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Effect of organic production system on broiler carcass and meat quality

C. Castellini*, C. Mugnai, A. Dal Bosco

Dipartimento di Scienze Zootecniche, Università di Perugia, Borgo XX Giugno 74, 06121 Perugia, Italy

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Abstract

The effect of organic production on broiler carcass and meat quality was assessed. Two hundred and fifty Ross male chickens were assigned to two different systems of production: conventional, housing in an indoor pen (0.12 m^2/bird); organic, housing in an indoor pen (0.12 m^2/bird) with access to a grass paddock (4 m^2/bird). At 56 and 81 days of age, 20 chickens per group were slaughtered to evaluate carcass traits and the characteristics of breast and drumstick muscles (*m. pectoralis major* and *m. peroneus longus*). The organic chickens had carcasses with a higher breast and drumstick percentages and lower levels of abdominal fat. The muscles had lower pHu and water holding capacity. Instead cooking loss, lightness values, shear values, Fe, polyunsaturated fatty acids of n-3 series and TBA-RS were higher. The sensory quality of the breast muscle was better. Organic production system seems to be a good alternative method, due to better welfare conditions and good quality of the carcass and meat. A negative aspect was the higher level of TBA-RS in the muscles, probably due to greater physical activity.

Keywords: Organic production; Chicken; Meat quality

1. Introduction

An increasing number of consumers demanding health and natural foods have favoured organic livestock farming, that is reputed to be environmentally friendly, sustaining animals in good health, with high welfare standards and resulting in high quality products (Sundrum, 2001). According to recent guidelines (Council Regulation (EC), 1999, Nos 2092/91 and 1804/99), the primary characteristics of this production system are: a defined standard; greater attention to animal welfare (stocking density, perches, free-range areas); no routine use of growth promoters, animal offal or any other additives; at least 80% of feed grown according to organic standards, without the use of artificial fertilisers or pesticides on crops or grass.

The higher guarantee of the absence of residues is certain, but the effect of this production system on the qualitative characteristics of the products is unknown. Hence, the aim of the present study was to contribute to the knowledge of qualitative traits of broiler carcass and meat produced organically.

2. Materials and methods

2.1. Animals and diets

From March to May 2000, 500, 1-day-old Ross male chicks, were randomly assigned to one of two housing conditions:

- control group, housed in an indoor pen (0.12 m^2/bird) where the temperature was 17.56 ± 2.7°C, the relative umidity 65–75%, and the photoperiod 12 h;
- organic group, housed in a similar indoor pen (0.12 m^2/bird), but with access to a grass paddock (4 m^2/bird).

Chicks were fed ad libitum the same diets (1–13 days: starter; 14 day-slaughter: finisher) containing, as required by EC Regulation, more than 80% of organic ingredients certified by a National agency. The characteristics of the finisher diet are presented in Table 1.

* Corresponding author. Tel.: +39-75-585-7104.
E-mail address: ccsarc@unipg.it (C. Castellini).

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2.2. Behaviour

The behaviour of the individual birds was recorded by two operators at 7 and 10 weeks of age, during two periods of 3 h each. The observations reported in this paper concerned motory activity and resting (sitting, dozing and sleeping). Furthermore, just before slaughter the plumage condition was empirically evaluated using a three-point scale and birds were subjected to a tonic immobility test for fear response as described by Scott and Moran (1993).

2.3. Sample collection and analytical determinations

At 56 and 81 days (standard slaughtering ages in Italy for conventional and organic broilers, respectively), after fasting of 12 h, 20 males were randomly selected from each group. The birds were electrically stunned, killed by manual exsanguination, plucked and eviscerated (non-edible viscera: intestines, proventriculus, gall bladder, spleen, oesophagus and full crop).

From the refrigerated carcasses (24 h at +4°C), head, neck, legs, edible viscera (heart, liver, gizzard), and fat (perivisceral, perineal and abdominal) were removed to obtain the ready-to-cook carcass. From breast and drumstick the *pectoralis major* and *peroneous longus* muscles were excised for analysis.

Whole samples of both muscles (about 20 g) were placed in open aluminium pans and roasted in an electric oven (pre-heated to 200°C) for 15 min to an internal temperature of 80°C (Cyril, Castellini, & Dal Bosco, 1996). Cooking loss was estimated as the percentage of the weight of the roasted samples, (cooled for 30 min to about 15°C and dried on the surface with a paper towel) with respect to the raw ones.

Ultimate pH (pHu) was measured at 24 h with a Knick digital pHmeter (Broadly Corp., Santa Ana, CA, USA) after homogenization of 1 g of raw muscles for 30 s in 10 ml of 5 M iodoacetate (Korkeala, Mäki-Petais, Alanko, & Sorvettula, 1986).

The water holding capacity (WHC) was estimated (Nakamura & Katoh, 1985) by centrifuging 1 g of the muscles placed on tissue paper inside a tube for 4 min at $1500\times g$. The water remaining after centrifugation was quantified by drying the samples at 70°C overnight. WHC was calculated as: (weight after centrifugation−weight after drying)/initial weight×100.

Shear force was evaluated on cores (1.25×2 cm) obtained from the mid-portions of the roasted samples (as above) by cutting them perpendicularly to the fibre direction, using an Instron, model 1011, equipped with a Warner–Bratzler Shear.

The colour parameters (L^*, a^*, b^*) were measured on the raw muscles using a tristimulus analyser (Minolta Chroma Meter CR-200), using the Cielab Colour System (1976). Chemical analyses of diet and meat were done according to AOAC (1995) methods.

The extent of lipid oxidation was evaluated on raw and cooked meat as TBA-RS (Thio Barbituric Acid Reactive Substances) by the modified method of Ke, Ackman, Linke, and Nash (1977). Ten grams of minced muscles were homogenised for 2 min with 95.7 ml of distilled water and 2.5 ml of 4 N HCl. The mixture was distilled until 50 ml was obtained. Then, 5 ml of the distillate and 5 ml of TBA reagent (15% trichloroacetic acid, 0.375% thiobarbituric acid) were heated in a boiling water bath for 35 min. After cooling under running tap water for 10 min, the absorbance was measured at 538 nm against an appropriate blank. TBA-RS values were obtained by multiplying optical density by 7.843. Oxidation products were quantified as malondialdehyde equivalents (MDA mg/kg muscle).

Total and haem iron of muscle were determined according to the Schricker, Miller, and Stouffer (1982) and O'Brien et al. (1992) procedures, respectively.

The fatty acid composition of diets, breast and drumstick was determined on lipids extracted from samples of about 5 g in a homogeniser with 20 ml of 2:1 chloroform/methanol (Folch, Lees, & Sloane-Stanley,

Table 1
Composition of the finisher diet

Ingredients	(%)
Ground maize	45.0
Whole soybean	12.5
Wheat	20.0
Soya meal[a]	14.0
Dehydrated alfalfa meal	2.8
Fish meal	3.0
Vitamin-mineral premix[b]	1.0
Calcium diphosphate	1.0
Sodium bicarbonate	0.5
NaCl	0.2
Chemical composition	
Crude protein	19.10
Ether extract	4.98
Crude fibre	4.01
Ash	5.59
NDF (neutral detergent fibre)	10.11
ADF (acid detergent fibre)	4.67
Cellulose	3.56
ADF (acid detergent liquid)	1.11
Hemicellulose	5.05
Metabolizable energy	13.03 MJ/kg
Fatty acids	
∑ Saturated	30.41
∑ Monounsaturated	37.49
∑ Polyunsaturated	32.10
∑ (n-6)	30.90
∑ (n-3)	1.20

[a] From conventional crops.
[b] Added per kg: Vit. A 11.000 IU; Vit. D_3 2.000 IU; Vit. B_1 2.5 mg; Vit. B_2 4 mg; Vit. B_6 1.25 mg; Vit. B_{12} 0.01 mg; α-tocopheryl acetate 50 mg; biotin 0.06 mg; Vit. K 2.5 mg; niacine 15 mg; folic acid 0.30 mg; panthotenic acid 10 mg; choline 600 mg; Mn 60 mg; Fe 50 mg; Zn 15 mg; I 0.5 mg; Co 0.5 mg.

1957), followed by filtration through Whatman No. 1 filter paper. Fatty acids were determined as methyl esters with a Mega 2 Carlo Erba Gas Chromatograph, model HRGC (Milano, Italy), using a D-B wax capillary column (25 mm ø, 30 m long). The fatty acid percentages were calculated using the Chrom-Card software.

2.4. Sensory analyses

Sensory panel test was performed on breast samples, roasted without salt or spice. The cooked samples were immediately sliced into eight pieces and randomly offered to nine trained panellists. The trial consisted of four sessions, and the traits assessed were: tenderness, juiciness, fibrousness and overall acceptability. A five-point scale was used, 1 referring to very disagreeable, very tough, very dry, very fibrous and 5 to very agreeable, extremely tender, very juicy, without fibre (Cross, Durland, & Seideman, 1978).

2.5. Statistical analyses

Data of qualitative traits were analysed with a linear model (SAS/STAT, 1990, procedure GLM) including the effect of age×production system. Significance of differences was evaluated by *t*-test.

3. Results and discussion

3.1. Feed efficiency and carcass characteristics

The feed efficiency, live and carcass weight and joint percentages were significantly affected by age and production system (Table 2). Control birds at 56 days reached the commercial weight with satisfactory carcass traits. Organic broilers, as expected, showed lower growth performance, but, at both ages, the amount of abdominal fat was significantly lower and the percentages of breast and drumstick were higher in comparison with the control birds.

The behaviour observations of the organic chicks showed more locomotory activity (×1.8; $P<0.05$) and less resting (×0.8; $P<0.05$), according to Andrews, Omed, and Phillips (1997). Thus, their growth rate and feed efficiency were poorer. Also the uncontrolled environment conditions in the paddock could have increased their energy requirements with consequent increase of feed conversion.

The greater motion reduced the abdominal fat, and favoured muscle mass development in agreement with Lewis, Perry, Farmer, and Patterson (1997).

Also, Ricard (1977) found less abdominal fat and an increase in breast muscles in broilers who had access to the open air. Likewise, Lei and Van Beek (1997) stated that forcing motory activity increased the breast percentage.

3.2. Chemical and physical characteristics of breast and drumstick

The chemical–physical characteristics of the breast and drumstick muscles (Table 3) showed higher values for moisture and lower for fat and energy in organic animals, confirming that motory activity favours myogenesis against lipogenesis.

The pHu and WHC were lower in organic broilers, so that cooking loss was higher. Also Wal et al. (1993) and Enfält, Lundstrom, Hansson, Lundeheim, and Nystrom (1997) reported a lower pHu in the *m. longissimus lumborum* and *m. biceps femoris* of outdoor reared pigs. Similarly, Maribo (1995) found the pHu of *m. biceps femoris* to be lower in pigs reared in large pens compared with conventional pens.

The lower pHu of the organic chickens could be due to the better welfare conditions that reduced the stress pre-slaughter and thus consumption of glycogen.

In fact, the behaviour observations of the organic birds showed a better response to the tonic immobility

Table 2
Feed efficiency and slaughter traits[a]

	Control		Organic		S.E.M.
	56 days	81 days	56 days	81 days	
Feed efficiency	2.31A	2.89C	2.75B	3.29D	0.92
Live weight (LW) (g)	3219B	4368D	2861A	3614C	214
Eviscerated weight (g)	2595B	3529D	2314A	2928C	137
Refrigerated weight (g)	2569B	3485D	2274A	2870C	98
Carcass weight (CW)[b] (g)	2263B	3071D	2011A	2537C	99
Dressing out (CW/LW) (%)	70.3	70.3	70.3	70.2	1.70
Abdominal fat (%)	1.9B	2.9C	0.9A	1.0A	0.8
Breast (%)	22.0a	23.5b	23.2b	25.2c	0.95
Drumstick (%)	14.8a	15.0a	14.9a	15.5b	0.62

[a] For each group $n=20$; a–c, $P<0.05$; A–D, $P<0.01$.
[b] Ready-to-cook

test (Scott & Moran, 1993), with times to right themselves, of 40 s compared with 180 s ($P<0.01$) in the conventional birds. They also showed a greater interest in the observer and the quality of their plumage was very good (3 vs 1.9; $P<0.01$). These all indicate better welfare conditions.

According to Andersson, Andersson, and Essen-Gustarsson (1990) increased exercise and calm behaviour make animals less susceptible to the stress connected with transport and slaughter.

Enfält et al. (1997) suggested that the lower pHu found in outdoor reared pigs could be the consequence of a better capacity to utilise substrates other than glycogen during transport to the slaughter-house.

The pHu is known to influence the structure of myofibrils and consequently the water holding capacity and the colour of the meat. It is well established (Warris, 2000) that shrinkage of the contractile fibres caused by a lower pHu reduces the water-binding ability and therefore increases light scattering. These relationships were confirmed in the present study where organic birds had muscles with lower water holding capacity and higher reflectance. Furthermore, a low pHu reduces the importance of myoglobin in selectively absorbing green light, resulting in meat that appears less red and more yellow. The variations in a^* were not clear because they were masked by the higher myoglobin content, mainly in the drumstick muscle, which is more oxidative.

The tenderness was high in all cases but decreased with age as observed by Touraille, Kopp, Valin, and Richard (1991) and Tawfik, Osman, Ristic, Hobeler, and Klein (1990). However other authors (Delpech, Dumont, & Nefzaoui, 1983; Mohan, Narahari, Venkatesan, & Jaya Prasad 1987; Sonaiya, Ristic, & Klein 1990) found no difference due to age.

Also the production system affected the shear value that was higher in either the breast or drumstick of the organic animals, presumably as a consequence of their greater motory activity. Farmer, Perry, Lewis, Nute, Piggott, and Patterson (1997) observed the same tendency for breast meat from birds reared under a lower stocking density.

3.3. *Fatty acid profile and oxidative status of breast and drumstick*

The fatty acid profile (Table 4) of the breast and drumstick muscles of the organic animals showed a higher fraction of saturated fatty acids (SFA) and lower one of monounsaturated (MUFA) with respect to the control. The percentage of polyunsaturated (PUFA) was higher, particularly the levels of eicosapentaenoic

Table 3
Chemical and physical characteristic of the breast and drumstick

	Control		Organic		S.E.M.
	56 days	81 days	56 days	81 days	
Breast					
Moisture (%)	75.54ab	74.85a	76.28c	75.78bc	0.48
Protein (%)	22.39	22.34	22.35	22.76	0.85
Lipids (%)	1.46B	2.37B	0.72A	0.74A	0.15
Ash (%)	0.61	0.64	0.65	0.72	0.11
Gross energy (MJ/kg d.m.)	21.81B	22.86B	20.18A	20.93A	0.57
Ultimate pH	5.96b	5.98b	5.75a	5.80a	0.25
WHC (%)	52.02a	55.26d	51.82a	53.17c	1.45
Cooking loss (%)	31.10A	30.26A	33.98B	33.45B	5.15
L^*	59.23a	58.95a	60.74b	60.39b	1.35
a^*	4.96	5.02	4.59	4.94	1.35
b^*	5.16a	4.38a	6.01b	5.76b	5.07
Shear value (kg/cm^2)	1.98a	2.10a	2.25a	2.71b	0.40
Drumstick					
Moisture (%)	76.02a	75.39a	77.32b	76.95b	1.02
Protein (%)	19.01	19.06	19.38	19.47	0.98
Lipids (%)	4.46B	5.01B	2.47A	2.83A	1.05
Ash (%)	0.51a	0.54a	0.72b	0.75b	0.21
Gross energy (MJ/kg d.m.)	24.30B	24.81B	22.11A	22.20A	1.04
Ultimate pH	6.18bc	6.25c	6.02a	6.10ab	0.19
WHC (%)	59.69b	60.15b	56.21a	57.45a	2.25
Cooking loss (%)	32.65a	31.03a	35.17b	34.02b	3.15
L^*	52.86a	51.74a	56.28b	54.93b	4.01
a^*	5.78	5.93	5.84	6.07	1.75
b^*	4.95ab	4.03a	5.83b	5.05b	4.48
Shear value (kg/cm^2)	2.39a	2.87b	3.08b	3.48c	0.50

For each group, $n=20$; a–d, $P<0.05$; A–B, $P<0.01$.

(EPA), docosapenaenoic (DHA) and total n-3 fatty acids. This trend could be partly due to the different compositions of the ingested foods, caused by grass intake. In lamb and beef (Enser, Hallet, Hewett, Fursey, Wood, & Harrington, 1998) a large effect of grass-based diets on the levels of α-linolenic acid and others n-3 PUFA was observed.

Furthermore, the leaner meat of these animals had a higher proportion of phospholipids, that are richer in PUFA and particularly in C_{20} and C_{22} fatty acids (Elmor, Mottram, Enser, & Wood, 1999). The TBA-RS values (Table 5) were higher in the organic animals than in the control, and in the drumstick than in the breast.

The cooking increased the TBA-RS level by 1.8 to 2.1 times, but the meat acceptability was not affected. In fact the sensory panel test gave significantly higher scores for juiciness (3.7 vs 3.3; $P<0.05$) and overal acceptability (3.5 vs 3.0; $P<0.05$) to the breast muscles from the organic chicks.

The lower lipid stability of the organic animals could be due to the higher content of metallic ions (total and haem Fe) that catalyse peroxidation, and to the greater degree of unsaturation of intramuscular lipids (Fukozawa & Fuji, 1992). It is known that exercise increases the amount of haem-iron (Hoffmann, 1995) particularly in the more oxidative muscles (O'Brien et al., 1992). It is also known that a greater degree of physical fitness increases the muscle oxidative capacity (Petersen, Henckel, Maribo, Oksbjer, & Sorensen, 1997) and that the exercise increases the number of mitochondria in αW fibres, hence turning them into αR fibres (Hulot & Ouhayoun, 1999). The intensification of the oxidative

Table 4
Oxidative status and Fe content of the breast and drumstick

	Control		Organic		S.E.M.
	56 days	81 days	56 days	81 days	
Breast					
TBA-RS					
Raw (mg MDA/kg)	1.82A	2.02A	2.14A	2.98B	0.16
Cooked (mg MDA/kg)	3.28A	3.75A	3.82A	5.32B	0.29
Fe total (mg/kg)	3.40a	3.51b	3.62ab	4.04b	0.58
Fe haeme (mg/kg)	1.53a	1.57a	1.67a	1.83b	0.30
Drumstick					
TBA-RS					
Raw (mg MDA/kg)	2.58A	3.21A	3.58AB	4.12B	0.65
Cooked (mg MDA/kg)	5.42A	6.35A	6.95A	7.81B	0.87
Fe total (mg/kg)	6.22a	6.49a	7.05ab	7.83b	0.60
Fe haem (mg/kg)	2.79a	2.92a	3.15b	3.56c	0.42

For each group, $n=20$; a–c, $P<0.05$; A–B, $P<0.01$.

Table 5
Fatty acid composition of the breast and drumstick

	Control		Organic		S.E.M.
	56 days	81 days	56 days	81 days	
Breast					
∑ Saturated	34.68A	35.89A	37.05B	37.89B	3.87
∑ Monounsaturated	33.89B	32.96B	30.21A	29.72A	0.99
∑ Polyunsaturated	31.43a	31.15a	32.74b	32.38b	2.57
C20:5(n-3) EPA	0.45a	0.42a	0.61b	0.56b	0.03
C22:6(n-3) DHA	0.96a	0.79a	1.85b	1.91b	0.29
∑ (n-3)	4.52a	4.01a	5.46b	5.12b	0.22
Drumstick					
∑ Saturated	33.90A	34.56A	35.91B	36.18B	1.98
∑ Monounsaturated	38.07B	37.89B	31.89A	31.69A	1.56
∑ Polyunsaturated	28.03A	27.55A	32.21B	32.13B	1.48
C20:5(n-3) EPA	0.21a	0.29b	0.28b	0.32b	0.02
C22:6(n-3) DHA	0.38a	0.45a	1.14b	1.27b	0.05
∑ (n-3)	3.34a	3.12a	4.85b	4.73b	0.19

For each group, $n=20$; a–b, $P<0.05$; A–B, $P<0.01$.

processes produced a higher amount of free radicals that favoured peroxidative processes after death.

4. Conclusion

From these results, it is concluded that rearing chickens by the organic system seems to be a possible alternative to the conventional method. This is due to the more natural rearing conditions, that increase motory activity, favour the development of the muscle mass and reduce fatness, make animals calmer and less sensitive to stressors, improving their response to pre-slaughter treatments. A negative aspect is the higher level of TBA-RS, but the oxidative status did not affect consumer acceptability.

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