body weight in broiler chickens that had free access to pasture. The above cited results differ from those of Wang *et al.* [2009] who reported that slow-growing Gushi chickens kept only indoors to day 112 of age were characterized by significantly higher body weight and better feed conversion compared to birds kept on free range. The negative effect of the organic rearing system of chickens on body weight gain and feed conversion ratio was also reported by Castellini *et al.* [2002b] for Ross cockerels aged 56 and 81 days.

Literature often states that housing conditions have an impact on dressing percentage and carcass quality of poultry. Bogosavljević-Bosković *et al.* [2006b] reported that Hybro G broilers with free-range access for 49 days of age showed better muscling compared to those reared indoors only. Likewise, Castellini *et al.* [2002b] showed that birds that had access to free-range achieved a higher percentage of breast and thigh muscles in the carcass. According to Skomorucha *et al.* [2008] 42-day old Cobb broilers reared indoors were characterized by higher dressing and breast muscle percentage compared to birds grown with outdoor access. These observations were not confirmed by the present study. Data from Table 2 indicate that housing system had no significant effect on either dressing percentage or carcass quality. Dressing percentage of chickens reared indoors was only by 0.64 per cent points (pp) lower than that of free-range chickens. Significant differences were observed only for carcass weight loss during 24-h chilling.

Table 2. Carcass quality of 42-day-old broiler chickens (x±SD)

Trait (%)	Group I		Group II	
	♂	♀	♂	♀
Carcass weight loss	4.66±0.69	4.20±0.50	4.33±0.85[a]	3.52±0.38[b]
Dressing percentage with giblets	73.09±2.72	73.00±2.26	73.51±1.99	73.87±0.69
Dressing percentage without giblets	68.56±3.00	68.38±2.37	68.96±2.37	69.12±1.12
Breast muscles	19.32±1.07	20.63±1.62	18.06±0.82	19.03±1.91
Leg muscles	18.28±0.76	17.95±1.16	16.92±1.15	17.92±1.15
Leg bones	6.23±0.65	5.94±0.40	5.68±0.63	6.14±0.64
Giblets	6.22±0.65	6.33±0.71	6.20±0.69	6.44±0.78
Abdominal fat	0.91±0.23	0.56±0.34	1.66±0.79	1.38±0.60

[ab]Means in rows with different letters differ at P≤0.05.

The breast and leg muscles content of carcass in chickens kept indoors totalled 38.1% and was by 2.13 pp higher compared to free-range birds. Therefore, although the intergroup differences were not significant, chickens kept indoors showed a tendency towards better carcass muscling. This trend was observed in both pullets and cockerels for both muscle types. No significant differences in the dressing percentage and percentage of breast muscles, leg muscles and wings were found by Wang *et al.* [2009] between chickens reared in free-range and conventional systems. Likewise, Husak *et al*. [2008] found no differences in raw dark and light meat yields between free-range and conventional chickens.

Many authors stress that free-range production system positively affects the quality of bird carcasses by reducing their fat content. According to Baeza *et al.* [2001] and Muriel and Pascual [1995] free-range rearing of both ducks and chickens reduces their carcass fatness. Similar relation was reported by Castellini *et al.* [2002a] and Wang *et al.* [2009] for chickens, being, however, not confirmed by the present study in which birds from Group I tended to deposit more abdominal fat than those from Group II.

Rearing system did not affect the proportion of giblets in chicken carcasses (mean 6.30%) confirming no results of Skomorucha *et al*. [2008].

Colour is one of the more important parameters considered by meat consumers. When buying whole poultry carcasses or carcass parts, they pay attention to skin colour, which is genetically determined by the bird's ability to produce melanin pigment in dermis and epidermis and to absorb and deposit carotenoids [Fletcher 1999]. According to Fanatico *et al.* [2007], giving fast-growing chickens access to free range does not affect their carcass colour. Also in the current study, the colour of carcasses in chickens from Group I and II did not differ significantly (Tab. 3). Two of the three colour parameters analysed: L* (lightness) and a* (redness) had almost the same values in both groups. Only the b* parameter was higher in Group II, which is evidence of (non-significantly) greater yellowness of carcasses from free-range chickens. Similar results were obtained by Fanatico *et al.* [2007] for slow-growing chickens. The greater yellowness of carcasses from Group II could thus result from their intake of pasture sward, which is a source of carotenoids. The observed trend could also be due to greater fatness of free-range chickens.

Table 3. Carcass colour of 42-day-old broiler chickens (x±SD)

Trait	Group I		Group II	
	♂	♀	♂	♀
Colour lightness L*	70.39±0.7	71.08±1.92	71.05±0.99	70.11±0.54
Colour redness a*	5.71±0.36	6.20±0.86	6.03±0.54	6.00±0.81
Colour yellowness b*	5.13±1.95	4.80±1.24	5.81±2.35	6.70±1.95

The results of physico-chemical evaluation of breast and leg muscles indicate that free-range access had no effect on the technological parameters of meat (Tab. 4 and 5). Significant differences were only identified for pH of breast muscles measured 24 h *post mortem*. Nonetheless, in both groups ultimate pH of breast muscles achieved values characteristic of normal meat and was 6.00 for indoor chickens and 6.19 for free-range birds. Literature often states that the meat of animals (pigs, poultry) reared on free range, which provides higher welfare levels and lower stress conditions, is characterized by lower pH due to lower glycogen use [Enfalt *et al.* 1997, Castellini *et al.* 2002b]. This trend ($P \leq 0.05$) was also suggested by Wang *et al.* [2009] and Fanatico *et al.* [2007]. However, these suggestions are supported neither by the present study nor by the recent findings of Ponte *et al.* [2008].

It is generally accepted that muscle pH determines certain physico-chemical properties of meat such as colour, water-holding capacity, thermal loss as well as tenderness of heat-treated meat [Połtowicz 2000, Le Bihan-Duval 2004]. All of these traits significantly affect consumer preferences. According to Castellini *et al.* [2002b], the production system affects, among others, the texture of poultry meat, and the associated shear force value is higher in free-range chickens. This is probably due to their higher physical activity. Husak *et al*. [2008] reported, that both the breast and thigh meat from conventional broilers were more tender than the breasts and thighs

Table 4. Breast muscle quality of 42-day-old broiler chickens (x±SD)

Trait	Group I		Group II	
	♂	♀	♂	♀
pH_{15min}	6.72±0.19	6.54±0.27	6.44±0.16	6.47±0.30
pH_{24h}	6.01±0.08	5.98±0.12 [a]	6.13±0.25	6.26±0.13 [b]
Colour lightness L*	57.36±1.43	59.88±1.90	59.54±1.14	57.67±1.68
Colour redness a*	10.57±0.71	9.70±1.48	10.63±0.85	10.38±1.22
Colour yellowness b*	6.44±0.73	7.19±1.17	7.17±2.18	7.50±1.27
WHC (%)	13.22±2.97	15.53±2.64	12.07±1.60	14.19±1.01
Drip $loss_{24h}$ (%)	0.69±0.48	1.00±0.31	0.93±0.51	0.79±0.31
Thermal loss (%)	19.52±2.14	22.34±1.97	21.01±3.13	20.88±1.39
Shear force (N)	16.35±2.36	12.79±2.26	14.68±1.00	16.17±2.99

[ab]Means in rows with different letters differ at P≤0.05.

Table 5. Thigh muscle quality of 42-day-old broiler chickens (x±SD)

Trait	Group I		Group II	
	♂	♀	♂	♀
pH_{15min}	6.63±0.19	6.67±0.12	6.57±0.25	6.52±0.18
pH_{24h}	6.45±0.05	6.40±0.08	6.30±0.13	6.48±0.06
Colour lightness L*	53.01±1.29	53.18±1.61	53.95±1.78	53.09±3.57
Colour redness a*	15.96±1.27	14.70±1.54	15.33±1.12	15.15±1.51
Colour yellowness b*	7.48±0.84	7.76±1.21	7.28±0.82	6.84±0.96
WHC (%)	9.92±2.99	9.61±1.66	12.74±2.31	10.29±1.69
Drip $loss_{24h}$ (%)	1.05±0.35	0.84±0.36 [a]	0.93±0.32	1.15±0.52 [b]
Thermal loss (%)	23.44±5.35	26.59±1.06	27.05±3.72	27.55±0.96

[ab]Means in rows with different letters differ at P≤0.05.

from free-range birds. Likewise, Farmer *et al.* [1997] showed that free-range access made the meat of free-range chickens tougher than the meat of birds raised under the standard production system. Those results are not in accordance with these reported here as a significant effect of the rearing system on meat tenderness was not shown and the difference in the shear force value of cooked meat from breast muscle of chickens of both groups was just 0.86 N. Likewise, Fanatico *et al.* [2007] found no effect of the rearing system on shear force value of the muscles from fast-growing chickens. Similar results were obtained by Wang *et al.* [2009] and Ponte *et al.* [2008] for slow-growing chickens. An earlier study by Fanatico *et al.* [2005b] indicates that the meat of 56-day old Cobb chickens given outdoor access was characterized by higher tenderness compared to the meat of birds reared indoors (P≤0.05).

Production system did not affect the colour of chickens' meat. Similar results were reported by Fanatico *et al.* [2005b]. In contrast, Fanatico *et al.* [2007] demonstrated that the meat of chickens kept indoors only was characterized by lighter colour than that of free-range reared birds. Meanwhile, Castellini *et al.* [2002a] reported that the organic production system with free-range access increased the lightness of meat,

which was paler than the meat of birds kept indoors. In a study of Husak *et al*. [2009] thigh muscles of free-range chickens were characterized by higher redness compared to conventional birds, but they were slaughtered at different age.

The rearing system had no effect on drip loss and thermal loss from breast muscles of chickens (mean of 0.86% and 20.94%, respectively). Lack of effect of housing system on thermal loss from the chicken breast muscle was also found by Dunn *et al.* [1993]. Significant differences within this trait were observed by Fanatico *et al.* [2007], who reported higher thermal loss in chickens reared indoors. Similarly, Muriel and Pascual [1995] showed significantly poorer water-holding capacity in Redstar Shaver cockerels reared indoors compared to birds from free-range system. In contrast, Castellani *et al.* [2002a] found the water-holding capacity to deteriorate as a result of using the organic production system with outdoor access. Brown *et al*. [2008] did not find difference in breast meat water-holding capacity (Grau and Hamm filter method) between standard and free-range chickens. Similarly, Wang *et al.* [2009] indicated that housing system has no effect on water-holding capacity determined in muscles with the filter paper method. Also in the present study, no significant differences were found in the water-holding capacity of muscles between the two groups of birds used, although leg muscles showed a tendency towards slightly poorer drip loss, thermal loss and water-holding capacity in birds from the free-range system (Tab. 5).

Summarizing, the findings presented here concur with the view of Gregory [1998] that free-range management of broiler chickens has no effect on quality traits of their meat. Similar conclusions were reached by Wang *et al.* [2009], who claimed that rearing slow-growing chickens with free-range access has no effect on carcass traits and meat quality. Inconsistent literature data on meat and carcass traits in alternative production systems indicate that other factors, like breed and slaughter age, can play an important role. According to Bonneau and Lebret [2010] organic production *per se* has little effect on eating quality of pork, and welfare-oriented specifications such as outdoor access or free-range rearing have limited consequences on pork quality. Certain authors claim that the free-range production system improves the eating quality of poultry meat [Lewis *et al.* 1997, Fanatico *et al.* 2007], but their results concern the meat of slow-growing chicken that are reared much longer than fast-growing birds.

This study has shown that giving free-range access to fast-growing broiler chickens had no effect on dressing percentage or carcass quality, while the quality of their meat was comparable to that of standard broilers . Further study is required to determine the effect of free-range production system on sensory characteristics of the meat from these birds.

REFERENCES

1. ABU-DIEYEH Z.H.M., 2006 – Effect of chronic heat stress and long-term feed restriction on broiler performance. ***International Journal of Poultry Science*** 5(2), 185-190.
2. BAEZA E., LESSIRE M., BERRI C., JUIN H., 2001 – Compared carcass and meat characteristics of label and standard guinea fowl. Proceedings of XV European Symposium on the Quality of Poultry Meat, Kusadasi, Turkey, 73-78.

3. BOGOSAVLJEVIĆ-BOSKOVIĆ S., KURĆUBIĆ V., PETROVIĆ M., RADOVIĆ V., 2006a – The effect of sex and rearing system on carcass composition and cut yields of broiler chickens. ***Czech Journal of Animal Science*** 51(1), 31-38.
4. BOGOSAVLJEVIĆ-BOSKOVIĆ S., KURĆUBIĆ V., PETROVIĆ M., RADOVIĆ V., 2006b – The effect of season and rearing systems on meat quality traits. ***Czech Journal of Animal Science*** 51(8), 369-374.
5. BONNEAU M., LEBRET B., 2010 – Production systems and influence on heating quality of pork. ***Meat Science*** 84(2), 293-300.
6. BROWN S.N., NUTE G.R., BAKER A., HUGHES S.I., WARRISS P.D., 2008 – Aspects of meat and eating quality of broiler chickens reared under standard, maize-fed, free-range or organic systems. ***British Poultry Science***, 49(2), 118-124
7. CASTELLINI C., MUGNAI C., DAL BOSCO A., 2002a – Effect of organic production system on broiler carcass and meat quality. ***Italian Journal of Food Science*** 14, 401-412.
8. CASTELLINI C., MUGNAI C., DAL BOSCO A., 2002b – Effect of organic production system on broiler carcass and meat quality. ***Meat Science*** 60, 219-225.
9. CASTELLINI C., MUGNAI C., PEDRAZZOLI M., DAL BOSCO A., 2006 – Productive performance and carcass traits of Leghorn chickens and their crosses reared according to the organic farming system. Proceedings of XII European Poultry Conference, Verona. Abstracts and Procedures CD, ID, 10704.
10. CIE, 1976. Supplement No. 2 to: Recommendations on uniform color spaces - Color difference equations. Psychometric Color Terms. Commission Internationale de l'Eclairage (1971) tc-1-1. CIE Publication No. 15 (E-1.3.1), Paris, France.
11. DUNN A.A., KILPATRICK D.J., GAULT N.F.S., 1993 – Influence of ultimate pH, sarcomere length and cooking loss on the textural variability of cooked M. Pectoralis Major from free range and standard broilers. ***British Poultry Science*** 34, 663-675.
12. ENFALT A.C.K., LUNDSTRON I., HANSSON N., LUNDEHEIM N., NYSTRON P.N., 1997 – Effect of outdoor rearing and sire breed (Duroc or Yorkshire) on carcass composition and sensory and technological meat quality. ***Meat Science*** 45, 1-15.
13. FANATICO A.C., PILLAI P.B., CAVITT L.C., OWENS C.M., EMMERT J.L., 2005a – Evaluation of slower-growing genotypes grown with and without outdoor access: growth performance and carcass yield. ***Poultry Science*** 84, 11321-1327.
14. FANATICO A.C., CAVITT L.C., PILLAI P.B., EMMERT J.L., OWENS C.M., 2005b – Evaluation of slower-growing genotypes grown with and without outdoor access: meat quality. ***Poultry Science***, 84, 1785-1790.
15. FANATICO A.C., PILLAI P.B., CAVITT L.C., EMMERT J.L., MEULLENET J.F., OWENS C.M., 2006 – Evaluation of slower-growing genotypes grown with and without outdoor access: sensory attributes. ***Poultry Science*** 85, 337-343.
16. FANATICO A.C., PILLAI P.B., EMMERT L.J., OWENS C.M., 2007 – Meat quality of slow- and fast-growing chicken genotypes fed low-nutrient or standard diets and raised indoors or with outdoor access. ***Poultry Science*** 86, 2245-2255.
17. FARMER L.J., PERRY G.C., LEWIS P.D., NUTE G.R., PIGGOTT J.R., PATTERSON R.L.S., 1997 – Responses of two genotypes of chicken to the diets and stocking densities of conventional UK and *Label Rouge* production systems- II. Sensory attributes. ***Meat Science*** 47, 77-93.
18. FLETCHER D.L., 1999 – Poultry meat colour. In: Poultry Meat Quality (R.I. Richardson and C. Mead, Eds). CAB Publishing, New York, pp. 159-176.
19. FLETCHER D.L., QIAO M., SMITH P., 2000 – The relationship of raw broiler breast meat colour and pH to coocked meat colour and pH. ***Poultry Science*** 79, 784-788

20. GRAU R., HAMM R., 1953. Eine Einfache Methode zur Bestimmung der Wasserbindung im Muskel. ***Naturwiss***, 40(1), 29-30.
21. GREGORY N.G., 1998 – Animal Welfare and Meat Science. CABI Publishing, New York, p. 184.
22. HAR L., RONG D. ZHANG Z.Y. 2000 – The effect of thermal environment on the digestion of broilers. ***Animal Physiology*** 83, 57-64.
23. HUSAK R.L., SEBRANEK J.G., BREGENDAHL K., 2008 – A survey of commercially available broilers marketed as organic, free-range, and conventional broilers for cooked meat yields, meat composition, and relative value. ***Poultry Science*** 87, 2367-2367.
24. JAHAN K., PARERSON A., SPICKETT C.M. 2004 – Fatty acid composition, antioxidants and lipid oxidation in chicken breasts from different production regimes, ***International Journal of Food Science and Technology*** 39, 443-453.
25. KNUST U., WICKE M., PINGEL H., LENGERKEN G. V., SALOMON V., 1995 – Muscle structure and meat quality of ducks reared on pasture and under intensive conditions respectively. Proceedings of XII European Symposium on the Quality of Poultry Meat. Zaragoza, 189-193.
26. LE BIHAN-DUVAL E., 2004 – Genetic variability within and between breeds of poultry technological meat quality. ***World's Poultry Science Journal*** 60, 331-340.
27. LEWIS P.D., PERRY G.C., FARMER L.J., PATTERSON R.L.S., 1997 – Responses of two genotypes of chicken to the diets and stocking densities typical of UK and "label rouge" systems: I. Performance, behaviour and carcass composition. ***Meat Science*** 45, 501-516.
28. MILLET S., MOONS C.P.H., VAN OECKEL M.J., JANSSENS G.P.J. 2005 – Welfare, performance and meat quality of fattening pigs in alternative housing and management systems: a review. ***Journal of the Science of Food and Agriculture***, 85(5), 709-719.
29. MILOŠEVIĆ N., PERIĆ L., STRUGAR V., ŽIKIĆ D., PAVLOVSKI Z. 2005 – Rearing of fattening chickens on free range and extensively in chickens coop. ***Biotechnology in Animal Husbandry*** 5-6, 125-136.
30. MURIEL A., PASCUAL M.R., 1995 – Carcass and meat characteristics from free range chickens. Proceedings of XII European Symposium on Quality of Poultry Meat, Zaragoza, 219-222.
31. ONYANGO B., BELLOWS A.C., DIAMOND A., HALLMAN W., 2006 – What we don't understand about public interest in organics. ***Appetite*** 47(3), 397.
32. ÖSKAN S., AKBAŞ Y., ALTAN Ö., ALTAN A., AYHAN V., ÖZKAN K., 2003 – The effect of short-term fasting on performance traits and rectal temperature of broilers during the summer season. ***British Poultry Scence*** 44, 88-95.
33. PAVLOVSKI Z., ŠKRABIĆ Z., LUKIĆ M., PETRIČEVIĆ V.L., TRENKOVSKI S., 2009 – The effect of genotype and housing system on production results of fattening chickens. ***Biotechnology in Animal Husbandry*** 25(3-4), 221-229.
34. POŁTOWICZ K., 2000 – Wpływ początkowego poziomu pH mięśni piersiowych na wybrane wskaźniki jakości mięsa kurcząt brojlerów należących do trzech genotypów. (Effect of breast muscles initial pH on selected indicators of meat of broiler chickens of three genotypes). In Polish, summary in English. ***Roczniki Naukowe Zootechniki***, Supplement 8, 161-165.
35. PONTE P.I.P., ROSADO C.M.C., CREPSO J.P., CREPSO D.G., MOURAO J.L., CHAVEIRO-SOARES M.A., BRAS J.L.A., MENDES I., GAMA L.T., PRATES J.A.M., FERREIRA L.M.A., FONTES C.M.G.A., 2008 – Pasture intake improves the performance and meat sensory attributes of free-range broilers. ***Poultry Science*** 87, 71-79.
36. SANTOS A.L., SAKOMURA N.K., FREITAS E.R., FORTES C.M.S., CARRILHO N.V.M., 2005 – Comparision of free range broiler chicken strains raised in confined and semi-confined systems. ***Brazilian Journal of Poultry Science*** 7, 85-92.

37. SKOMORUCHA I., MUCHACKA R., SOSNÓWKA-CZAJKA E., HERBUT E., 2008 – Effects of rearing with or without outdoor access and stocking density on broiler chicken productivity. ***Annals of Animal Science*** 8(4), 387-393.
38. SOSNÓWKA-CZAJKA E., SKOMORUCHA I., HERBUT E., MUCHACKA R., 2007 – Effect of management systems and flock size on the behaviour of broiler chickens. ***Annals of Animal Science*** 7(2), 329-335.
39. WANG K.H., SHI S.R., DOU T.C., SUN H.J. 2009 – Effect of a free-raising system on growth performance, carcass yield, and meat quality of slow-growing chicken. ***Poultry Science*** 88, 2219-2223.
40. WARD J.M., HOUSTON., D.C., RUXTON G.D., MCCAFFERTY D.J., COOK P, 2001 – Thermal resistance of chicken (*Gallus domesticus*) plumage: a comparison between broiler and free-range birds. ***British Poultry Science*** 42, 558-563.