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EFFECT OF ORGANIC PRODUCTION SYSTEM ON THE PERFORMANCE AND MEAT QUALITY OF TWO PUREBRED SLOW-GROWING CHICKEN BREEDS*

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Abstract

The objective of the study was to compare the effect of organic and conventional rearing systems on the productivity and meat quality of Yellowleg Partridge (Ż-33) and Rhode Island Red (R-11) chickens. A total of 492 sexed experimental birds (*Gallus domesticus*) were assigned to four groups. In groups I-C and III-C, the Ż-33 and R-11 chickens were reared under intensive conditions following conventional farming principles. In groups II-O and IV-O, the Ż-33 and R-11 chickens were kept according to organic farming principles. Body weight, feed conversion (kg/kg gain) and mortality were recorded throughout the study. On day 140 of rearing, the native breed chickens were subjected to simplified slaughter analysis, and meat pH, muscle colour, water holding capacity and chilling loss were determined. The meat samples were analysed for the chemical composition and profile of fatty acids, and the peroxidizability index (PI), thrombogenic index (TI) and atherogenicity index (AI) were calculated. The organically raised chickens were characterised by higher body weight (P≤0.01), better feed conversion (P≤0.01) and more favourable fatty acid profile of the muscles compared to the conventionally reared birds. Under organic conditions, the R-11 chickens showed better productivity but slightly poorer fatty acid profile of the muscles compared to the Ż-11 chickens.

Key words: chickens, native breeds, organic production system, performance, meat quality, fatty acid profile

Organic farming is becoming increasingly popular in Europe and around the world. The main cause is the growing demand from consumers who are looking for safer and better controlled food products and who show concern for a healthy environment and animal welfare.

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In accordance with the legal regulations, organic poultry producers feed chickens with diets that should fully meet the nutrient requirement and ensure high welfare. Depending on the type of organic production, the birds are fed semi-intensively or on a low plane of nutrition based on natural and organic feeds. These regulations also specify the rearing conditions, stocking density and access to an outdoor range.

Numerous studies on alternative poultry production systems have demonstrated that lower stocking density, greater freedom of movement and eating green vegetation have a positive effect on the health of birds and on product quality (Dal Bosco et al., 2012; Chen et al., 2013). Fanatico et al. (2005 b) and Dou et al. (2009) observed higher breast and leg yield, improved sensory quality of meat, and lower carcass fatness in free-range chickens compared to those kept indoors. Funaro et al. (2014) reported on a higher level of polyunsaturated fatty acids, including PUFA-6 and PUFA-3, in the muscle of birds with outdoor access, which is highly desirable due to prevention of cardiovascular diseases. Sokołowicz et al. (2016) reported that organic poultry meat is characterised by low fat content and has the colour, taste and aroma desired by the consumer. On the other hand, birds kept on free range are susceptible to negative effects of environmental stimuli (Berg, 2001; Rizzi et al., 2007), whereas the high fibre content of plants may impair nutrient utilisation, which decreases growth rate and increases feed conversion (Ponte et al., 2008 b; Sales, 2014).

Proper selection of birds is essential in organic poultry production. Considering the many dietary and technological limitations, it is recommended that local breeds of hens adapted to free range and less susceptible to adverse weather conditions should be used in organic production (Rizzi et al., 2007; Rizzi and Chiericato, 2010; Dal Bosco et al., 2012). In Poland, the best hens for organic production are the native breeds such as Greenleg Partridge, Yellowleg Partridge, Polbar, Rhode Island Red, Sussex or Leghorn (Cywa-Benko, 2002; Sokołowicz et al., 2016), which are well adapted to the environment and feeding, in addition to showing natural resistance and viability. To prevent many valuable breeds of farm animals from extinction, the European Union has taken various measures to popularise the farming of native breeds, as well as offering different forms of financial support, also for organic farming (Krawczyk and Sokołowicz, 2015).

Fanatico et al. (2005 a) and Rizzi et al. (2007) report that birds with different genetic backgrounds show differences in the rate of growth and development, the results of dissection analysis, and the quality and sensory value of meat depending on the rearing system. Therefore, the selection of the native breeds such as Yellowleg Partridge and Rhode Island Red for production of organic slow-growing chickens could provide a valuable source of poultry products for the production of quality or regional foods.

The objective of the study was to compare the effect of organic and conventional rearing systems on the productivity and meat quality of Yellowleg Partridge (Ż-33) and Rhode Island Red (R-11) chickens.

Material and methods

The experiment was conducted at the Experimental Station of the National Research Institute of Animal Production in Chorzelów, Poland. The subjects were 492 sexed one-day-old chicks (*Gallus domesticus*) of the native Polish breeds Yellowleg Partridge (Ż-33) and Rhode Island Red (R-11). At one day of age, after weighing and identifying with tags, the chicks were allocated to four experimental groups, each of which included 3 replicates. Each replicate consisted of the same number of males and females (1:1). In groups I-C and III-C, Ż-33 and R-11 chickens, respectively, were reared following conventional farming principles. In groups II-O and IV-O, Ż-33 and R-11 chickens, respectively, were kept according to organic farming principles. The conventionally raised birds were kept in a separate building under the same environmental conditions as in the organic system.

Table 1. Nutritive value of the diets*

Item	Starter diet I (1–4 weeks of rearing)**		Diet II (from 5 weeks to end of rearing)***	
According to feed manufacturing plant formula				
metabolisable energy (MJ/kg)	12.00		12.20	
crude protein (%)	22.50		20.50	
crude fat (%)	5.00		5.70	
crude fibre (%)	4.70		4.50	
methionine (%)	0.38		0.35	
calcium (%)	0.80		0.80	
phosphorus (%)	0.70		0.65	
sodium (%)	0.17		0.17	
vitamin A (I.E./kg)	12 000		12 000	
vitamin D (I.E./kg)	3 000		3 000	
vitamin E (mg/kg)	30		30	
iron (mg/kg)	70[1]		70[1]	
manganese (mg/kg)	80[2]		80[2]	
zinc (mg/kg)	55[3]		55[3]	
copper (mg/kg)	12[4]		12[4]	
iodine (mg/kg)	1[5]		1[5]	
selenium (mg/kg)	0.21[6]		0.21[6]	
Analysed	conventional	organic	conventional	organic
dry matter (%)	88.15	88.14	88.14	88.14
crude protein (%)	22.48	22.46	20.53	20.49
crude fat (%)	4.97	4.98	5.72	5.73
crude fibre (%)	4.68	4.69	4.51	4.50
crude ash (%)	6.19	6.20	6.19	6.19

*Birds from all groups received diets of the same nutritional value, but in groups II-O and IV-O they were made from certified feed materials authorised for use in the organic production system, in accordance with Council Regulation (EC) No. 834/2007 of 28 June 2007.

**Composition of diet I: wheat, soybean expeller, maize, wheat bran, rapeseed cake, potato protein, maize gruel, calcium carbonate, monocalcium phosphate.

***Composition of diet II: wheat, soybean expeller, maize, wheat bran, rapeseed cake, maize gruel, calcium carbonate, monocalcium phosphate.

[1]iron as ferrous sulfate monohydrate, [2]manganese as manganous oxide, [3]zinc as zinc sulfate, [4]copper as copper sulfate pentahydrate, [5]iodine as calcium iodate, [6]selenium as sodium selenite.

The chickens from the conventional system were reared on litter at a stocking density of 12 birds/m^2 of floor space without outdoor access and were fed diets for slow-growing chickens (Table 1). In the organic system, chickens were kept on litter at a density of 10 birds/m^2 of floor space and had access to pasture (4 m^2/bird). Outdoor runs were equipped with drinkers, roofed to protect the birds from adverse weather conditions, fenced, and protected against predators (wire netting buried 50 cm deep). Outdoor runs were available from day 1 of rearing. The birds received diets of the same nutritional value as the conventionally raised birds, but made from certified feed materials authorised for use in the organic production system, in accordance with Council Regulation (EC) No. 834/2007 of 28 June 2007.

In both housing systems the birds had free access to feed and water throughout the experiment. From 1 to 4 weeks of age, the chickens were fed the standard diet I which contained 22.5% protein and 12.0 MJ ME/kg feed. Diet I consisted of wheat, soybean expeller, maize, wheat bran, rapeseed cake, potato protein, maize gruel, calcium carbonate, monocalcium phosphate, as well as vitamins and minerals listed in Table 1. From 5 weeks of age until the end of rearing, diet II containing 20.5% protein and 12.2 MJ ME/kg feed was used. Diet II consisted of wheat, soybean expeller, maize, wheat bran, rapeseed cake, maize gruel, calcium carbonate and monocalcium phosphate, as well as vitamin-mineral supplements. In all the four experimental groups, the slow-growing chickens were reared for 140 days.

Individual body weight (BW), feed conversion (kg/kg gain) and mortality were recorded during the study in each replicate. On day 140 of rearing, 20 birds (10 females and 10 males) whose BW was similar to the group and sex average were selected from each group. The selected chickens were slaughtered and the pH of the breast and leg muscles was measured 15 min postmortem (pH_{15}) and 24 h after chilling of the carcass at 4°C (pH_{24}), using a CyberScan 10 pH meter (Singapore) and EC-FG 73905 electrode. The chilled carcasses were subjected to simple carcass analysis according to the method described by Ziołecki and Doruchowski (1989), and the dissected muscles were evaluated for selected technological parameters. All the carcasses were chilled in cold storage at 4°C immediately after evisceration and weighing. After 24 h of chilling, the carcasses were reweighed, and the dressing percentage without giblets was determined as the proportion of chilled eviscerated carcass (without giblets) to pre-slaughter BW of the chickens. The chilled carcasses were subjected to a simplified carcass analysis, the results of which were used to calculate the proportion of breast muscle, leg muscle, leg bone, giblets (liver, gizzard and heart) and abdominal fat in the carcass.

Next, the colour of dissected breast and leg muscles was determined with a Minolta CR310 (Japan) reflectance colorimeter using illuminant C as a light source. Colour was measured in the CIE $L^*a^*b^*$ system (CIE, 1976), where L^* is lightness, a^* is redness, and b^* is yellowness. Muscle colour was measured immediately after bone dissection, on the inner surface of the left breast muscle (*M. pectoralis maior*) and on the inner surface of the left thigh muscle, with four measurements per muscle and calculation of the mean for individual colour parameters of L* (lightness), a* (redness) and b* (yellowness) (Calik et al., 2015). The measurements were made on the surfaces with no discolorations, visible blood vessels and defects that could affect the readings (Fletcher et al., 2000).

Determinations were made of the water holding capacity (WHC) of the left breast (*M. pectoralis maior* and *minor*) and thigh muscles according to Grau and Hamm (1953). A sample of ground meat weighing ~300 mg was placed in the geometric centre of Whatman no. 1 filter paper (8 cm × 8 cm), sandwiched between two glass plates and subjected to 2-kg pressure for 5 min. After squeezing, the areas covered by the meat sample were marked, and both the stain and sample areas were planimetered. Expressible juice was calculated according to the model:

$$\text{WHC (\%)} = \frac{\text{stain area (cm}^2\text{)} - \text{sample area (cm}^2\text{)}}{\text{sample weight (mg)}} \times 100$$

Drip loss was determined from meat weight loss after 24 h of cold storage at 4°C. To this end, samples weighing ~80 g (e = 0.001 g) were collected from the left breast (*M. pectoralis maior*) and left thigh muscles, placed in airtight containers and cold stored for 24 h. The samples were then weighed again, and drip loss was determined as a percentage loss of initial weight (Kaczor et al., 2016).

Meat samples collected from the dissected right breast (*M. pectoralis maior* and *minor*) and right leg muscles (thighs and drumsticks) were ground and analysed for the profile of fatty acids and chemical composition. Analysis of the meat for chemical composition was performed at the Central Laboratory of the National Research Institute of Animal Production according to the following procedures: determination of water content (SOP M.011a PN-ISO 1442:2000 'Meat and Meat Preparations', ver. 1 of 28 March 2011); determination of nitrogen in the meat – Kjeldahl method (SOP M.007 PN-ISO 1442:2000, ver. 2 of 21 February 2008), conversion of nitrogen content to protein using a factor of 6.25 (PN-75/A-04018/Az3: 2002); and determination of total fat using the Soxhlet method in a Büchi 810 apparatus (SOP M.013a PN-ISO 1442:2000, ver. 1 of 28 March 2011). The fatty acid profile of the meat was determined by gas chromatography on a Varian 3400 CX using helium as a carrier gas and Agilent J&W CP-Wax 58 FFAP column (25 m). The following indices were calculated based on the proportions of individual acids and their groups: PI – peroxidizability index (Arakawa and Sagai, 1986), TI – thrombogenic index; and AI – atherogenicity index (Ulbricht and Southgate, 1991).

The results were statistically analysed with two-way analysis of variance and significant differences were estimated with Duncan's test. Statgraphics plus 6.0 was used for the statistical calculations. Effects were considered significant at a probability of $P \leq 0.05$ and $P \leq 0.01$.

The experiment was conducted with the approval (no. 1203/2015) of the Local Ethics Committee for Animal Experimentation.

Results

The organically raised Ż-33 and R-11 chickens had higher ($P \leq 0.05$) BW compared to birds from the conventional system (Table 2). Breed had an effect on the

chickens' BW (P≤0.01). Breed and the housing system also influenced feed conversion (P≤0.01 and P≤0.05, respectively). The mortality of the organically raised Ż-33 birds was 0.29%. For the R-11 breed, no mortality during rearing was recorded in either the conventional or organic system.

Table 2. Production results of 140-day-old native breed chickens (1♀:1♂) (n=123)

Item	Group				SEM	Breed (A)	Rearing system (B)	A×B
	Ż-33		R-11					
	I-C	II-O	III-C	IV-O				
BW (g)	1710.35 Aa	1862.68 ABb	2012.46 BCc	2144.39 Cd	20.38	<0.01	<0.05	NS
Feed conversion (g) per kg weight gain	4466.19 Ca	4155.69 BCb	3827.87 ABc	3620.08 A	34.53	<0.01	<0.05	NS
Mortality (%)	0	0.29	0	0	-	-	-	-

Ż-33 – Yellowleg Partridge.
R-11 – Rhode Island Red.
C – conventional rearing system.
O – organic rearing system.
a, b – significant differences (P≤0.05).
A, B – significant differences (P≤0.01).
NS – not significant.

The Ż-33 chickens from the organic system were characterised by lower (P≤0.01) dressing percentage with and without giblets compared to the R-11 birds raised under the same system (Table 3). The interaction of treatments showed an effect on dressing percentage with and without giblets for the Ż-33 chickens (P≤0.05 and P≤0.01, respectively). The genetic factor also had an effect on carcass bone percentage (P≤0.05).

Table 4 shows the results for pH, WHC, drip loss, colour and chemical composition of breast and leg muscle in the experimental birds. The Ż-33 chickens were characterised by higher pH_{15} and pH_{24} of the breast muscle compared to the conventionally reared R-11 chickens (P≤0.01). Differences were also observed in the percentage of drip loss from the breast muscle, which was influenced by both the breed (P≤0.01) and rearing system (P≤0.05). The breast muscle of the Ż-33 chickens had a darker colour compared to that of the second native breed (P≤0.01). In the case of the organic production system, higher b^* values were noted for the breast muscle from the chickens of both breeds (P≤0.01). The breed × rearing system interaction had an effect on the b^* colour values of the breast muscle from the organically raised chickens (P≤0.05). When evaluating the meat quality of the leg muscle, we found that breed had an effect on pH_{24} (P≤0.01), drip loss (P≤0.01) and b^* colour value of the meat (P≤0.05). The rearing system also contributed to the difference between L^* colour values of the leg muscle from the R-11 chickens (P≤0.05). Breed also had an effect on the percentage of crude protein in the breast muscles of the chickens at P≤0.05.

Table 3. Dissection analysis of 140-day-old native breed chickens (1♀:1♂) (n=20)

Item	Group				SEM	Breed (A)	Rearing system (B)	A×B
	Ż-33		R-11					
	I-C	II-O	III-C	IV-O				
Dressing percentage with giblets (%)	72.85 bc	70.64 Aa	72.49 bc	73.36 Bc	0.25	<0.01	NS	<0.05
Dressing percentage without giblets (%)	69.30 Bc	66.82 Aa	68.72 bc	69.67 Bc	0.26	<0.01	NS	<0.01
Breast muscle (%)	17.54	17.92	16.73	17.67	0.16	NS	NS	NS
Leg muscle (%)	22.77	23.19	23.21	22.57	0.24	NS	NS	NS
Leg bones (%)	5.81 ab	5.58 a	6.57 c	6.12 bc	0.09	<0.05	NS	NS
Abdominal fat (%)	0.87	1.08	1.47	1.26	0.10	NS	NS	NS
Giblets (%)	4.88	5.41	5.20	5.05	0.08	NS	NS	NS

Ż-33 – Yellowleg Partridge.
R-11 – Rhode Island Red.
C – conventional rearing system.
O – organic rearing system.
a, b – significant differences (P≤0.05).
A, B – significant differences (P≤0.01).
NS – not significant.

Table 4. Quality of breast and leg muscles from 140-day-old native breed chickens (1♀:1♂)

Item		Group				SEM	Breed (A)	Rearing system (B)	A×B
		Ż-33		R-11					
		I-C	II-O	III-C	IV-O				
Breast muscle									
pH[1]	15 min	6.54 B	6.50 B	6.19 A	6.25	0.03	<0.01	NS	NS
	24 h	6.17 B	6.20 B	6.04 A	6.13	0.01	<0.01	NS	NS
WHC[2] (%)		19.03	15.92	17.70	17.53	0.56	NS	NS	NS
Drip loss[2] (%)		0.50 Aa	0.82 b	0.92 Bb	0.91 Bb	0.04	<0.01	<0.05	NS
Colour[1]	L*	55.96 A	55.96 A	59.41 B	58.29 B	0.24	<0.01	NS	NS
	a*	4.73	5.65	5.14	4.92	0.21	NS	NS	NS
	b*	8.33 A	11.72 Ba	9.12 AC	10.68 Bb	0.14	NS	<0.01	<0.05
Chemical composition[2] (%)	Dry matter	25.61	25.28	26.30	26.22	0,19	NS	NS	NS
	Crude protein	24.33 a	24.20 a	24.63	24.89 b	0,08	<0,01	NS	NS
	Crude fat	1.00	1.33	1.46	1.21	0,07	NS	NS	NS
Leg muscle									
pH[1]	15 min	6.67	6.64	6.58	6.55	0.02	NS	NS	NS
	24 h	6.48 B	6.51 B	6.30 A	6.30 A	0.02	<0.01	NS	NS
WHC[2] (%)		15.72	14.75	16.07	17.39	0.53	NS	NS	NS
Drip loss[2] (%)		0.46 Aa	0.40 Aa	0.78 Bb	0.52 a	0.04	<0.01	<0.05	NS
Colour[1]	L*	44.93	44.84	43.76	44.25	0.34	NS	NS	NS
	a*	10.14	10.60	10.38	10.85	0.15	NS	NS	NS
	b*	11.19 a	11.47 a	11.74	12.56 b	0.15	<0.05	NS	NS
Chemical composition[2] (%)	Dry matter	23.66	25.13	26.03	25.76	0,32	NS	NS	NS
	Crude protein	20.77	20.99	20.95	20.52	0.08	NS	NS	NS
	Crude fat	2.49	3.74	4.65	4.74	0.34	NS	NS	NS

Ż-33 – Yellowleg Partridge.
R-11 – Rhode Island Red.
C – conventional rearing system.
O – organic rearing system.
[1]n=20; [2]n=10.
a, b – significant differences (P≤0.05).
A, B – significant differences (P≤0.01).
NS – not significant.

Table 5. Fatty acid profile of breast muscles (%) (1♀:1♂) (n=10)

Item	Group				SEM	Breed (A)	Rearing system (B)	A×B
	Ż-33		R-11					
	I-C	II-O	III-C	IV-O				
C-10:0	0.03	0.04	0.02	0.03	0.002	NS	NS	NS
C-12:0	0.08	0.08	0.05	0.05	0.006	NS	NS	NS
C-14:0	0.56	0.63	0.63	0.63	0.015	NS	NS	NS
C-14:1	0.10	0.08	0.11	0.10	0.005	NS	NS	NS
C-15:0	0.13	0.15	0.12	0.12	0.004	NS	NS	NS
C-16:0	27.00	26.68	28.49	26.93	0.306	NS	NS	NS
C-16:1 *n-9*	0.53	0.55	0.58	0.52	0.020	NS	NS	NS
C-16:1 *n-7*	3.96	3.19	4.15	3.99	0.136	NS	NS	NS
C-17:0	0.18	0.20	0.21	0.19	0.009	NS	NS	NS
C-17:1	0.07	0.09	0.13	0.09	0.008	NS	NS	NS
C-18:0	8.07	8.45	8.76	8.04	0.205	NS	NS	NS
C-18:1 *n-9*	35.55	30.62	34.31	35.06	0.574	NS	NS	NS
C-18:1 *n-7*	3.33	3.13	3.10	3.09	0.046	NS	NS	NS
C-18:2 *n-6*	13.89 a	16.73 b	14.19	15.20	0.326	NS	<0.05	NS
C-18:3 *n-6*	0.12	0.13 a	0.12	0.10 b	0.003	<0.05	NS	NS
C-18:3 *n-3*	0.48 a	0.68 b	0.55 A	0.78 B	0.024	NS	<0.01	NS
C-20:0	0.10	0.11	0.09	0.09	0.005	NS	NS	NS
C-20:1	0.38	0.42	0.33	0.42	0.012	MS	NS	NS
C-20:2	0.14 a	0.21 b	0.11	0.14 a	0.008	<0.05	<0.05	NS
C-20:3 *n-6*	0.29 a	0.39 b	0.17 a	0.25 b	0.017	NS	<0.05	<0.05
C-20:4 *n-6*	3.23	3.53	2.36	1.94	0.221	NS	NS	NS
C-20:5 *n-3* (EPA)	0.05 A	0.23 B	0.06 A	0.18 B	0.013	NS	<0.01	NS
C-22:4 *n-6*	0.40	0.31	0.33	0.18	0.027	NS	NS	NS
C-22:5 *n-3* (DPA)	0.42 A	0.87 B	0.36	0.58	0.042	NS	<0.01	NS
C-22:6 *n-3* (DHA)	0.59 A	1.83 B	0.41 A	1.16 B	0.085	NS	<0.01	<0.05

Ż-33 – Yellowleg Partridge.
R-11 – Rhode Island Red.
C – conventional rearing system.
O – organic rearing system.
a, b – significant differences (P≤0.05).
A, B – significant differences (P≤0.01).
NS – not significant.

The breed of birds had an effect on the percentage of γ-linolenic acid (C-18:3 *n-6*) and eicosadienoic acid (C-20:2) at P≤0.05 (Table 5). In turn, the effect of the housing system was noted for linoleic (C-18:2 *n-6*), eicosadienoic (C-20:2), and dihomo-γ-linolenic acids (C20:3 *n-6*) at P≤0.05, and for α-linolenic acid (C18:3 *n-3*), EPA (C20:5 *n-3*), DPA (C22:5 *n-3*) and DHA (C22:6 *n-3*) at P≤0.01. The interaction of treatments had an effect on the profile of fatty acids: dihomo-γ-linolenic (C20:3 *n-6*) and DHA (C22:6 *n-3*) at P≤0.05.

Bird origin had an effect on the percentage of PUFA, PUFA-6 and PUFA-3 in the breast muscle and on the PUFA/SFA and PUFA6/3 ratios at P≤0.05 (Table 6). The rearing system had an effect on MUFA percentage (P≤0.05), on the proportion of

PUFA and PUFA-3, and on the PUFA/SFA and PUFA6/3 ratios (P≤0.01). The breed and rearing system had an effect on the PI value (P≤0.05 and P≤0.01, respectively). In turn, the interaction of treatments had an effect on MUFA percentage (P≤0.05).

Table 6. Total fatty acid groups and their ratios in breast muscles (%) (1♀:1♂) (n=10)

Item	Group				SEM	Breed (A)	Rearing system (B)	A×B
	Ż-33		R-11					
	I-C	II-O	III-C	IV-O				
SFA	36.16	36.26	38.37	36.08	1.12	NS	NS	NS
UFA	63.60	63.75	61.63	63.93	1.12	NS	NS	NS
MUFA	43.96 b	37.22 Aa	42.70 B	42.76 b	1.56	NS	<0.05	<0.05
PUFA	19.63 A	26.53 B	18.93 A	21.17 A	1.25	<0.05	<0.01	NS
PUFA-6	17.93 b	21.09 a	17.18 b	17.68 b	1.06	<0.05	NS	NS
PUFA-3	1.65 A	3.60 C	1.38 A	2.69 B	0.23	<0.05	<0.01	NS
DFA	71.67	72.20	70.39	71.96	0.87	NS	NS	NS
OFA	27.56	27.31	29.12	27.56	0.86	NS	NS	NS
UFA/SFA	1.77	1.76	1.65	1.78	0.07	NS	NS	NS
DFA/OFA	2.56	2.66	2.47	2.62	0.10	NS	NS	NS
MUFA/SFA	1.22	1.14	1.15	1.49	0.08	NS	NS	NS
PUFA/SFA	0.55 B	0.73 Aa	0.50 B	0.59 b	0.04	<0.05	<0.01	NS
PUFA6/3	11.14 Ba	6.11 A	13.57 Bb	7.07 A	0.78	<0.05	<0.01	NS
CLA	0.11	0.27	0.08	0.05	0.03	NS	NS	NS
PI	36.81 A	60.72 Bb	31.54 A	43.63 a	4.17	<0.05	<0.01	NS
TI	0.96	0.87	1.10	0.88	0.07	NS	NS	NS
AI	0.44	0.46	0.50	0.46	0.03	NS	NS	NS

Ż-33 – Yellowleg Partridge.
R-11 – Rhode Island Red.
C – conventional rearing system.
O – organic rearing system.
a, b – significant differences (P≤0.05).
A, B – significant differences (P≤0.01).
NS – not significant.
SFA – saturated fatty acids (C10, C12, C14, C15, C16, C17, C18, C20).
UFA – unsaturated fatty acids (C14-1, C16-1, C17-1, C18-1, C18-2, C18-3, C20-1, C20-2, C20-3, C20-4, C20-5, C22-4, C22-5, C22-6).
PUFA – polyunsaturated fatty acids (C18-2, C18-3, C20-2, C20-3, C20-4, C20-5, C22-4, C22-5, C22-6).
MUFA – monounsaturated fatty acids (C14-1, C16-1, C17-1, C18-1, C20-1).
OFA – hypercholesterolemic fatty acids (C14:0 + C16:0).
DFA – neutral and hypocholesterolemic fatty acids (C18:0 + UFA).
PI – peroxidizability index.
TI – thrombogenic index.
AI – atherogenicity index.

Analysis of the fatty acid profile of leg muscle (Table 7) revealed the effect of breed on the proportion of dihomo-γ-linolenic acid (C20:3 *n-6*), DPA (C22:5 *n-3*) and DHA (C22:6 *n-3*) at P≤0.05. The organically raised Ż-33 and R-11 chickens were characterised by a higher percentage of α-linolenic acid (C18:3 *n-3*), eicosenoic acid (C20:1) and EPA (C20:5 *n-3*) at P≤0.01, as well as lower percentage of docosatetraenoic acid (C22:4 *n-6*) at P≤0.05.

Table 7. Fatty acid profile of leg muscles (%) (1♀:1♂) (n=10)

Item	Group				SEM	Breed (A)	Rearing system (B)	A×B
	Ż-33		R-11					
	I-C	II-O	III-C	IV-O				
C-10:0	0.02	0.02	0.02	0.01	0.001	NS	NS	NS
C-12:0	0.04	0.04	0.03	0.03	0.003	NS	NS	NS
C-14:0	0.59	0.71	0.68	0.78	0.018	NS	NS	NS
C-14:1	0.12	0.12	0.12	0.15	0.005	NS	NS	NS
C-15:0	0.11	0.13	0.12	0.13	0.004	NS	NS	NS
C-16:0	26.41	25.41	28.05	27.10	0.359	NS	NS	NS
C-16:1 *n-9*	0.50	0.51	0.57	0.52	0.012	NS	NS	NS
C-16:1 *n-7*	5.05	4.76	4.69	5.34	0.144	NS	NS	NS
C-17:0	0.17	0.19	0.17	0.18	0.004	NS	NS	NS
C-17:1	0.07	0.10	0.11	0.10	0.006	NS	NS	NS
C-18:0	8.23	8.63	8.78	7.88	0.251	NS	NS	NS
C-18:1 *n-9*	36.02	34.23	35.12	36.42	0.591	NS	NS	NS
C-18:1 *n-7*	3.12	2.83	2.87	2.75	0.048	NS	NS	NS
C-18:2 *n-6*	14.99	17.88	15.13	15.38	0.402	NS	NS	NS
C-18:3 *n-6*	0.12	0.12	0.13	0.11	0.003	NS	NS	NS
C-18:3 *n-3*	0.56 A	0.97 B	0.59 A	0.94 B	0.036	NS	<0.01	NS
C-20:0	0.09	0.10	0.08	0.08	0.004	NS	NS	NS
C-20:1	0.37 A	0.51 B	0.33 A	0.50 B	0.014	NS	<0.01	NS
C-20:2	0.14	0.18	0.10	0.13	0.007	NS	NS	NS
C-20:3 *n-6*	0.16 a	0.15 a	0.10 b	0.10 b	0.007	<0.05	NS	NS
C-20:4 *n-6*	2.03	1.24	1.32	0.54	0.131	NS	NS	NS
C-20:5 *n-3* (EPA)	0.03	0.10 B	0.03 A	0.10 B	0.007	NS	<0.01	NS
C-22:4 *n-6*	0.34 a	0.17 b	0.23 a	0.09 b	0.019	NS	<0.05	NS
C-22:5 *n-3* (DPA)	0.21	0.28 a	0.13	0.15 b	0.017	<0.05	NS	NS
C-22:6 *n-3* (DHA)	0.31	0.42 a	0.18	0.23 b	0.024	<0.05	NS	NS

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a, b – significant differences (P≤0.05).
A, B – significant differences (P≤0.01).
NS – not significant.

Both bird origin and rearing system had an effect on the percentage of *n-3* PUFA and the PUFA 6/3 ratio in the leg muscle at P≤0.05 and P≤0.01, respectively (Table 8).

Table 8. Total fatty acid groups and their ratios in leg muscles (%) (1♀:1♂) (n=10)

Item	Group				SEM	Breed (A)	Rearing system (B)	A×B
	Ż-33		R-11					
	I-C	II-O	III-C	IV-O				
SFA	35.64	35.21	37.91	36.19	1.412	NS	NS	NS
UFA	64.19	64.79	62.09	63.80	1.414	NS	NS	NS
MUFA	45.25	43.05	43.82	45.77	1.782	NS	NS	NS
PUFA	18.93	21.74	18.28	18.04	1.360	NS	NS	NS
PUFA-6	17.63	19.34	16.90	16.21	1.204	NS	NS	NS
PUFA-3	1.19 B	1.78 Ab	0.93 Bb	1.41 a	0.121	<0.05	<0.01	NS
DFA	72.41	73.42	70.87	71.69	1.073	NS	NS	NS
OFA	27.00	26.12	28.73	27.88	1.064	NS	NS	NS
UFA/SFA	1.81	1.86	1.68	1.80	0.101	NS	NS	NS
DFA/OFA	2.70	2.81	2.54	2.55	0.151	NS	NS	NS
MUFA/SFA	1.28	1.24	1.18	1.28	0.083	NS	NS	NS
PUFA/SFA	0.53	0.62	0.50	0.51	0.042	NS	NS	NS
PUFA6/3	15.08 B	11.09 A	18.22 C	11.54 A	0.722	<0.05	<0.01	NS
CLA	0.05	0.09	0.04	0.06	0.015	NS	NS	NS
PI	28.62	36.25	28.15	25.08	4.401	NS	NS	NS
TI	0.96	1.01	0.99	0.92	0.051	NS	NS	NS
AI	0.43	0.46	0.46	0.44	0.020	NS	NS	NS

Ż-33 – Yellowleg Partridge.
R-11 – Rhode Island Red.
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a, b – significant differences (P≤0.05).
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NS – not significant.
SFA – saturated fatty acids (C-10, C12, C14, C15, C16, C17, C18, C20).
UFA – unsaturated fatty acids (C14-1, C16-1, C17-1, C18-1, C18-2, C18-3, C20-1, C20-2, C20-3, C20-4, C20-5, C22-4, C22-5, C22-6).
PUFA – polyunsaturated fatty acids (C18-2, C18-3, C20-2, C20-3, C20-4, C20-5, C22-4, C22-5, C22-6).
MUFA – monounsaturated fatty acids (C14-1, C16-1, C17-1, C18-1, C20-1).
OFA – hypercholesterolemic fatty acids (C14:0 + C16:0).
DFA – neutral and hypocholesterolemic fatty acids (C18:0 + UFA).
PI – peroxidizability index.
TI – thrombogenic index.
AI – atherogenicity index.

Discussion

Fanatico et al. (2008) observed higher BW and higher feed conversion in slow-growing chickens with outdoor access compared to those raised indoors. Wang et al. (2009) showed lower BW (by 191 g) and less efficient feed conversion (by 46 g) in slow-growing chickens in the free-range treatment compared to conventionally raised birds. Castellini et al. (2002 a) report that under the organic production system, weight gains and feed conversion are poorer than in the conventional system. However, in our study, both the Ż-33 and R-11 chickens from the organic system had

higher final BW and better feed conversion compared to the indoor system, which may confirm that the native breeds of hens are suited to free-range and organic production systems (Krawczyk et al., 2013). Different results, however, were obtained by Puchała et al. (2015), who found lower BW in 56-week-old Greenleg Partridge (Z-11) and R-11 chickens raised with free-range access. Studies by Holcman et al. (2003) and Fanatico et al. (2005 a) showed no effect of the housing system on the BW of birds.

Tauson and Holm (2001) reported lower mortality in birds from alternative, as compared to conventional, production systems. In turn, Fanatico et al. (2008) showed higher mortality for birds raised with outdoor access compared to confined birds. In our study, the R-11 birds showed 100% survival rate regardless of the rearing system. In the case of the Ż-33 chickens, a small mortality percentage was observed in the organic system.

Fanatico et al. (2005 b) report that the differences in production performance in the alternative systems are influenced by the origin of the birds. However, Rizzi and Chiericato (2010) observed no differences in BW or feed consumption between two general-purpose breeds of hens from the organic production system. In turn, Rizzi et al. (2007) found higher BW in the local breed of Robusta Maculata hens compared to the local breed of Ermellinata di Rovigo. In our study, the R-11 chickens were characterised by higher final BW and better feed conversion compared to the Ż-33 chickens, regardless of the rearing system. Likewise, Puchała et al. (2015) noted higher pre-slaughter BW for R-11 compared to Z-11 chickens.

Many authors report that the rearing system has an effect on the slaughter parameters of the birds (Castellini et al., 2002 a; Holcman et al., 2003; Fanatico et al., 2008; Dou et al., 2009; Wang et al., 2009; Sun et al., 2013; Sales, 2014). In our study, we only observed the origin × housing system interaction, which contributed to differences in the dressing percentage of the Ż-33 chickens. Birds from the indoor system were characterised by better dressing percentage with and without giblets compared to the organically raised birds.

Fanatico et al. (2005 b, 2008) observed differences in the dressing percentage and proportion of breast and leg muscle in chickens of different origin. Similar results were obtained by Rizzi et al. (2007), who found significant differences in the percentage of breast and leg muscles in two local breeds of chickens. In our study, the R-11 chickens from the organic system showed better dressing percentage with and without giblets compared to the Ż-33 chickens raised organically. The leg bone percentage was also higher in the R-11 compared to the Ż-33 chickens, which may be indicative of the differences in skeletal robustness between these two breeds.

In our study, rearing system had an effect only on the amount of drip loss from the muscle and on the yellowness of the breast muscle. Puchała et al. (2015) observed a higher percentage drip loss from the leg muscle of the chickens with outdoor access. Different results were obtained by Funaro et al. (2014), who found lower drip loss of breast and leg muscles in birds raised with outdoor access. In our study, the organically raised Ż-33 chickens had a higher drip loss of breast muscle, whereas the organically reared R-11 chickens had lower drip loss for leg muscle compared to the birds raised indoors. In turn, Almasi et al. (2015) reported no effect of rearing system

on percentage drip loss of breast and leg muscles in slow- and medium-growing broilers.

In general, the meat of chickens with outdoor access is yellower, which is due to foraging of plant material abundant in carotenoids (Chen et al., 2013; Sales, 2014). This is supported by our study, in which the yellower breast muscles were observed in birds from the organic system. Similar results were obtained by Castellini et al. (2002 a) who compared the breast muscles of broiler chickens from organic and conventional production systems. Similarly, Puchała et al. (2014) found higher b* colour values of breast and leg muscles in chickens with access to pasture. In addition, Funaro et al. (2014) showed that the birds' access to the free range contributed to the higher yellowness of their meat. The opposite results were obtained by Husak et al. (2008); organically raised broiler chickens had less yellow breast and leg muscles compared to conventionally raised birds.

The research demonstrates that genotype has a strong effect on the activity of muscles, in particular breast muscles. The R-11 chickens were characterised by lower pH compared to the Ż-33 chickens. Puchała et al. (2015) also observed lower pH_{24} of breast muscle in R-11 compared to Z-11 hens. Likewise, Rizzi et al. (2007) found differences in the final pH of breast muscles from hens of the Italian breeds Ermellinata di Rovigo and Robusta Maculata. Differences in the muscle pH of native breed hens were also reported by Puchała et al. (2014). Genotype can also influence muscle colour, which is associated with the level of final pH, and on myoglobin content in the muscle (Rizzi et al., 2007). Puchała et al. (2014, 2015) demonstrated that native breeds differ in the colour of breast and leg muscles, which is also confirmed by our study.

Rizzi and Chiericato (2010) report that the fatty acid composition of lipids depends on the diet, hepatic lipogenesis, as well as age and genotype of chickens (Bean and Leeson, 2003). The essential fatty acids (EFA) include linoleic (C18:2) and α-linolenic acids (C18:3), which are not synthesised in the body and have to be supplied with the diet (Marciniak-Łukasiak, 2011). A typical poultry diet is based on cereals that have a high omega-6 to omega-3 fatty acids ratio (Haug et al., 2010). Ponte et al. (2008 a) report that pastures are a rich source of α-linolenic acid (ALA), and access to high quality pasture can markedly improve the *n-3* fatty acids content of poultry meat. This is consistent with our study in which LA and ALA acids increased considerably in the breast muscle of the Ż-33 and R-11 chickens raised in the organic system. ALA increased in both breeds reared in the organic compared to conventional system also for leg muscles. According to Haug et al. (2010), a natural diet rich in ALA increases the percentage of EPA (eicosapentaenoic acid), DPA (docosapentaenoic acid) and DHA (docosahexaenoic acid) in chicken muscles, as well as reducing the omega-6 to omega-3 fatty acids ratio, which was confirmed by our study. A higher percentage of PUFA, mainly *n-3*, in the muscles of birds reared in the organic system was reported by Castellini et al. (2002 a), Castellini (2005) and Dal Bosco et al. (2016). In turn, Givens et al. (2011) and Funaro et al. (2014) observed a higher *n-6/n-3* ratio in the muscles of chickens reared with outdoor access compared to intensively managed birds.

It is desirable to enrich poultry meat in PUFA, but they are susceptible to oxidation and their high content favours lipid peroxidation, which reduces the shelf life of

meat and meat products (Funaro et al., 2014). PI index is a measure of the susceptibility of lipids to oxidation and of the auto-oxidation of fatty acids. In our study, PI percentage was higher in the breast muscle of the Ż-33 chickens from the organic system, in which a higher level of PUFA was also observed. Similarly, Batkowska et al. (2011) found the PI value to be higher in the muscle of birds with a higher PUFA content, namely in extensively compared to intensively, managed birds. At the same time, in the thigh muscle of extensively managed broiler turkeys, the authors found lower AI and TI values, which shows that the obtained meat has better health-promoting properties. In our study, we observed no differences in the AI and TI values between the breast and leg muscles of chickens from the different management systems.

Many authors report that the origin of birds determines the profile of fatty acids (Rizzi and Chiericato, 2010; Dal Bosco et al., 2012; Franco et al., 2012 a, b), which can be attributed to genetic properties that have an effect on lipid metabolism and fatty acid deposition (Dal Bosco et al., 2012). In our study, we found such differences in the level of fatty acids between the native breeds, in particular for the breast muscle. The Ż-33 chickens were characterised by a higher percentage of PUFA, including PUFA-6 and PUFA-3, more favourable PUFA/SFA and PUFA6/3 ratio, and a higher PI value. In turn, Puchała et al. (2015) observed differences in the percentage of unsaturated and saturated fatty acids in the muscles of R-11 and Z-11 hens. The authors found the fatty acid profile in both breeds to be more favourable for the breast muscle, which is also supported by our study.

In summary, the organic production system had a beneficial effect on the BW, feed conversion and fatty acid profile of muscle from the chickens of the two native breeds. Under organic conditions, the Rhode Island Red (R-11) chickens showed better productivity but slightly poorer fatty acid profile of the muscles compared to the Yellowleg Partridge chickens (Ż-33). In terms of the investigated traits, both breeds can be recommended for organic rearing in Poland. Both breeds of chickens may be particularly recommended for small-scale organic farming because they tolerate adverse weather conditions, are relatively undemanding with respect to their diets, and are perfectly capable of finding additional food on the free range.

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