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Comparison of qualitative and quantitative properties of the wings, necks and offal of chicken broilers from organic and conventional production systems

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ABSTRACT: The aim of the present study was to investigate qualitative and quantitative properties of wings, offal (liver, heart and gizzard) and necks of chickens from organic and conventional production systems, currently available on the market for Czech consumers. Production properties (yield and weight), surface colour (lightness, redness, yellowness) and chemical indicators (dry matter, total protein, net protein, collagen, hydroxyproline, fat, ash and phosphorus) were evaluated in fresh chicken broilers. Conventionally produced chickens had higher carcass yields but higher wing yields and weights were observed in organic broilers. The skin, bones, tip (left wings) and the meat with skin (right wings) of organic broilers were heavier ($P < 0.05$) than those of conventional chickens. The dry matter and total protein content of deboned organic broiler wings (meat with skin) was greater ($P < 0.01$) than those of conventional wings. Similarly as for yields, the offal (heart, gizzard) and necks of organic chickens had significantly ($P < 0.01$) higher weights in comparison with conventional chickens. Colour indicators showed that the external surface of the livers, necks and gizzards (muscle) from organic chickens were darker (lightness; $P < 0.01$). Total protein content in livers, hearts and necks of organic chickens was greater; fat content in the livers and necks of organic broilers was also higher ($P < 0.05$) than those of conventional broilers. The ash and phosphorus in the necks of conventional broilers was higher ($P < 0.05$) than in organic chickens. This study indicates that the quantity and quality of offal and neck from organic broilers are slightly superior compared to conventional chickens.

Keywords: meat quality; broiler; chemical indicators; liver; heart; gizzard

One of the fastest growing segments of the European food market is organic food (Lawlor et al. 2003). Consumption of organic food in the Czech Republic is rising despite the economic challenges (Zivelova and Crhova 2013). It is believed that organic food contains no harmful ingredients and thus is healthier for consumers than conventionally produced food (Grashorn and Serini 2006). According to Council Regulation (EC) No. 834/2007, the rules of organic livestock production include a high level of animal welfare (access to open air areas, preferably pasture, stocking densities) and organic feed that meets the animal's nutritional requirements (growth promoters and synthetic amino-acids should not be used). In the last few decades, the amount of available edible meat offal has increased considerably from slaughterhouses, meat processors and wholesalers (Darine et al. 2010).

Consumption of chicken by-products is increasing due to their low cost, their low content of fat as well as short time required for preparation (Alvarez-Astorga et al. 2002). Edible chicken offal is widely consumed in most countries worldwide (Nollet and Toldra 2011). Culture, religion and preference are the basic factors that affect consumption of meat offal. Therefore, while certain meat offal can be considered as valuable meal in some regions, the same might be considered as inedible in other areas (Toldra et al. 2012). The yield of edible chicken offal is approximately 6.3% (Poltowicz and Doktor 2011), neck 3% and wings 10% (Kokoszynski et al. 2013); thus, they constitute a significant part of chicken weight. The importance of edible offal is underlined by their good nutritional value for consumers (Seong et al. 2015). During the last decades, most studies have dealt with chicken muscle tissue

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and have focused only on meat quality evaluation and processing methods. Very few studies were published on the quality of chicken offal (Seong et al. 2015), particularly those from organic production systems. Quality parameters of organic and conventional broilers are affected by many factors, e.g. hybrid genotype, nutrition, age, sex, season as well as production methods (organic/conventional) (Fanatico et al. 2007; Ponte et al. 2008). There is a large price difference between edible by-product organs of organic and conventional chickens. It is, therefore, important that consumers should receive objective information about quality parameters, especially because no similar data have been published so far to the best of our knowledge.

The objective of this study was to evaluate the qualitative and quantitative characteristics of wings, necks and giblets of broilers from organic and conventional production systems as they are currently sold in retail markets.

MATERIAL AND METHODS

Production properties. This experimental analysis was carried out at the Department of Meat Hygiene and Ecology (DMHE) of the Faculty of Veterinary Hygiene and Ecology, University of Veterinary and Pharmaceutical Sciences Brno (Czech Republic). A total of 15 organic broiler chicken (OC) and 20 conventional broiler chicken (CC) carcasses were obtained directly from farms utilising organic production systems (Biopark s.r.o., Lipova, Czech Republic) meeting requirements laid down in Commission Regulation (EC) No. 889/2008 and from conventional production systems (Vodnanska drubez, a.s., Vodnany, Czech Republic) meeting requirements for safety and product quality according to the Regulation (EC) No. 852/2004 and the Regulation (EC) No. 853/2004. The conditions for breeding were as follows: (1) organic production system – Colour yield hybrid, age at slaughter 81 days, stocking density was 10 birds/m^2, birds had access to a free range area during the summer period, weight of the birds at the time of slaughter was 2379 ± 384.80 g; (2) conventional production system – Ross 308 hybrid, age at slaughter 38 days, stocking density was 18 birds/m^2, birds did not have access to a free range area, weight of the birds at the time of slaughter was 2284 ± 235.51 g.

Chickens slaughter and processing was carried out by both producers in compliance with Council Regulations (EC) No. 1099/2009 and 853/2004. The samples (packed cold carcasses) were transported from both farms to DMHE at temperature of between 2 ± 2 °C. In the DMHE, the samples were stored in a refrigerator with controlled temperature (2 ± 2 °C) until analysis. Dissection of the carcasses was done according to the Commission Regulation (EC) No. 543/2008.

The eviscerated carcass (without neck, feet and gut), wings, neck and giblets (liver, heart and gizzard) were weighed and yields were calculated according to Decree of the Ministry of Agriculture No. 471/2000. The wings were dissected from the carcasses at the shoulder joint, and then weighed as pairs and singly. The wings (drumette and wing flat) were deboned after dissection of the wing tip. The remaining meat (triceps, biceps and forearm muscles) of the wing and skin were weighed separately, whereas the meat and skin of the right wing were weighed together. The wing bones (humerus, radius, and ulna) and tip were weighed as well. Yield measurement: (1) yield of whole eviscerated carcass, pair of wings, neck and giblets were measured mathematically by the formula: yield = (weight of the aforementioned carcass cuts/live weight) × 100; (2) the yield of wing components – meat, skin, (meat with skin), bone and tip; yield = (weight of the aforementioned wing components/ wing weight) × 100.

Colour indicators. The colour indicators (lightness, L^*; redness, a^*; yellowness, b^*) of raw external surfaces (liver, heart, gizzard and neck) were measured according to the CIE $L^*a^*b^*$ system using a Minolta CM 2600d (Konica Minolta, Japan). Spectra Magic 3.61 Software was used for calculating the parameters and the mean ± SD of five measurements of each sample was reported.

Chemical analysis. The basic chemical composition indicators of the right deboned wing (meat with skin), neck and giblets (liver, heart, and gizzard) from OC and CC were evaluated. Five samples of each bird, i.e. deboned wings, neck, liver, heart and gizzard were homogenised as one sample in order to obtain an adequate amount for analysis. The amount of dry matter was determined gravimetrically by drying samples for 24 h at 103 ± 2 °C (ISO 1442 1997). The content of total protein was determined using a Kjeltec 2300 analyser (Foss Analytical AB, Hoganas, Sweden) according to

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ISO 937 (1978), net protein content was determined as the amount of nitrogen that was organically bound using the Kjeltec 2300 (Foss Analytical AB, Hoganas, Sweden) after precipitation with hot tannin solution (SOP 2000); the collagen content was computed (coefficient factor $f = 8$) from the content of the amino acid hydroxyproline (SOP 2000). The quantity of hydroxyproline was evaluated by photometric measurement of absorbance at 550 nm on a Genesys^{TM} 6 (Thermo Electron Corporation, USA) spectrophotometer (SOP 2000). The fat content was analysed on a Soxtec 2055 (Foss Analytical AB, Hoganas, Sweden) with petrol ether as extraction agent (ISO 1443 1973). Ash was detected gravimetrically by burning the sample at 550 °C until black carbon particles disappeared in a muffle oven (Elektro LM 212.11, Germany) according to ISO 936 (1978). The amount of phosphorus was determined gravimetrically after conversion to orthophosphate and was precipitated as chinolinphosphomolybdenate (SOP 2009).

Statistical analysis. Statistical analysis of data was conducted using Microsoft Office Excel 2003. Student's *t*-test was used for determination of differences between OC and CC samples. The 0.05 and 0.01 levels of significance were used.

RESULTS

The results are summarised in Tables 1–5. As shown in Table 1, no differences were observed between the weights of organic and conventional live broilers in this study. The eviscerated carcasses of CC yielded more than OC, whereas no differences were observed between their weights. The wings (pair) of OC yielded more than the wings of CC and were heavier. The results associated with the yield and weight of wing components indicated the following: the meat with skin of from the OC wings (right) weighed more than the wings of chickens from conventional production systems; the skin of wings (left) from OC had higher yields and weights than those from CC. The bones of the left wing (humerus, radius, and ulna) of OC were heavier than those of CC. The tips of the wings (left) of the OC yielded and weighed more than in CC. Hearts, gizzards and necks of OC yielded and weighed more, whereas no differences were observed in yield and liver weights.

The surface colour of liver, neck and gizzard (muscle) was darker (L^*) in OC in comparison with the CC. The heart of OC was lighter (L^*) and was less yellow (b^*) than in CC. No difference in redness

Table 1. Production properties (yield and weight of carcass portions) of organic chickens (OC, $n = 15$) and conventional chickens (CC, $n = 20$), values are presented as mean ± SD

Carcass part	Yield (%)		*P*	Weight (g)		*P*
	OC	CC		OC	CC	
Live bird	–	–		2379 ± 384.80	2284 ± 235.51	NS
Eviscerated carcass	69.22 ± 2.10^a	73.12 ± 1.54^b	**	1630.36 ± 274.81	1671.86 ± 182.43	NS
Pair wings[1]	8.75 ± 0.54^b	7.90 ± 2.32^a	**	200.39 ± 24.36^b	182.78 ± 18.40^a	*
RW (meat + skin)[2]	56.82 ± 3.28	57.22 ± 3.13	NS	57.76 ± 10.96^b	51.35 ± 6.76^a	**
LW (meat)[2]	39.14 ± 3.65	40.66 ± 3.79	NS	40.86 ± 8.06	36.24 ± 6.47	NS
LW (skin)[2]	19.57 ± 2.39^b	16.46 ± 1.13^a	**	20.29 ± 3.32^b	14.57 ± 1.83^a	**
LW (bones)[2]	29.87 ± 3.22	29.02 ± 2.08	NS	30.11 ± 4.83^b	25.98 ± 3.26^a	**
LW (tip)[2]	11.82 ± 0.75^b	10.21 ± 0.84^a	**	11.96 ± 1.92^b	9.11 ± 0.98^a	**
Neck[1]	2.14 ± 0.09^b	1.82 ± 0.50^a	**	50.96 ± 8.80^b	39.70 ± 9.10^a	**
Liver[1]	1.89 ± 0.43	1.85 ± 0.41	NS	44.11 ± 8.67	41.65 ± 7.79	NS
Heart[1]	0.57 ± 0.13^b	0.39 ± 0.06^a	**	13.32 ± 3.15^b	8.71 ± 0.99^a	**
Gizzard[1]	1.75 ± 0.58^b	1.16 ± 0.22^a	**	36.65 ± 9.65^b	26.12 ± 3.76^a	**
Giblets[1]	4.21 ± 0.72^b	3.40 ± 0.66^a	*	94.08 ± 14.59^b	76.48 ± 14.39^a	*

LW = left wing, NS = not significant, *P* = statistical significance, RW = right wing

[1]Yield from whole alive chicken, [2]yield from single wing

[a,b]Values in the same row with different letters are significantly different

*$P < 0.05$, **$P < 0.01$

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Table 2. Colour indicators of giblets and necks from organic chickens (OC, n = 15) and conventional chickens (CC, n = 20), values are presented as mean ± SD

Carcass part	Type	L^*	P	a^*	P	b^*	P
Liver	OC	36.05 ± 1.24[a]	**	14.83 ± 0.16	NS	11.46 ± 0.31	NS
	CC	38.84 ± 0.84[b]		16.37 ± 1.76		12.93 ± 1.50	
Heart	OC	40.38 ± 2.41[a]	*	15.55 ± 0.74	NS	11.12 ± 1.25[a]	*
	CC	44.22 ± 1.62[b]		15.96 ± 1.91		12.97 ± 0.73[b]	
Gizzard	OC[1]	64.11 ± 1.51[b]	**	4.01 ± 0.91	NS	13.19 ± 0.95	NS
	CC[1]	59.99 ± 0.60[a]		5.30 ± 2.69		12.95 ± 1.54	
	OC[2]	34.23 ± 1.51[a]	**	11.73 ± 0.56	NS	6.71 ± 0.52[a]	**
	CC[2]	42.14 ± 1.22[b]		15.17 ± 3.80		11.30 ± 2.79[b]	
Neck	OC	55.23 ± 1.45[a]	**	8.98 ± 1.87	NS	14.24 ± 1.87	NS
	CC	59.27 ± 1.20[b]		7.19 ± 0.72		11.58 ± 1.12	

a^* = redness, b^* = yellowness, L^* = lightness, NS = not significant, P = statistical significance
[1]Mucosa, [2]muscle
[a,b]Values in the same column with different letters between two groups (e.g. liver OC/liver CC) are significantly different
*P < 0.05, **P < 0.01

(a^*) was indicated between organic and conventional livers, hearts, gizzards and necks (Table 2).

The wings (meat with skin) from OC had higher dry matter and total protein content in comparison with CC. Although OC wings harboured higher levels of net protein, collagen, fat, ash and phosphorus content, these differences were not significant (Table 3).

Table 3. Chemical indicators of wings from organic chickens (OC, n = 15) and conventional chickens (CC, n = 20), values are presented as mean ± SD

Parts of wings	Chemical parameters (%)	OC	CC	P
Meat with skin	dry matter	32.06 ± 0.53[b]	29.73 ± 1.36[a]	*
	total protein	20.60 ± 0.62[b]	19.27 ± 0.50[a]	*
	net protein	18.74 ± 0.29	17.83 ± 0.81	NS
	collagen	2.26 ± 0.64	1.93 ± 0.31	NS
	fat	8.17 ± 1.69	5.51 ± 1.34	NS
	ash	0.87 ± 0.01	0.86 ± 0.03	NS
Meat	dry matter	25.66 ± 0.99	25.67 ± 0.69	NS
	total protein	21.67 ± 0.82	20.83 ± 0.48	NS
	net protein	20.12 ± 0.37[b]	18.93 ± 0.44[a]	*
	collagen	0.92 ± 0.21	1.22 ± 0.22	NS
	fat	1.34 ± 0.49	1.95 ± 0.12	NS
	ash	1.07 ± 0.14	0.90 ± 0.04	NS
Skin	dry matter	48.63 ± 1.91[b]	42.88 ± 1.38[a]	**
	total protein	15.50 ± 0.17	15.33 ± 1.20	NS
	net protein	12.74 ± 0.78	13.79 ± 0.51	NS
	collagen	4.41 ± 0.26	4.56 ± 0.38	NS
	fat	24.11 ± 3.73	21.35 ± 2.96	NS
	ash	0.66 ± 0.01	0.63 ± 0.02	NS

NS = not significant, P = statistical significance
[a,b]Values in the same row with different letters are significantly different
*P < 0.05, **P < 0.01

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Table 4. Chemical indicators of necks from organic chickens (OC, n = 15) and conventional chickens (CC, n = 20), values are presented as mean ± SD

Chemical parameters	OC	CC	P
Dry matter (%)	29.09 ± 0.98	27.45 ± 0.83	NS
Total protein (%)	17.61 ± 0.66[b]	16.59 ± 0.25[a]	*
Fat (%)	7.52 ± 0.90[b]	3.60 ± 0.26[a]	**
Ash (%)	2.58 ± 0.90[a]	4.77 ± 0.20[b]	**
Phosphorus (mg/100 g)	356.26 ± 111.41[a]	768.81 ± 28.36[b]	**

NS = not significant, P = statistical significance

[a,b]Values in the same row with different letters are significantly different

*P < 0.05, **P < 0.01

Total protein and fat contents of neck from the OC were higher than that of CC. The necks of CC contained more ash and phosphorus than OC (Table 4).

The content of dry matter, total protein, fat, ash and phosphorus in the livers of OC was higher than that of CC. Hearts of OC had higher total protein content than the hearts of CC. On the other hand, ash content of the gizzards of CC was higher than that of organically produced chickens (Table 5).

DISCUSSION

The results of our study showed that the yield of conventional eviscerated carcass was higher than OC carcasses, which could be due to the greater physical activity and larger energy expenditures related to thermoregulation of organic poultry (Rembialkowska and Badowski 2012). In contrast, the wings and necks of OC yielded more than CC, which is in agreement with the results found by Fanatico et al. (2005) indicating that birds with slow- and medium-growing genotypes had higher wing yields than chickens with fast-growing genotypes. The increase in breast yield, which is the result of fast-growing genotype selection, leads to a decreased yield of other chicken parts.

More usage of wings by chickens promotes an increase in bone and muscle masses. Lower stocking density of free-range production systems did not have an effect on the wing yield due to forced motor activity (Wang et al. 2009). Generally the yield of deboned meat is an important economical factor for consumers and producers (Nakano et al. 2012). The bones of the wing (humerus, radius, and ulna) from OC were heavier than CC. Fanatico et al. (2005) reported that the lower density of chickens in the raised area in organic production systems and intensive exercise in free-ranging birds (outdoor system) led to stronger bones. In contrast, Wang et al. (2009) found that the strength of tibia bones in birds reared in free-range systems was tenderer than the tibia of broilers from indoor raising systems, which was a result of the low calcium level in the diet.

The percentage of offal yield from OC was greater than from CC. Murawska et al. (2011) observed the influence of chicken age and the percentage content of giblets. They found a relationship between increased muscle tissue weights and decreased giblet contents. The average yield of the chicken giblets of the OC was 4.21% whereas in CC the value was 3.40%. However, Somsen et al.

Table 5. Chemical indicators of giblets from organic chickens (OC, n = 15) and conventional chickens (CC, n = 20), values are presented as mean ± SD

Chemical indicators	Liver		P	Heart		P	Gizzard		P
	OC	CC		OC	CC		OC	CC	
Dry matter (%)	29.53 ± 1.11[b]	24.56 ± 0.77[a]	**	25.44 ± 2.04	25.18 ± 0.51	NS	21.37 ± 0.39	21.40 ± 1.38	NS
Total protein (%)	19.95 ± 0.36[b]	17.07 ± 0.67[a]	**	15.36 ± 0.36[b]	13.77 ± 0.60[a]	*	17.33 ± 0.55	17.34 ± 0.76	NS
Fat (%)	2.74 ± 1.06[b]	1.70 ± 0.51[a]	**	3.36 ± 1.76	6.97 ± 1.01	NS	0.74 ± 0.25	0.76 ± 0.49	NS
Ash (%)	1.36 ± 0.05	1.21 ± 0.06	*	1.10 ± 0.04	0.98 ± 0.06	NS	0.88 ± 0.02[b]	0.97 ± 0.09[a]	**
Phosphorus (mg/100 g)	307.83 ± 6.81[b]	275.23 ± 11.08[a]	**	205.07 ± 8.74	174.58 ± 0.75	NS	131.72 ± 2.67	137.55 ± 9.35	NS

NS = not significant, P = statistical significance

[a,b]Values in the same row with different letters are significantly different

*P < 0.05, **P < 0.01

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(2004) reported that the average yield of chicken giblets was 4.36% at an average live weight prior to slaughtering of 1898 g in the case of conventional broilers. Dal Bosco et al. (2014) affirmed rapid muscular-skeletal development in fast-growing birds as well as excessive development of the cardiovascular system in slow-growing chickens; in line with these observations, OC showed higher heart percentages than CC. The gizzards of OC were heavier and yielded more due to differences in feeding (access to grassy paddock) which could include various kinds of forage, insects, worms and sand particles. Furthermore, the diet of organically and free-range system-produced chickens is rich in crude fibre and could stimulate the development of the gizzard (Dou et al. 2009). In agreement with our findings, Skomorucha et al. (2008) reported that the type of rearing system affected the production properties of chicken giblets; however, the observations of Poltowicz and Doktor (2011) indicated no differences in giblet yields. The results obtained in our study are in agreement with the findings of Adedeji et al. (2014), who found that the livers, hearts and gizzards of organically raised chicken broilers were heavier than conventionally fed birds.

Feeding and housing conditions are considered as environmental conditions, and may affect the colour of meat (Du and Ahn 2002). The colour of meat depends on many factors including myoglobin concentration and the degree of its oxidation as well as the structure of meat (Ruiz de Huidobro et al. 2005). The L^* values of organic giblets in the present study (liver, heart, muscular surface of gizzard) and necks were significantly lower than those of CC, which could be ascribed to poor bleeding of OC. Previous studies (Fanatico et al. 2007; Mikulski et al. 2011; Chen et al. 2013), suggested that outdoor access had a positive effect on L^* values, producing darker meat. Trampel et al. (2005) reported that lighter liver colours were associated with more total liver lipid. In contrast, we found that livers of CC were lighter in colour and contained lower fat. There is a relationship between low pH values on the one hand and poor water retention capacity and meat colour on the other (Woelfel et al. 2002; Husak et al. 2008). According to Castellini et al. (2002), the higher levels of welfare provided for birds in organic farming reduce stress conditions leads to reduced pH (lower levels of glycogen catabolised to lactic acid), and as a result the lightness value (L^*) of meat products increases. The hearts of broilers that were reared conventionally in our study were more yellow (b^* $P < 0.05$) than OC, probably due to their higher lipid content resulting from storage of lipophilic pigments (Sirri et al. 2010) However, factors that were not monitored in the present study such as pH values, feeding, pre-slaughter stress conditions and bleeding efficiency could affect the colour of giblets.

Generally, the wings are eaten by consumers as meat together with skin. The proportion of skin in the wings is the highest among all culinary chicken meat portions, representing about 22%, i.e., twice the amount present in thighs (Tomaszewska-Gras and Konieczny 2010). Generally, the data of the present study indicate that the higher dry matter and protein (total and net) content in the wing parts from OC could be due to high dietary calorie-protein ratios (Faria Filho et al. 2005) associated with the ingestion of insects and worms in the yard. Higher contents of total protein (in meat with skin) and net protein (in meat) in organic wings could be due to the higher levels of motor activity that is characteristic of birds in organic production systems; levels of myogenesis are higher than those of lipogenesis in the muscles of these birds (Castellini et al. 2002; Husak et al. 2008). Higher protein content on one hand, and lower ash and phosphorus content in OC on the other, could be explained by an increase in muscle mass and a decrease in bone mass in the neck.

Higher protein and lower fat contents in the hearts of OC can be due to the effect of motor activity on the hearts of organically reared birds (Castellini et al. 2002). Chickens reared in organic systems have more chance to ingest organic and inorganic substances from soil which may explain the higher ash content in the livers of OC.

The results of this study demonstrate differences in qualitative and quantitative properties of wings, giblets (liver, heart and gizzard) and necks between OC and CC, which could be due to various factors such as genotype, age, feeding, that may not necessarily reflect the effect of the production system only. It should be remembered that the results of this study reflect the characteristics of wings, necks and giblets from chickens provided to the consumer in markets. The main differences between OC and CC observed in our study are the following: CC had higher eviscer-

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ated carcass yields; OC had higher wing yields, were heavier and contained more total protein; the giblets (heart, liver and gizzard) and necks of OC had higher yields and protein content, making this edible offal more valuable. Generally, the yield of edible offal in chickens is low. Yield improvement is beneficial for consumers, both quantitatively and qualitatively and may lead to consumers reconsidering the inclusion of these products in their diet, making it more versatile.

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