EFFECT OF FREE-RANGE SYSTEM AND HEN BIODIVERSITY ON CARCASS AND MEAT QUALITY

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Abstract

The aim of this study was to determine the effect of the free-range system and the genotype of one-year-old hens on carcass and meat quality. The study included hens of the conserved breeds Yellowleg Partridge (Ż-33) and Rhode Island Red (R-11) as well as the commercial hybrid Messa 45 (M45), 120 hens per strain. The hens of each breed/strain (Ż-33, R-11, M45) were divided as follows: group I - control, 60 hens kept in a litter-floor system without outdoor access, at a stocking density of 5 hens/m2 of usable poultry-house area; and group II - experimental, 60 hens kept in a poultry house on litter with year-round access to outdoor runs. The study showed that, for most traits, the meat quality of 56-week-old hens was good irrespective of genotype and rearing system, and the high protein content increased its nutritional value. In addition, hens kept with access to grass paddocks and fed a farm-produced diet had lower body weight and dressing percentage, but also lower fatness and lower yellowness (b) of the carcass and meat. Partial replacement of the complete DJ feed mixture with wheat grain under backyard rearing conditions reduces costs and does not impair meat quality, but may reduce hen body weight and dressing percentage.*

Keywords: laying hens, free range, meat quality

Introduction

Meat plays an important role in the human diet by supplying many nutrients, the amounts of which depend, among other factors, on the species and age of the animal, feeding, and rearing system (Sokolowicz et al., 2016; Grochowska et al., 2016). Leroy et al. (2023) point out that meat supplies most of the world's vitamin B12 intake and plays a significant role in providing other B vitamins, retinol, long-chain omega-3 fatty acids, several minerals in bioavailable forms (e.g. iron and zinc), and a variety of bioactive compounds with health-promoting potential. Poultry meat is very popular and its consumption shows a steady upward trend. Most studies on poultry meat quality concern young meat-type poultry. Meat obtained from laying hens after one year of production is of little importance to slaughterhouses and processing plants, which offer a low price for such birds, not exceeding 10% of the price of a pullet placed into egg production. The sensory quality of meat from one-year-old laying hens is also unattractive, mainly because of its low tenderness and high toughness, which prolong the heat-treatment time before consumption. Gornowicz and Lewko (2010) noted that meat obtained under organic conditions from Yellowleg Partridge (Ż-33) and Rhode Island Red (R-11) hens crossed with Ross meat-type cocks and reared with outdoor access was tasty and less fatty than meat obtained from birds kept under intensive indoor conditions.

Many authors point out that the rapid body-weight gain of young meat-type poultry contributes to metabolic disorders and reduces meat quality; this quality can be improved by modifying the nutrient composition of the diet and supplementing it with bioactive compounds (Nir, 2000; Duclos et al., 2007; Che et al., 2022). At the same time, European consumers have shown increasing interest in poultry welfare and in products from birds kept in extensive systems with access to grass paddocks, using slow-growing chickens or native breeds (Fanatico et al., 2007a and 2007b; Sokolowicz and Krawczyk, 2010; Mikulski et al., 2011; Sokolowicz et al., 2016).

Meat-quality traits of laying hens depend primarily on the breed/strain of the layers, the age of the slaughtered birds, and environmental factors (Poltowicz and Doktor, 2012; Puchala et al., 2014). The conserved laying-hen populations studied here are characterized by variation in body weight and carcass colour and may serve as source material for studies on the quality of meat obtained from layers after one year of egg production (Poltowicz and Cywa-Benko, 1999). Yellowleg Partridge (Ż-33) is a native dual-purpose breed developed by crossing Greenleg Partridge hens with New Hampshire cocks. The breed is characterized by yellow shanks, partridge plumage with a brownish tinge, and yellow skin. These hens tolerate large-flock production better than Greenleg Partridge hens and have higher egg production, egg weight, and body weight. Rhode Island Red (R-11) hens are among the most typical dual-purpose breeds, widely distributed in Poland and formerly known locally as karmazyn. They were imported to Poland from Great Britain before 1939. Because of their dual-purpose utility, until the mid-1970s they accounted for about 50% of birds on commercial farms and in backyard flocks. These hens are recommended for extensive production of Label Rouge-type meat chickens. Cockerels reared in poultry houses with access to grass paddocks have yellow skin and good dressing percentage. Messa 45 (M45) hens are commercial hybrids from a domestic breeding farm in Mienia, most commonly used in litter-floor systems, and obtained by crossing two parental strains: V-44 cocks and M-55 hens. They are laying hens with a slightly higher body weight than layers originating from foreign breeding programmes.

The aim of the study was to determine the carcass and meat quality of genetically diverse hens at 56 weeks of age kept under different rearing systems.

Material and methods

The study involved hens of the conserved breeds Yellowleg Partridge (Ż-33) and Rhode Island Red (R-11), and commercial Messa 45 (M45) hybrids, with 120 birds of each breed/strain. Hens of each breed/strain (Ż-33, R-11, M45) were divided as follows: group I - control, 60 hens kept in a litter-floor indoor system without outdoor access, at a stocking density of 5 hens/m2 of usable poultry-house area; and group II - experimental, 60 hens kept in a poultry house on litter with year-round access to outdoor runs. Each hen had 5 m2 of usable poultry-house area and 4 m2 of outdoor-run area. Hens with outdoor access were fed ad libitum a feed mixture formulated to resemble a farm-produced diet, consisting of one-third complete DJ feed and two-thirds whole wheat grain.

The chemical composition of the complete DJ feed mixture and the farm-produced diet fed to the hens is presented in Table 1.

Table 1. Results of chemical analysis of feed (%)

Feed mixture	Dry matter	Crude ash	Crude protein	Crude fat	Crude fibre
Complete DJ	89,46	14,74	18,24	2,18	2,60
Farm-produced (1/3 DJ feed + 2/3 wheat grain)	85,81	6,71	14,12	1,97	3,28

The hens were kept at the farm of the Experimental Station of the National Research Institute of Animal Production in Chorzelow from 20 to 56 weeks of age. The poultry house was equipped with automatic ventilation and heated with fuel-oil blow heaters. Depending on the season, the mean indoor temperature ranged from 15 to 20 C and relative humidity from 60 to 70%.

The results were analysed statistically using two-way analysis of variance (genotype x rearing system). The significance of differences between group means was estimated using Duncan's test (Statistica 6.0). Significance was denoted as follows: NS - statistically non-significant differences, * significant differences ($P<=0.05$), ** highly significant differences ($P<=0.01$). The study was approved by the Local Ethics Committee (No. 2/2010).

Results

In the experiment, R-11 hens had the highest pre-slaughter body weight (2186 g), whereas Ż-33 layers were the lightest (1905 g) (Table 2). Similar relationships were found for carcass weight without giblets and leg-muscle weight, and the differences were statistically significant ($P<=0.01$). The lowest breast-muscle weight was found in the commercial M45 hybrids ($P<=0.01$). Irrespective of genotype, hens kept in the backyard system had lower body weight, carcass weight, and weights of individual carcass components ($P<=0.01$). Considerable variation in carcass colour was recorded between strains and between rearing systems ($P<=0.01$). Carcasses of the conserved breeds (Ż-33 and R-11) had higher L* values than the commercial M45 hybrids, indicating a lighter colour. R-11 carcasses had the highest saturation towards red (a*) and yellow (b*). Carcasses, particularly the skin, of hens kept indoors without outdoor access (control group) showed greater lightness (L*) and redness (a*) and lower yellowness (b*) than carcasses from the backyard system.

The smallest carcass weight losses after chilling were found in R-11 hens (1.75%), particularly those kept with outdoor access in the backyard system (1.45%), whereas losses were higher and similar in Ż-33 and M45 layers (Table 3). According to the data in Table 3, there were no statistically significant differences in carcass weight loss depending on the rearing system ($P>=0.05$). The heaviest R-11 hens had the highest dressing percentage, 65.7%, with statistically significant differences compared with Ż-33 and M45 hens ($P<=0.01$). In addition, dressing percentage was significantly higher in hens kept under farm indoor conditions than in those with outdoor access. Both conserved strains had a higher proportion of breast muscles in the carcass (P<=0.05), whereas the rearing system had no significant effect on this trait (P>=0.05). Neither hen genotype nor rearing system significantly affected the proportion of leg muscles. A lower proportion of giblets was found in R-11 hens and in hens kept under farm conditions (P<=0.01). Compared with Ż-33 and R-11 layers, carcasses of commercial M45 hybrids contained more abdominal fat (5.83%), as did hens kept without outdoor access (6%) (P<=0.01).

In all hens studied, regardless of origin, breast-muscle pH15min was similar, although a tendency towards a lower value was observed in the R-11 strain (Table 4).
At 24 hours post mortem (pH24h), the lowest value was found in R-11 hens, and the difference compared with Ż-33 and M45 strains was statistically confirmed (P<=0.01). Differences in drip loss after 24 hours of sample storage were small and statistically non-significant among the strains. However, cooking losses in breast-muscle samples from birds kept in the backyard system were 4% greater than in samples from control layers (P<=0.05). Water-holding capacity of breast muscles ranged from 13.5% (Ż-33) to 18.6% (R-11), and differences among the strains were statistically confirmed (P<=0.01). Breast muscles of R-11 hens had the highest L* value (60.6) and differed in this respect from the other two strains (P<=0.05). Breast muscles of hens from the free-range backyard system had a high b* yellowness value of 11.4 and differed in this respect from hens from the farm system (P<=0.01).

Measurements of leg-muscle acidity, 24-hour drip loss, cooking loss, and water-holding capacity showed no significant differences either between strains or as a result of the rearing system (Table 5). Colour evaluation showed that muscles obtained from birds in the backyard (free-range) system were darker than those from the farm system (P<=0.05). Differences in the a* and b* colour parameters were small and statistically non-significant for both experimental factors (genotype x rearing system).

The results presented in Table 6 show that breast muscles of R-11 hens contained the most protein as well as the most fat, differing in this respect from both other strains (P<=0.01). There was an interaction between the two experimental factors (genotype x rearing system) for breast-muscle protein content (P<=0.01): protein content increased in Ż-33 hens under free-range conditions, whereas it decreased in the other two strains. Differences in leg-muscle protein content were small and statistically non-significant, while greater variation was found in crude fat content, which was about 1.5% higher in R-11 hens than in Ż-33 and M45 layers (P<=0.01). Leg muscles of hens kept without outdoor access also contained 0.83% more crude fat (P<=0.05).

Discussion

Effect of hen genotype on body weight and meat quality

The international literature confirms a significant effect of bird genotype and rearing system on carcass and meat quality in fast-growing broilers, slow-growing hybrids, and native breeds (Miguel et al., 2011; Guan et al., 2013; Jayasena et al., 2013; Yousif et al., 2014; Puchala et al., 2014; Comert et al., 2016; Sokolowicz et al., 2016). Conserved laying-hen populations show considerable variation in phenotypic traits, including body weight (www.bioroznorodnosc.izoo.krakow.pl/drob), as was also confirmed in the present study. At slaughter, the Z-11, Ż-33 and M45 hens studied were not particularly heavy, and their dressing percentage was low (62-65%) and similar to values reported by Murawska and Bochno (2007) for layer-type cockerels. These authors also noted that such a low dressing percentage may make production uneconomical. In a search for slow-growing chickens suitable for extensive production, Koreleski et al. (2008) found that the optimum rearing period for some dual-purpose chickens used for meat production was 12 weeks, because at that age the birds achieved body weight and dressing percentage comparable with young broilers. Puchala et al. (2015), studying Greenleg Partridge and Rhode Island Red laying hens, found a significant effect of genotype on body weight and dressing percentage, although differences in the proportions of breast and leg muscles were smaller than in the present study and were statistically non-significant. In the present study, differences in body weight, muscling, carcass colour, and the proportion of abdominal fat were statistically confirmed both between groups of different origin and between hen rearing systems.

Published studies on carcass and meat quality in older birds usually concern meat-type chickens. In Spain, meat-type varieties of native chickens are kept that reach about 4-5 kg body weight at 10 months of age and have a dressing percentage exceeding 80% (Franco et al., 2012a). Poltowicz and Doktor (2012), studying meat quality in hybrids resulting from crossing four native hen strains with Hubbard meat-type cocks, obtained birds that at 12 weeks of age reached 2126-2968 g body weight and a dressing percentage of 70.66-76.26%, similar to results obtained by Puchala et al. (2014) in heavier hens (WJ-44 and N-11). Koenig et al. (2012) also obtained good dressing percentages (about 67%) when rearing surplus layer-type cockerels of two genotypes to 49 days, although their body weight at the end of fattening was low, ranging from 616 to 678 g. Murawska et al. (2005 and 2011), in turn, obtained dressing percentages in layer-type cockerels reared to 18 weeks that were similar to those found in the present study.

Table 2. Body, breast and leg muscle weights (g) and carcass colour of hens

Item	Hen strain (A)			Rearing system (B)		A B						SEM	Strain	Rearing system (B)	A B
	Ż-33	R11	M45	K	W	Ż-33 K	Ż-33 W	R-11 K	R-11 W	M45 K	M45 W				
Live weight (g)	1905	2186	2088	2197	1923	2107	1702	2361	2012	2122	2053	44,77	**	**	*
Weight of chilled carcass without giblets (g)	1223^{B}	1438^{A}	1299^{B}	1458	1182	1386	1060	1600	1276	1388	1209	37,69	**	**	NS
Breast weight (g)	223^{b}	261^{a}	214^{b}	254	211	238	208	291	230	232	196	16,79	*	**	NS
Leg weight (g)	234^{B}	299^{A}	267^{B}	289	244	257	211	331	267	253	281	19,71	**	**	NS
Carcass colour:															
L*	$70{,}81^{a}$	$70{,}56^{a}$	$68{,}92^{b}$	71,26	68,93	73,42	68,20	70,36	70,76	70,00	67,85	0,47	*	**	**
a*	$2{,}28^{a}$	$3{,}71^{b}$	3,20c	3,85	2,28	2,25	2,32	5,58	1,85	3,72	2,68	0,30	*	**	**
b*	$14{,}34^{B}$	$16{,}96^{A}$	$12{,}30^{B}$	13,16	15,91	13,10	16,16	16,55	22,02	16,83	16,53	0,68	**	**	*

Notes: K - control (hens kept indoors without outdoor access), W - free range (hens kept indoors with year-round outdoor access);
Ż-33 - Yellowleg Partridge, R-11 - Rhode Island Red, M45 - Messa 45.
Significance of differences: NS - statistically non-significant, * significant (P<=0.05), ** highly significant (P<=0.01)
Significance of differences for breeds/strains: a,b,c - significant (P<=0.05), A,B,C - highly significant (P<=0.01)

Table 3. Dressing percentage (%)

Item	Hen strain (A)			Rearing system		A B						SEM	Strain	Rearing system (B)	A B
	Ż-33	R-11	M45	K	W	Ż-33K	Ż-33 W	R-11 K	R-11W	M45K	M45W				
Carcass weight loss	2,25	1,75	2,26	1,75	2,43	1,91	2,6	1,45	2,05	1,88	2,64	0,21	NS	NS	NS
Carcass yield with giblets	64,0^{A}	65,7^{A}	62,1^{B}	66,3	61,6	65,8	62,2	67,8	63,7	65,4	58,9	0,70	**	**	NS
Breast muscles	17,2^{a}	17,5^{a}	15,3^{b}	16,5	16,8	16,3	18,1	17,4	17,5	15,8	14,9	0,36	*	NS	NS
Leg muscles	18,0	19,5	19,1	18,8	19,9	17,6	18,4	19,8	19,1	19,1	19,2	0,40	NS	NS	NS
Giblets	5,88^{B}	4,91^{A}	6,62^{C}	4,75	6,85	4,84	6,92	3,95	5,86	5,47	7,77	0,29	**	**	NS
Leg bones	10,8	9,8	10,9	10,1	10,9	10,2	11,4	10,1	9,6	10,0	11,8	0,31	NS	NS	NS
Abdominal fat	4,57^{B}	4,2^{A}	5,83^{C}	6,00	3,73	6,47	2,67	4,5	3,89	7,04	4,62	0,38	**	**	*

For explanations see Table 2.

Table 4. Physical characteristics of breast muscles

Item	Hen strain (A)			Rearing system		A B						SEM	Strain	Rearing system	A B
	Ż-33	R-11	M45	K	W	Ż-33K	Ż-33W	R-11K	R-11W	M45K	M45W				
pH15min	6,41	6,27	6,37	6,33	6,37	6,43	6,38	6,28	6,26	6,28	6,45	0,03	NS	NS	NS
pH24h	$6,15^{a}$	$5,98^{b}$	$6,24^{c}$	6,11	6,13	6,12	6,18	6,05	5,91	6,17	6,31	0,03	*	NS	NS
Drip loss after 24 h (%)	0,40	0,45	0,43	0,42	0,44	0,38	0,42	0,44	0,47	0,45	0,42	0,02	NS	NS	NS
Cooking loss (%)	26,5	22,6	24,1	22,6	26,2	23,9	29,2	21,3	24,0	22,7	25,4	0,80	NS	*	NS
Water-holding capacity (%)	$13,5^{A}$	$18,6^{B}$	$14,1^{A}$	15,2	15,5	12,5	14,5	18,1	19,1	15,2	12,9	0,69	**	NS	NS
Colour:															
L*	58,1	$60,6^{a}$	$57,1^{b}$	$58,5^{b}$	58,6	58,6	57,5	59,2	61,9	57,8	56,5	0,59	*	NS	NS
a*	7,76	9,63	9,36	9,18	8,65	8,30	7,23	9,44	9,81	9,79	8,92	0,39	NS	NS	NS
b*	9,21	10,20	9,10	7,60	11,40	7,88	10,5	6,73	13,60	8,20	10,0	0,52	NS	**	**

For explanations see Table 2.

Table 5. Physical characteristics of leg muscles

Item	Hen strain (A)			Rearing system		A B						SEM	Strain	Rearing system (B)	A B
	Ż-33	R-11	M45	K	W	Ż-33K	Ż-33W	R-11K	R-11W	M45K	M45W				
pH15min	6,61	6,59	6,51	6,54	6,60	6,57	6,64	6,64	6,54	6,41	6,61	0,02	NS	NS	NS
pH24h	6,47	6,19	6,35	6,29	6,39	6,35	6,60	6,25	6,13	6,25	6,44	0,04	NS	NS	NS
Drip loss after 24 h (%)	0,39	0,34	0,29	0,35	0,34	0,35	0,43	0,29	0,40	0,40	0,19	0,03	NS	NS	NS
Cooking loss (%)	37,6	40,2	39,5	39,2	38,7	36,5	38,7	40,9	39,5	40,3	38,7	0,60	NS	NS	NS
Water-holding capacity (%)	13,0	16,0	13,5	14,1	14,2	14,1	12,0	15,3	16,7	12,9	14,0	0,65	NS	NS	NS
Colour:															
L*	43,1	45,0	43,4	45,3	42,4	44,8	41,5	45,3	44,6	45,8	41,0	0,67	NS	*	NS
a*	16,3	16,0	16,7	16,4	16,3	16,0	16,6	16,1	15,9	17,1	16,3	0,28	NS	NS	NS
b*	6,61	7,94	6,85	6,58	7,69	6,23	6,99	6,39	9,49	7,11	6,59	0,35	NS	NS	NS

For explanations see Table 2.

Table 6. Chemical composition of breast and leg muscles

Content (%)	Hen strain (A)				Rearing system		A B						SEM	Strain	Rearing system (B)	A B
	Ż-33	R-11	M45		K	W	Ż-33K	Ż-33W	R-11K	R-11W	M45K	M45W				
Breast muscles																
Crude protein	24,1	25,3	24,8		24,7	24,7	23,5	24,7	25,5	25,1	25,2	24,4	0,17	**	NS	**
Crude fat	$0,86^{A}$	$1,38^{B}$	$0,72^{A}$		1,02	0,96	0,81	0,90	1,37	1,40	0,87	0,58	0,07	**	NS	NS
Leg muscles																
Crude protein	20,9	20,6	20,8		20,6	20,9	20,6	21,3	20,3	20,9	20,9	20,6	0,10	NS	NS	NS
Crude fat	$4,44^{A}$	$5,90^{B}$	$4,14^{A}$		5,24	4,41	5,28	3,59	6,13	5,67	4,32	3,96	0,26	**	*	NS

For explanations see Table 2.

The present study indicates that the genotype (origin) of laying hens affects the proportion of breast muscles in the carcass. Depending on genotype, the proportion of breast muscles ranged from about 15% in M45 hens to more than 17% in the native Ż-33 and R-11 breeds. These results were comparable with those obtained by Berri et al. (2005) and Comert et al. (2016) in slow-growing chickens reared to 12 weeks of age. Studies by Murawska et al. (2005 and 2007) in layer-type cockerels show that extending the rearing period improves dressing percentage and increases the proportion of breast muscles in the carcass from 15% to more than 20%, but this relationship does not occur in one-year-old hens.

The proportion of leg muscles in the carcasses of all hens studied was greater than that of breast muscles, which is a characteristic feature of laying hens confirmed by Puchala et al. (2014 and 2015). The proportion of these muscles was considerably lower than that reported by Berri et al. (2005) and Poltowicz and Doktor (2012) in slow-growing chickens, and by Koenig et al. (2012) in layer-type cockerels, but was comparable with results obtained in native-breed hens by Poltowicz and Cywa-Benko (1999).

Carcass weight losses after chilling were small and much lower than those reported for young broilers (Poltowicz and Doktor, 2011). Carcasses of all breeds/strains studied were slightly less fatty than in the study of Puchala et al. (2014), while abdominal fat content varied among strains from 4.2% (R-11) to 5.83% (M45), whereas in studies of slow-growing chickens this value did not exceed 3% (Berri et al., 2005; Poltowicz and Doktor, 2012). Even in broilers reared for an extended period to 63 days, this value remained below 4% (Zhu et al., 2012). In the study by Gornowicz (2008), abdominal fat in carcasses of 42-day-old chickens ranged from 1 to 2%, while according to Polak (2004) it increased to 3% in 48-day-old birds. The present results indicate that carcass fatness increases in laying hens after sexual maturity (about 20 weeks of age), particularly in layers with a genetically determined higher body weight.

Colour is an important element in consumers' evaluation of carcasses. In traditional Polish cuisine, hens used for preparing broth were expected to have yellow carcasses, and this expectation is met by carcasses of the native Ż-33 and R-11 hens, whereas M45 hens show less yellow coloration. Poltowicz and Cywa-Benko (1999) reported that, among six conserved hen strains, White Leghorns (H-22) showed the lowest carcass yellowness.

Muscle acidity is considered an important indicator of meat quality because it reflects the intensity of glycolytic changes occurring in the muscles. According to Jakubowska et al. (1999), pH measured 15 minutes after slaughter in normal meat should range from 5.9 to 6.2. According to these guidelines, the muscles of the hens studied exhibited the DFD (dark, firm, dry) defect because pH was >=6.3. Okruszek et al. (2007) also recorded similarly high pH15min values in ducks from conserved strains, suggesting that some muscles of these birds may exhibit the DFD defect because of the long rearing period. In all three strains, breast-muscle pH was higher than leg-muscle pH, and a similar relationship occurs in broiler chickens (Gornowicz, 2008). Lesiow and Kijowski (2003) point out that elevated pH does not accelerate the growth of spoilage organisms, but shortens their lag phase and results in a faster development of unpleasant odours in DFD meat than in chicken fillets affected by the PSE defect.

In the muscles of the hens studied, lighter muscles were associated with higher water-holding capacity, a relationship previously confirmed in broiler chickens (Poltowicz and Doktor, 2011). Drip loss from breast muscles of all strains was low and much lower than that measured in broilers (Poltowicz and Doktor, 2011). Drip loss from thigh muscles was lower, indicating greater juiciness, and was similar to values obtained by Berri et al. (2005) in hybrids of native breeds and meat-type strains reared to 13 weeks. In the present study, cooking losses were greater in leg muscles than in breast muscles, consistent with studies in broilers (Gornowicz, 2008) and slow-growing chickens (Castellini et al., 2002; Wattanachant et al., 2004). Franco et al. (2012b), however, studying heavy hens of the native Spanish Mos breed reared to

10 months of age, recorded lower cooking losses in breast muscles and found no effect of bird origin on this trait.

An important meat trait indicating technological suitability is water-holding capacity, i.e. the ability to retain and bind water during processing. Meat with high water-holding capacity is juicier than meat that readily releases water. Breast and leg muscles of the hen strains studied had almost twofold lower water-holding-capacity values than muscles of fast-growing meat chickens (Gornowicz, 2008).

Meat colour depends on the amount and oxidation state of haem pigments and is one of the important attributes used by consumers to assess meat (Jakubowska et al., 2004). The present study indicates an effect of hen genotype (origin) on colour saturation. The lightest breast and leg muscles and the greatest yellowness were found in R-11 hens, which was also confirmed by Puchala et al. (2015). Poltowicz and Cywa-Benko (1999), in turn, noted substantial variation in breast- and leg-muscle colour among native hen strains, further confirming their biodiversity and the potential use of their meat in different dishes.

In the breast muscles of all hens studied, crude protein content exceeded 24% and was 3-4% higher than in young meat chickens (Gornowicz, 2008; Poltowicz and Doktor, 2011), but similar to that in hens of the native Spanish Mos breed (Franco et al., 2012a, 2012b). Wattanachant et al. (2004) reported 2% more protein and less fat in the breast muscles of native-breed chickens than in broilers. Berri et al. (2005), however, found that muscle protein content increases with chicken age, which is confirmed by the present results. Leg muscles contained four to five times more fat than breast muscles; these findings are consistent with similar results reported by Puchala et al. (2014). Franco et al. (2012b) and Wattanachant et al. (2004) also reported lower muscle fat levels in native-breed chickens than in broilers.

Effect of rearing system on dressing percentage and physicochemical characteristics of meat

Laying hens are among the animals with the highest productivity relative to body weight, because a bird weighing 1.6-1.9 kg can lay as much as 20 kg of eggs. With such a physiological burden, the hen's diet must be precisely balanced and environmental conditions adjusted to the birds' needs. The lower body weight and associated lower breast- and leg-muscle weights in hens with outdoor access may have resulted from feeding that was not adapted to the free-range system. The results confirm the well-known relationship that, apart from age and genotype, the nutritional value of the feed has the greatest effect on bird body weight and egg weight (Keshavarz and Nakjima, 1995; Zhu et al., 2012). In young, fast-growing birds, an optimal amino-acid composition of dietary protein is a prerequisite for good body-weight gains (Jozefiak et al., 2001; Pawlak et al., 2005; Lipinski et al., 2019). The present study involved one-year-old hens in which the growth phase had already ended. The low nutritional value of the farm-produced diet commonly used for hens in backyard systems (14% protein), its high proportion of wheat grain, and the birds' greater energy expenditure due to increased activity on the ranges may have contributed to lower body weight, lower carcass dressing percentage, and lower weights of individual carcass components. In feeds containing a high proportion of cereals, feed additives that improve digestibility and utilization of individual nutrients are recommended (Engberg et al., 2004). Such additives were not used in the present study because the aim was to evaluate hen meat quality under conditions resembling backyard production. The present results for body weight, muscling, and abdominal fat content are consistent with those of Castellini et al. (2002), who obtained birds under organic conditions that were 700 g lighter than conventionally reared birds. Chickens kept in the Label Rouge free-range system also achieve lower body weight and lower weights of individual carcass components than conventionally reared birds (Smith et al., 2012).

The free-range system mainly increased the yellow colour saturation of the carcasses. Carcass colour is determined by the colour of subcutaneous fat, which depends on lutein. The more intense yellow colour of carcasses from hens with outdoor access probably resulted from the birds consuming plants on the range that supplied xanthophylls deposited in subcutaneous fat, as confirmed by Fanatico et al. (2007a) in slow-growing birds with outdoor access. The rearing system had no significant effect on carcass weight loss after chilling in any of the strains studied, and these results are consistent with similar studies by Poltowicz and Doktor (2011) in broiler chickens.

The study showed that the acidity of breast and leg muscles measured immediately after slaughter (pH15min) and after 24 hours (pH24h) was similar in hens kept with and without outdoor access. The pH values allow this meat to be classified as exhibiting the DFD (dark, firm, dry) defect, because pH15 was >=6.3. Higher pH values were recorded in both breast and leg muscles of hens kept with outdoor access, but the differences were small and statistically non-significant. The literature indicates that bird rearing system does not have an unequivocal effect on muscle pH. Richardson (2004) and Comert et al. (2016) reported significantly higher pH values, whereas Gornowicz and Lewko (2010) reported lower values in broiler chickens with outdoor access.

Irrespective of rearing system, lighter muscles had greater water-holding capacity, but the rearing system had no effect on the water-holding capacity of either breast or thigh muscles. In contrast, Poltowicz and Doktor (2011) reported an increase and Gornowicz and Lewko (2010) a decrease in the water-holding capacity of leg muscles in broilers with outdoor access. The present experiment did not confirm the findings of Castellini et al. (2002) and Fanatico et al. (2007b), who showed that free-range rearing produces meat with lower cooking losses. According to Castellini et al. (2002), organic broiler production increases meat shear force, which is an indicator of tenderness, and a similar tendency was found in the present study. Free access to grass paddocks significantly increased yellowness of breast and thigh muscles, consistent with most studies on both young and older meat chickens (Castellini et al., 2002; Poltowicz and Doktor, 2011; Galvez et al., 2020).

No significant effect of rearing system on crude protein content was found in the breast muscles of the hens studied, whereas Galvez et al. (2020) reported significantly higher muscle protein levels in meat chickens reared free range and organically. In the present study, regardless of rearing system, muscle protein content was considerably higher than in young meat chickens (Wattanachant et al., 2004) and ducks (Mazanowski and Bernacki, 2004). In both experiments, hens with outdoor access had lower fat content in both leg and breast muscles, consistent with many studies of free-range systems for meat poultry (Castellini et al., 2002; Gornowicz and Lewko, 2010; Smith et al., 2012; Galvez et al., 2020).

Conclusions

The study showed that, for most traits, the meat quality of 56-week-old hens was good irrespective of genotype and rearing system, and the high protein content increased its nutritional value. Hens kept with access to grass paddocks and fed a farm-produced diet had lower body weight and lower dressing percentage, but at the same time lower fatness and favourable yellow colour saturation (b*) of the carcass and meat. Partial replacement of the complete DJ feed mixture with wheat grain under backyard rearing conditions reduces costs and does not impair meat quality, but may reduce hen body weight and dressing percentage.

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EFFECT OF FREE-RANGE SYSTEM AND HEN BIODIVERSITY ON CARCASS AND MEAT QUALITY

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SUMMARY

The aim of this study was to determine the effect of the free-range system and the genotype of one-year-old hens on carcass and meat quality. The study included hens of the conserved breeds Yellowleg Partridge (Ż-33) and Rhode Island Red (R-11) as well as the commercial hybrid Messa 45 (M45), 120 hens per strain. The hens of each breed/strain (Ż-33, R-11, M45) were divided as follows: group I – control, 60 hens kept in a litter floor system, without free range, with a stocking density of 5 hens/m² of usable area of poultryhouse, and group II – experimental, 60 hens kept in a poultryhouse on litter with year-round access to free range. As a result of the study, it was found that the meat quality of 56-week-old hens, in terms of most traits, irrespective of genotype and rearing system, is good, and the high protein content increases its nutritional value. In addition, hens kept with access to grass paddocks and fed with farm feed were characterized by lower body weight and lower slaughter yield, but at the same time by lower fatness and lower yellowness of carcass and meat (b*). Partial replacement of the complete DJ mixture with wheat grain under the conditions of the backyard system reduces costs and does not impair meat quality, but may be a reason for lower hen body weight and slaughter performance.

Keywords: laying hens, free range, meat quality