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Effect of feeding and genotype on the lipid profile of organic chicken meat

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Lipid profile of organic chicken meat ((Running title))

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Abbreviations: AA, arachidonic acid; **ALA**, α-linolenic acid; **DHA**, docosahexaenoic acid; **DPA**, docosapentenoic acid; **EPA**, eicosapentaenoic acid; **FB**, faba bean diet; **FG**, fast-growing genotype; **MG**, medium-growing genotype; **MUFA**, monounsaturated fatty acid; **SB**, soybean diet; **SFA**, saturated fatty acid; **SG**, slow-growing genotype

Received: October 6, 2009 / Revised: January 5, 2010 / Accepted: February 2, 2010
DOI: 10.1002/ejlt.200900204

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((Abstract))

The effects of partial substitution of soybean with faba bean and of genotypes [fast-growing Cobb 700 (FG), medium-growing naked-neck Kabir (MG), slow-growing Brown Classic Lohman (SG)] on the lipid composition as well as the meat quality attributes of chickens reared under organic conditions were evaluated. A total of 720 1-day-old male chicks were equally divided into three groups according to genotype and raised for 81 (MG and FG) or 96 days (SG): half birds of each genotype received either soybean grower diet or faba bean grower diet. Meat from SG and MG birds exhibited a lower lipid content than that from FG birds. Both in breast and thigh meat, MUFA were significantly increased from SG to MG and FG. SG meat contained the highest amounts of either arachidonic acid, eicosapentenoic acid, docosahexaenoic acid or docosapentaenoic acid, but the lowest amounts of α-linolenic acid. Total PUFA gradually decreased from SG to MG and FG birds (413, 358 and 324 g/kg of fat), as well as total *n*-6 and total *n*-3. The Δ^5- plus Δ^6-desaturase index was 54.0, 34.4 and 23.6 for SG, MG and FG birds, respectively. The *n*-6/*n*-3 ratio was lower in SG and MG than in FG birds. The partial replacement of soybean with faba bean had a lesser effect than the genotype on the meat quality characteristics.

Keywords: Fatty acid composition / Feeding / Genotype / Meat / Organic chicken

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Practical application

The data produced in this experiment may be useful to understand the impact that different chicken genotypes as well as feed ingredients have on the lipid and fatty acid profiles of breast and thigh meat from organic chickens.

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1 Introduction

The chemical composition and in particular the fatty acid profile of organic chicken meat is not well characterized and varies considerably since a wide range of ages, breed types and feed ingredients are used [1]. One of the most critical factors for organic meat quality is the genetic strain. Indeed, even if the organic system regulations 1804/99 [2] and 889/2008 [3] suggest the use of indigenous breeds, the same fast-growing broiler genotypes as used in conventional rearing systems are mostly utilized. However, commercial broiler hybrids do not have a growth profile suited to 81-day production, the standard slaughtering age for organic chickens, while slow-growing birds, even though less efficient than fast-growing ones, fit better with the organic system requirements [4]. In several experiments carried out to compare fast-, medium-, and slow-growing broiler chicken genotypes reared under organic conditions, important differences were observed both in meat quality attributes and productivity [5–8]. In particular, slow-growing birds, in comparison with medium- and fast-growing chickens reared for 81, 67 and 53 days, respectively, exhibited the highest drip and cook losses and less tender meat [5, 9]. Moreover, Quentin et al. [7] observed that the breast meat color of slow-growing chickens showed lower lightness (L*) as well as higher yellowness (b*) and redness (a*) than medium- and fast-growing birds.

Diets also play an important role in the carcass and meat characteristics. Poultry diets are based on corn-soybean ingredients and the concern for contamination of organic feeds with genetically modified organisms (GMO), which are banned by the regulation in force, has led researchers to investigate the potential introduction of alternative protein sources. Among the grain legumes, faba bean represents the most interesting alternative protein source. In the literature, the results of partial inclusion of bean in poultry diets on digestibility are described, along with the detrimental effect on productivity [10, 11]. Farrell et al. [12] found that faba bean gave a better growth rate and feed efficiency when administered to broilers at the inclusion of 200 g/kg feed. However, there is a lack of information concerning the impact of faba bean as well as of different genotypes on the lipid profile of organic chicken meat.

The objective of this study was to evaluate the effects of partial substitution of soybean with faba beans and of different genotypes on carcass yields and meat quality attributes of chickens reared under organic conditions.

2 Materials and methods

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2.1 Animals and treatment

The experiment was approved by the Ethics Committee of the University of Perugia. A total of 720 1-day-old male chicks were used: meat-type fast-growing Cobb 700 (FG; $n = 240$), meat-type medium-growing naked-neck Kabir (MG; $n = 240$), egg-type slow-growing Brown Classic Lohman (SG; $n = 240$). The birds were housed in three indoor pens in the same environmentally controlled poultry house till 21 days of age and fed *ad libitum* the same starter diets formulated according to the EC regulations [2, 3] by using only organic raw materials (Tables 1, 2). Birds of each genotype were then split into two groups and transferred to six different poultry houses with outdoor pens covered with grass. From 22 days to slaughtering, half birds of each genotype received either soybean grower diet (SB; $n = 360$) or faba bean grower diet (FB; $n = 360$) in partial substitution of soybean (Tables 1, 2). FG and MG birds were raised for 81 days, the minimum age required by regulations 1804/99 and 889/2008 [2, 3], while SG birds were raised for 96 days according to the achievement of the market live weight typical for these birds due to their slow growth rate. Feed and representative samples of grass were collected during the experimental period for proximate and fatty acid analysis.

((Table 1, Table 2))

The birds of each experimental group were individually weighed and 15 birds were randomly selected, labeled and subsequently processed under commercial conditions. After chilling, carcasses were stored at 4 °C for 24 h and used for subsequent meat quality evaluation.
Moisture, protein, total lipid, ash, and fatty acid composition were determined on *Pectoralis minor* and *Biceps femoris* muscles and color attributes were evaluated on skin and on breast fillets (*Pectoralis major* muscle).

2.2 Analytical methods

Proximate analysis (moisture, protein, lipid, and ash content) was carried out on feed, grass and meat, both breast (*P. minor*) and thigh (*B. femoris*). Moisture content was determined in duplicate according to the AOAC procedure [13]. Proteins were determined using a standard Kjeldahl copper catalyst method [13]. Ashes were determined according to the procedure described by the AOAC [13].

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Total lipids were measured using a modification of the chloroform/methanol procedure described by Folch et al. [14]. After the extraction of total lipids, fatty acids of feed, grass and both breast and thigh meat were converted to their methyl esters following the method described by Christopherson and Glass [15]. The separation of fatty acids was carried out by using a Shimadzu GC17A gas chromatograph (Shimadzu Corporation, Tokyo, Japan) with a WP-4 Shimadzu integration system, equipped with a Varian CP-SIL88 capillary column (100 m length; 0.25 mm i.d.; 0.20 μm film thickness) (Varian, Walnut Creek, CA, USA) and a flame ionization detector. The operating conditions of the gas chromatograph were as follows: The oven temperature was kept at 170 °C for 15 min, increased to 190 °C at a rate of 1 °C/min, then increased to 220 °C at a rate of 5 °C/min and kept at this temperature for 17 min. The temperature of the injector was 270 °C and that of the detector was 300 °C. Helium was used as the carrier gas at a constant flow rate of 1.7 mL/min. The identification of individual fatty acids was carried out by using PUFA-2 fatty acid methyl ester standards (Matreya, Pleasant Gap, PA, USA).

The International Commission on Illumination (CIE) [16] system color profile of lightness (L*), redness (a*), yellowness (b*), hue (H* = arctan b*/a*), and chrome ($C^* = \sqrt{a^{*2} + b^{*2}}$) was performed by a reflectance colorimeter (Minolta Chroma Meter CR-400, Minolta Italia, Milano, Italy) using illuminant source C. The colorimeter was calibrated throughout the study using a standard white (reference number 1353123; $Y = 92.7$, $x = 0.3133$, and $y = 0.3193$) ceramic tile. The carcass skin color was determined on the thickest part of the skin located on the *pectoral pterilae* (the area between the pectoral and sternal feather tracts). Breast meat color was evaluated averaging three measurements taken on the medial surface of the fillet (bone side) in an area free of obvious color defects (bruises, discolorations, hemorrhages, full blood vessels, or any other condition that may have affected uniform color reading).

2.3 Calculations and statistical analysis

To evaluate the activity of both Δ^5-desaturase and Δ^6-desaturase, the enzymes catalyzing the formation of long-chain *n*-6 and *n*-3 polyunsaturated fatty acids (PUFA) starting from the precursors C18:2*n*-6 and C18:3*n*-3, the following equation was calculated: Δ^5-desaturase plus Δ^6-desaturase = [C20:2*n*-6 + C20:4*n*-6 + C20:5*n*-3 + C22:5*n*-3 + C22:6*n*-3/C18:2*n*-6 + C18:3*n*-3 + C20:2*n*-6 + C20:4*n*-6 + C20:5*n*-3 + C22:5*n*-3 + C22:6*n*-3] × 100. Data were analyzed using two-way ANOVA and means were separated by the Student–Newman–Keuls

test [17]. The statistical model for carcass yields and color, meat chemical composition and fatty acid composition involved the fixed effects of genotype, diet and their interaction.

3 Results

3.1 Diet composition

The average ingredients and the chemical and fatty acid compositions both of the diets and the grass are given in Tables 1 and 2. The grower diets were formulated to achieve similar energy and protein contents. In the FB diet, about 40% soybean was substituted with faba bean at the level of 150 g/kg diet. The FB diet thus had a lower content of energy and lipids and a higher content of fiber. The fatty acid composition of the grower diets was almost identical. The most abundant fatty acids were C18:2*n*-6 and C18:1*n*-9, C16:0 and C18:3*n*-3, together accounting for more than 93% of the total fatty acids. The grass composition of the six outdoor pens was similar and the average values are reported in Table 2. The most representative fatty acid of the grass was C18:3*n*-3, followed by C18:2*n*-6, C16:0 and C18:1*n*-9.

3.2 Body live weight and carcass yields

Table 3 reports data concerning body live weight and carcass yields. The genotype dramatically affected all the parameters (p <0.01) whereas the diet had no effect. Even if slaughtered 2 weeks later than the MG and FG birds, the SG birds had the lightest live weight (1782 g *vs.* 2659 and 5184 g, respectively; p <0.01). Total mortality ranged from 6 to 20% but was affected by predators (data not shown). FG birds showed a significantly higher dressing out percentage than both MG and SG birds (p <0.01). The same birds exhibited the highest proportion of breast and the lowest proportions of thigh plus drumstick and of wing (p <0.01). The partial substitution of soybean with faba bean produced birds with a body live weight that did not differ from that of the SB group (3200 *vs.* 3216 g). The same trend was observed for carcass weight, dressing out and cut-up yields.

((Table 3))

3.3 Meat quality traits

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The chemical composition of breast and thigh meat is given in Table 4. The genotype influenced all the parameters considered (moisture, protein, lipid and ash) of breast meat. Both FG and SG breast meat had higher moisture and lower ash contents than MG meat (p <0.01). The SG group showed a higher content of protein in comparison with the FG birds while the MG birds had an intermediate value. SG and MG birds exhibited a lower lipid content than the FG group (p <0.01). The diet had a minor effect on the chemical composition of breast meat, influencing only the moisture content, which was significantly higher in FB birds.

((Table 4))

As for thigh meat, SG and MG birds showed higher moisture values than the FG group (p <0.01). The lipid content of the thigh meat gradually increased from SG to MG and FG birds (p <0.01). As for the effect of the diet, only ash was significantly higher in the SB group.

Table 5 reports the data concerning the fatty acid composition of breast meat. The total saturated fatty acids (SFA) were not influenced by the genotype, even if C14:0, C18:0 proportions differed among groups. Total MUFA significantly increased from SG to MG and FG birds, reflecting the trends of both C16:1*n*-7 and C18:1*n*-9.

((Table 5))

Total PUFA gradually decreased from SG to MG and FG birds (p <0.01), as well as total *n*-6 and total *n*-3. In detail, SG breast contained an amount of arachidonic acid (AA) about twice and three times higher than that of MG and FG, respectively; moreover, it had higher contents of long-chain *n*-3 PUFA (C20:5, C22:5, C22:6) but lower amounts of α-linolenic acid (ALA). This trend is explained by the Δ^5- plus Δ^6-desaturase index, used to estimate the enzymes activity, which was 54.0, 34.4 and 23.6 for SG, MG and FG birds, respectively (p <0.01). The *n*-6/*n*-3 ratio was favorably lower in SG than in MG and FG birds (p <0.01). The diet influenced only the PUFA, which were higher in SB than in FB groups (p <0.01), mainly due to the higher proportion of total *n*-6 (p <0.01).

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Table 6 shows the data concerning the fatty acid composition of thigh meat. The effect of the genotypes on thigh meat was very similar to that described for breast meat. MG and SG birds showed significantly higher levels of SFA in comparison with the FG group, with small numerical differences among groups (p <0.01). MUFA significantly increased from SG to MG and FG birds (p <0.01), mainly due to the C18:1 content. PUFA gradually decreased from SG to MG and FG birds (p <0.01) as well as total n-6 and total n-3. The Δ^5- plus Δ^6-desaturase index showed the same trend described for breast meat, but the differences among genotypes were smaller. The n-6/n-3 ratio was lower in SG and MG birds than in FG birds (p <0.01).

((Table 6))

The partial substitution of soybean with faba bean affected the proportion of SFA and MUFA, which were higher and lower in the FB groups in comparison to SB. The diet influenced the total PUFA, which were higher in SB than in FB groups (p <0.01), mainly due to the higher proportion of total n-6 (p <0.01).

The skin and breast meat color attributes are given in Table 7. The skin of SG and MG birds was similar and significantly paler than that of FG birds (p <0.01), with lightness (L*) values being 72.9, 72.5 and 69.4, respectively. Skin redness (a*) gradually decreased from FG to MG and SG birds (p <0.01), whereas yellowness (b*) and chrome (C*) were higher in MG birds than in FG and SG birds, which did not differ from each other (p <0.01). The effect of the diet on skin color was less pronounced than that of the genotype, with only yellowness and chrome being significantly different among groups. The skin of the FB birds was less yellow than that of the SB birds (p <0.01) and the chrome values of the FB birds were also lower (p <0.01).

((Table 7))

The breast meat from FG birds was significantly paler than that of MG birds (p <0.01), with intermediate values for the SG group. Both FG and MG birds had higher values of yellowness and chrome than SG birds (p <0.01). As observed for skin, yellowness and chrome were higher in the SB than in the FB group also in breast meat (p <0.01).

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4 Discussion

All the experimental groups were kept on the same farm and were reared with the same organic production system, allowing the birds to have access to similar outdoor pens. The animals received two different diets but with similar chemical and fatty acid compositions. The FG birds being selected for rapid growth rate and SG not selected for this purpose, the body live weight was dramatically influenced by the genotype, whereas the diets did not influence the growth pattern. In the literature there are few reports dealing with genotype comparisons on birds selected for meat production and slaughtered according to the minimum age (81 days) required by the organic regulations. Our findings are partially consistent with those of Rizzi et al. [18] who obtained significantly different body live weights in two dual-purpose local breeds and two egg-type hybrids reared under organic conditions and slaughtered at the same age.

The chemical composition of breast and thigh meat was markedly influenced by the genotype and to a lesser extent by the diet. Even if statistically significant, the numerical differences in moisture, protein and ash were not large and may not be of particular practical relevance, unlike the lipid content. The higher content of lipids observed both in breast and thigh meat of FG birds is probably related to genetic factors. These birds were selected to reach their market live weight at an early age (56–60 days) and when the slaughter age is increased to 81 days, as requested for organic production, the birds increase in fatness. Lonergan et al. [19] found that breast meat from slow-growing broilers had a lower fat content than that of fast-growing birds, and Havenstein et al. [20] reported that older strains, similar to the slow-growing genotypes, had less carcass fat than modern fast-growing strains.

The fatty acid composition of breast and thigh meat was quite different in the three genotypes. The literature contains few data concerning the relationship between fatty acid composition and chicken genotypes. Our results regarding MUFA proportions are in accordance with Legrand and Hermier [21] who found that palmitoleic acid, produced by hepatic Δ^9-desaturation, was observed in a higher proportion in fat lines whereas it was lower in the lean lines. They concluded that Δ^9-desaturase activity was significantly higher in the fat animals.

Using two fast-growing broiler genotypes (Cobb 500 and Ross 308) which were genetically selected pursuing the same purposes, Rymer and Givens [22] did not find significant

differences in the efficiency of the incorporation of *n*-3 PUFA into edible tissues. However, in their experiment the authors found that Ross 308 appeared more responsive than Cobb 500 in the incorporation of C18:3*n*-3 in dark meat. In other animal species, when studying the effect of breed on meat quality, Barton et al. [23], Siebert et al. [24], and Malau-Aduli et al. [25] found remarkable differences in fatty acid composition. The different fatty acid metabolism was estimated by the authors, adopting the Δ^9-desaturase index which is correlated to the enzyme activity [24]. Since in monogastric animals the differences in the MUFA concentrations could be related either to the endogenous synthesis or to the gut absorption from the diet, we did not estimate the Δ^9-desaturase activity but we followed the same approach to evaluate the effect of Δ^5- plus Δ^6-desaturase enzymes. Indeed, the Δ^5- plus Δ^6-desaturase index may represent a valid means to estimate the long-chain *n*-6 and *n*-3 PUFA, which are not present in the feed but are synthesized from their precursors (C18:2*n*-6 and C18:3*n*-3, respectively) absorbed from the diet. Showing significantly lower concentrations of C18:2*n*-6 and C18:3*n*-3 and higher proportions of their long-chain family derivatives (C20:2*n*-6, C20:4*n*-6, C20:5*n*-3 C22:5*n*-3 and C22:6*n*-3) along with the highest Δ^5- and Δ^6-desaturase index, SG birds appeared more responsive than MG and FG birds in the long-chain fatty acid synthesis. The different distribution of long-chain PUFA among the genotypes could also be attributed to the different intramuscular fat content of thigh meat and, to a lesser extent, of breast meat. Indeed, as reported by Barton et al. [23], high proportions of muscle PUFA are often observed in lean animals, owing to a relative increase in membrane phospholipids, which present a high content of PUFA, and a relative decrease in triacylglycerols. Another hypothesis formulated to explain the different fatty acid concentration in meat could be related to the different pasture utilization by the three genotypes as suggested by Castellini et al. [1] since, in comparison with fast-growing strains, slow-growing strains show intensive foraging behavior and spend a lot of time outdoors. Other investigations on the same fast- and slow-growing chickens we used in this trial have demonstrated that the latter are more active and made better use of the outdoor pasture [26]. The different intake of pasture containing very high levels of C18:3*n*-3 might explain the higher proportions of *n*-3 and *n*-6 PUFA derivative families in the slow-growing birds, which are produced at the expense of C18:3*n*-3. However this hypothesis is in contrast to the findings of Ponte et al. [27] who reported that pasture consumption has little effect on the

fatty acid profile of broiler meat since grass biomass intake represented between 2.5 and 4.5% on a dry matter basis of the total feed intake.

Further studies are needed to better clarify the fatty acid metabolism with particular regard to the Δ^5- and Δ^6-desaturase activity in relation to chicken genotype.

The partial substitution of soybean with faba bean affected the proportion of some fatty acids, particularly in thigh meat, even if the fatty acid composition of the two diets was similar. It can be argued that, even if the anti-nutritional factors of faba bean did not affect the bird performance, in accordance with Farrell et al. [12], they could have impaired the absorption of some dietary nutrients, including C18:2*n*-6 and C18:3*n*-3.

The genotype affected lightness and yellowness of both skin and breast meat while the diet only influenced yellowness. Our data concerning breast meat lightness (L*) are consistent with those of other authors who found that slow-growing birds are darker than fast-growing ones [7, 28–30].

In this experiment, we found lower yellowness values in breast meat from SG birds. Our data are in contrast with the results of Fanatico et al. [5] who reported that slow-growing birds with outdoor pens have more yellow meat than fast-growing birds. The authors argued that the greater yellowness of slow-growing birds may be related to the increased foraging for plant material.

The higher value of skin yellowness (b*) of FG and MG birds than SG birds may be attributable to the skin thickness associated with the higher lipid content, even if this was not measured in this experiment. The lipid content of skin is also strictly related to the muscle fatness, and the higher lipid content of breast meat from different genotypes may explain the variations observed in breast yellowness, with the lipophilic pigments being stored in intramuscular fat.

The lower value of yellowness in birds receiving faba bean in substitution of soybean emerged from the comparison of skin and breast meat color. The differences in color might be related to the different pigment content of the feeds due to the lower proportion in the FB diet of corn, a notoriously good source of yellow pigments.

The results of this study demonstrated that, in organic farming, chicken genotypes play an important role both in the chemical and fatty acid composition of thigh and breast meat. Among the genotypes studied, slow-growing birds had healthier nutritional characteristics of the meat, due to their low content of lipid associated with a higher content of total PUFA,

particularly with regard to the *n*-3 family. The partial replacement of soybean with faba bean produced only minor effects on some fatty acids, particularly in thigh meat.

Acknowledgments

This study was supported by the Italian interregional project "E.QU.I.ZOO.BIO" (Efficiency, Quality and Innovation in Organic Livestock). The authors acknowledge Stefano Pignata for his valuable technical assistance.

((Funded by

Italian interregional project "E.QU.I.ZOO.BIO" (Efficiency, Quality and Innovation in Organic Livestock)))

The authors have declared no conflict of interest.

References

[1] C. Castellini, C. Berri, E. Le-Bihan Duval, G. Martino: Qualitative attributes and consumer perception of organic and free-range poultry meat. *World Poult Sci J.* 2008, **64**, 500–512.

[2] EU: Council Regulation (EC) No. 1804/99 supplementing Regulation (EEC) No. 2092/91 on organic production of agricultural products. *Off J Eur Union* 1999, **L222**, 1–28.

[3] EU: Council Regulation (EC) No. 889/08 laying down detailed rules for the implementation of council regulation (EC) No. 834/2007 on organic production and labelling of organic products with regard to organic production, labelling and control. *Off J Eur Union* 2008, **L250**, 1–84.

[4] S. H. Gordon, D. R. Charles: *Niche and Organic Chicken Products*. Nottingham University Press, Nottingham (UK) 2002.

[5] A. C. Fanatico, L. C. Cavitt, P. B. Pillai, J. L. Emmert, C. M. Owens: Evaluation of slower growing broiler genotypes grown with and without outdoor access: Meat quality. *Poult Sci.* 2005, **84**, 1785–1790.

[6] C. Berri, E. Le Bihan-Duval, E. Baeza, P. Chartrin, L. Picgirard, N. Jehal, M. Quentin, M. Picard, M. J. Duclos: Further processing characteristics of breast and leg meat from fast-, medium- and slow-growing commercial chickens. *Anim Res.* 2005, **54**, 123–134.

[7] M. Quentin, I. Douvarel, C. Berri, E. Le Bihan-Duval, E. Baéza, Y. Jego, M. Picard: Growth, carcass composition and meat quality response to dietary concentrations in fast-, medium- and slow-growing commercial broilers. *Anim Res.* 2003, **52**, 65–77.

[8] C. Castellini, C. Mugnai, A. Dal Bosco: Effect of organic production system on broiler carcass and meat quality. *Meat Sci.* 2002, **60**, 219–225.

[9] A. C. Fanatico, P. B. Pillai, L. C. Cavitt, J. L. Emmert, J. F. Meullenet, C. M. Owens: Evaluation of slower growing broiler genotypes grown with and without outdoor access: Sensory attributes. *Poult Sci.* 2006, **85**, 337–343.

[10] K. J. Lamb, T. Acamovic: The effect of tunning-binding agents with or without enzyme supplementation, on the dry matter digestibility and ME of faba beans. *Proc. of the World's Poultry Association Annual Spring Meeting*, Scarborough (UK) 1998, pp 75–76.

[11] A. J. M. Jansen, J. Huisman, A. F. Van Der Poel: Performance of broiler chicks fed diets containing different varieties of faba bean (*Vicia faba* L.). *Arch Geflügelk.* 1993, **57**, 220–227.

[12] D. J. Farrell, R. A. Perez-Maldonato, P. P. Mannion: Optimum inclusion of field peas, faba beans, chick peas and sweet lupin in poultry diets. II. Broiler experiments. *Br Poult Sci.* 1999, **40**, 674–680.

[13] AOAC: Meat and meat products. In: *Official Methods of Analysis of the Association of Analytical Chemists.* 15th Edn., Vol. 2. AOAC, Washington, DC (USA) 1990, pp 931–948.

[14] J. Folch, M. Lees, G. H. Sloane-Stanley: A simple method for the isolation and purification of total lipids from animal tissues. *J Biol Chem.* 1957, **226**, 497–509.

[15] S. W. Christopherson, R. L. Glass: Preparation of milk methyl esters by alcoholysis in an essentially non-alcoholic solution. *J Dairy Sci.* 1969, **52**, 1289–1290.

[16] International Commission on Illumination (CIE): Recommendations on uniform colour spaces, colour difference equations, psychometric colour terms. *CIE Publication* No. 15, E-1.3.1, 1971/TO-1.3, Suppl. 15, Bureau Central de la CIE, Paris (France) 1978.

[17] SAS Institute: *SAS®/STAT Guide for Personal Computers, Version 6.03.* SAS Institute Inc., Cary, NC (USA) 1988.

[18] C. Rizzi, A. Marangon, G. M. Chiericato: Effect of genotype on slaughtering performance and meat physical and sensory characteristics of organic laying hens. *Poult Sci.* 2007, **86**, 128–135.

[19] S. M. Lonergan, N. Deeb, C. A. Fedler, S. J. Lamont: Breast meat quality and composition in unique chicken populations. *Poult Sci.* 2003, **82**, 1990–1994.

[20] G. B. Havenstein, P. R. Ferket, M. A. Qureshi: Carcass composition and yield of 1957 *versus* 2001 broilers when fed representative 1957 and 2001 broiler diets. *Poult Sci.* 2003, **82**, 1509–1518.

[21] P. Legrand, D. Hermier: Hepatic Δ^9 desaturation and plasma VLDL level in genetically lean and fat chickens. *Int J Obes.* 1992, **16**, 289–294.

[22] C. Rymer, D. I. Givens: Effect of species and genotype on the efficiency of poultry meat with *n*-3 polyunsaturated fatty acids. *Lipids* 2006, **41**, 445–451.

[23] L. Barton, M. Marounek, V. Kudrna, D. Bures, R. Zahradkova: Growth, carcass traits, chemical composition and fatty acid profile in beef from Charolais and Simmental bulls fed different types of dietary lipids. *J Sci Food Agric.* 2008, **88**, 2622–2630.

[24] B. D. Siebert, W. S. Pitchford, Z. A. Kruk, H. Kuchel, M. P. B. Deland, C. D. K. Bottema: Differences in Δ^9 desaturase activity between Jersey and Limousin-sired cattle. *Lipids* 2003, **38**, 539–543.

[25] A. E. O. Malau-Aduli, B. D. Siebert, C. D. K. Bottema, W. S. Pitchford: Breed comparison of the fatty acid composition of muscle phospholipids in Jersey and Limousin cattle. *J Anim Sci.* 1998, **76**, 766–773.

[26] C. Castellini, A. Dal Bosco, M. Guarino, C. Mugnai: Assessment of kinetic activity in slow- and fast-growing organic chickens by GPS monitoring and with visual observation. *Proc. of the VIIIth European Symposium on Poultry Welfare*, 18–22 May, Cervia (Italy) 2009, pp 114–■.

[27] P. I. P. Ponte, S. P. Alves, R. J. B. Bessa, L. M. A. Ferriera, L. T. Gama, J. L. A. Brás, C. M. G. A. Fontes, J. A. M. Prates: Influence of pasture intake on the fatty acid composition, and cholesterol, tocopherols, and tocotrienols content in meat from free-range broilers. *Poult Sci.* 2008, **87**, 80–88.

[28] E. Le Bihan-Duval, N. Millet, H. Remignon: Broiler meat quality: Effect of selection for increased carcass quality and estimates of genetic parameters. *Poult Sci.* 1999, **78**, 822–826.

[29] C. Berri, N. Wacrenier, N. Millet, E. Le Bihan-Duval: Effect of selection for improved body composition on muscle and meat characteristics of broilers from experimental and commercial lines. *Poult Sci.* 2001, **80**, 833–838.

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[30] M. Debut, C. Berri, E. Baéza, N. Sellier, C. Arnould, D. Guémené, N. Jehl, B. Boutten, Y. Jego, C. Beaumont, E. Le Bihan-Duval: Variation of chicken technological meat quality in relation to genotype and pre-slaughter stress condition. *Poult Sci.* 2003, **82**, 1829–1838.

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Table 1. Ingredient composition and calculated analysis of the feed.

	Starter	Grower	
		Soybean	Faba bean
Bird's age [days]	0–21	22 to slaughering	22 to slaughtering
Ingredients [g/kg]			
Corn	471	536	501
Soybean whole seed	325	240	150
Faba bean	–	–	155
Wheat bran	55.0	60.0	52.0
Pea whole seed	50.0	50.0	25.0
Corn gluten meal	40.0	40.0	40.0
Wheat shorts	25.0	40.0	40.0
Calcium carbonate	16.0	16.0	16.0
Calcium phosphate	11.0	11.0	11.0
Soybean oil	–	–	3.0
Salt	1.5	1.0	2.0
Vitamin-mineral premix[§]	4.0	4.0	4.0

[§] Provided the following per kilogram of diet: vitamin A (retinyl acetate), 12,500 IU; vitamin D3 (cholecalciferol), 3000 IU; vitamin E (DL-α-tocopheryl acetate), 60 IU; vitamin K (menadione sodium bisulfite), 1.02 mg; riboflavin, 2.0 mg; pantothenic acid, 8.0 mg; niacin, 6 mg; pyridoxine, 4 mg; folic acid, 0.5 mg; biotin, 0.10 mg; thiamine, 1.0 mg; vitamin B_{12}, 20 μg; Mn, 120 mg; Zn, 80 mg; Fe, 52 mg; Cu, 15 mg; I, 1.5 mg; Se, 0.4 mg.

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Table 2. Chemical composition of the feed.

	Starter	Grower		Grass
		Soybean	Faba bean	
Chemical composition				
ME[§] [MJ/kg]	13.03	12.94	12.61	–
Dry matter [g/kg]	890	889	889	34.28
Crude protein [g/kg]	202	173	172	4.46
Lipid [g/kg]	85.8	60.1	53.4	1.63
Ash [g/kg]	50.2	51.9	49.3	2.91
Crude fiber [g/kg]	39.1	36.5	39.9	4.01
Lysine [g/kg]	1.06	0.89	0.88	
Sulfur amino acids [g/kg]	0.68	0.63	0.59	
Fatty acids [g/kg fat]				
14:0	1.1	0.8	0.9	2.8
16:0	120	119	120	170
17:0	1.0	0.6	0.5	1.8
18:0	40.2	37.6	35.4	20.4
20:0	3.4	2.4	2.5	0
Total SFA	166	160	159	195
16:1*n*-7	1.6	1.4	1.5	1.6
18:1*n*-9	239	245	247	58.8
20:1*n*-9	2.5	2.0	2.3	2.7
Total MUFA	243	248	251	63.1
18:2*n*-6	527	530	530	172
Total *n*-6 PUFA	527	530	530	172
18:3*n*-3	58.0	50.0	47.2	508
Total *n*-3 PUFA	58.0	50.0	47.2	508
Total PUFA	585	580	572	648
Others	6.0	12.0	18.1	93.9
n-6/*n*-3	9.08	10.6	11.2	0.33

[§] ME, Metabolizable energy.

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Table 3. Effect of chicken genotype and diet on slaughtering performance

	Genotype (G)				Diet (D)			*p*-Value		
	FG	MG	SG	SEM	SB	FB	SEM	G	D	G*D
n	30	30	30		45	45				
Body live weight [g]	5184^{A}	2659^{B}	1782^{C}	60.11	3216	3200	49.08	0.0001	0.8187	0.8737
Carcass weight [g]	3503^{A}	1665^{B}	1017^{C}	42.72	2009	2047	34.88	0.0001	0.5403	0.6913
Dressing out[§] [g/kg]	680^{A}	626^{B}	570^{C}	0.37	626	623	0.31	0.0001	0.1554	0.0533
Breast[§] [g/kg]	289^{A}	160^{B}	140^{C}	0.26	195	193	0.21	0.0001	0.0515	0.0594
Thigh and drumstick[$] [g/kg]	319^{B}	369^{A}	378^{A}	0.30	358	355	0.25	0.0001	0.7350	0.8003
Wing[§] [g/kg]	102^{C}	130^{B}	143^{A}	0.13	126	125	0.11	0.0001	0.5518	0.1306

FG, Fast-growing; MG, medium-growing; SG, slow-growing; SB, soybean; FB, faba bean.
[§] Ready-to-cook carcass/body weight.
[$] Calculated on ready-to-cook carcass.
[A–C] Means within a row followed by different superscript letters differ significantly ($p \leq 0.01$).■please check■.

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Table 4. Effect of chicken genotype and diet on chemical composition of breast and thigh meat (g/kg).

	Genotype (G)				Diet (D)			*p*-Value		
	FG	MG	SG	SEM	SB	FB	SEM	G	D	G*D
Breast										
n	15	15	15		15	15				
Moisture	748^{A}	723^{B}	744^{A}	0.19	735^{B}	742^{A}	0.15	0.0001	0.0031	0.0015
Protein	237^{B}	242^{AB}	246^{A}	0.19	239^{b}	244^{a}	0.16	0.0043	0.0287	0.2029
Lipid	12.7^{A}	10.0^{B}	9.4^{B}	0.05	10.8	10.6	0.04	0.001	0.7518	0.7444
Ash	12.0^{B}	13.7^{A}	11.6^{B}	0.02	12.5	12.4	0.02	0.001	0.7870	0.3508
Thigh										
n	15	15	15		15	15				
Moisture	744^{B}	762^{A}	768^{A}	0.26	758	759	0.21	0.0001	0.6251	0.1359
Protein	201	200	204	0.18	200	203	0.14	0.3905	0.2704	0.0404
Lipid	43.4^{A}	30.7^{B}	22.9^{C}	0.19	34.8^{a}	29.9^{b}	0.15	0.0001	0.0305	0.1166
Ash	10.1	9.8	10.2	0.02	10.4^{A}	9.7^{B}	0.01	0.1970	0.0008	0.1769

FG, Fast-growing; MG, medium-growing; SG, slow-growing; SB, soybean; FB, faba bean.

^{a,b} Means within a row followed by different superscript letters differ significantly ($p \leq 0.05$).

$^{A–C}$ Means within a row followed by different superscript letters differ significantly ($p \leq 0.01$).

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Table 5. Effect of chicken genotype and diet on breast meat fatty acid composition (g/kg).

Fatty acid	Genotype (G)				Diet (D)			*p*-Value		
	FG	MG	SG	SEM	SB	FB	SEM	G	D	G*D
n	30	30	30		45	45				
14:0	4.8^{A}	4.2^{B}	3.0^{C}	0.02	3.7^{b}	4.3a	0.01	0.0001	0.0246	0.8301
16:0	234	240	234	0.36	232	240	0.29	0.3862	0.0628	0.6210
17:0	1.2	1.3	1.3	0.01	1.2	1.3	0.01	0.7676	0.8928	0.2789
18:0	77.6^{B}	70.9^{C}	87.8^{A}	0.17	80.0	77.0	0.13	0.0001	0.3006	0.0627
21:0	3.5	3.4	3.9	0.02	3.7	3.5	0.35	0.3165	0.3798	0.1144
Total SFA	322	321	331	0.37	321	328	0.29	0.1101	0.0904	0.4273
16:1*n*-7	33.2^{A}	27.2^{B}	10.4^{C}	0.18	20.9^{b}	26.6^{a}	0.14	0.0001	0.0131	0.8372
18:1*n*-9	305^{A}	273^{B}	226^{C}	0.55	264	273	0.44	0.0001	0.1976	0.4597
20:1*n*-9	3.1^{a}	2.8^{a}	2.1^{b}	0.02	2.5	2.8	0.02	0.0140	0.2033	0.7848
Total MUFA	341^{A}	303^{B}	239^{C}	0.69	287	303	0.56	0.0001	0.0895	0.6810
18:2*n*-6	234^{A}	226^{A}	202^{B}	0.55	228^{a}	214^{b}	0.45	0.0002	0.0207	0.2661
20:2*n*-6	4.8^{b}	5.4^{ab}	6.1^{a}	0.03	5.0^{b}	5.8^{a}	0.03	0.0160	0.0331	0.6610
20:4*n*-6	41.9^{C}	69.8^{B}	127^{A}	0.51	80.6	77.6	0.41	0.0001	0.8071	0.9737
Total *n*-6 PUFA	281^{C}	301^{B}	336^{A}	0.46	314^{A}	297^{B}	0.37	0.0001	0.0045	0.0918
18:3*n*-3 α-	15.1^{A}	13.4^{A}	6.9^{B}	0.78	12.4	11.3	0.06	0.0001	0.1624	0.6395
20:5*n*-3 (EPA)	10.6^{C}	15.6^{B}	21.4^{A}	0.11	15.3	16.2	0.09	0.0001	0.3634	0.3518
22:5*n*-3 (DPA)	9.9^{C}	15.4^{B}	25.9^{A}	0.11	18.2	15.7	0.09	0.0001	0.0707	0.7059
22:6*n*-3 (DHA)	7.8^{C}	12.0^{B}	23.0^{A}	0.09	15.7	12.6	0.08	0.0001	0.0604	0.4836
Total *n*-3 PUFA	43.5^{C}	56.4^{B}	77.1^{A}	0.23	61.6^{a}	55.8^{b}	0.18	0.0001	0.0479	0.8334
Total PUFA	324^{C}	358^{B}	413^{A}	0.60	375^{A}	353^{B}	0.48	0.0001	0.0034	0.1768
Other	9.1^{B}	12.7^{A}	13.9^{A}	0.06	12.1	11.6	0.06	0.0001	0.6178	0.1378
n-6/*n*-3	6.64^{A}	5.47^{B}	4.44^{C}	0.21	5.34	5.74	0.17	0.0001	0.1459	0.4296
Δ^5/Δ^6-desaturase index	23.6^{C}	34.4^{B}	54.0^{A}	1.88	36.6	37.0	1.54	0.0001	0.4185	0.3748

FG, Fast-growing; MG, medium-growing; SG, slow-growing; SB, soybean; FB, faba bean; SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; DHA, docosahexaenoic acid; DPA, docosapentenoic acid; EPA, eicosapentaenoic acid.

[a,b] Means within a row followed by different superscript letters differ significantly ($p \leq 0.05$).

[A–C] Means within a row followed by different superscript letters differ significantly ($p \leq 0.01$).

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Table 6. Effect of chicken genotype and diet on thigh meat fatty acid composition (g/kg).

Fatty acid	Genotype (G)				Diet (D)			*p*-Value		
	FG	MG	SG	SEM	SB	FB	SEM	G	D	G*D
n	30	30	30		45	45				
14:0	5.4^{A}	5.6^{A}	4.7^{B}	0.02	5.0	5.5	0.02	0.0067	0.0617	0.1805
16:0	217^{A}	221^{A}	204^{B}	0.30	206^{B}	222^{A}	0.24	0.0006	0.0001	0.0810
17:0	1.5^{B}	1.6^{B}	1.9^{A}	0.01	1.7	1.7	0.00	0.0001	0.5971	0.4257
18:0	71.4^{C}	76.0^{B}	99.4^{A}	0.15	82.0	82.5	0.12	0.0001	0.7955	0.0770
21:0 c	2.8^{C}	3.4^{B}	3.9^{A}	0.02	3.5	3.2	0.01	0.0001	0.1227	0.0866
Total SFA	298^{B}	308^{A}	314^{A}	0.31	299^{B}	315^{A}	0.25	0.0001	0.0001	0.0001
16:1*n*-7	44.6^{A}	43.5^{A}	22.3^{B}	0.19	33.9^{b}	39.6^{a}	0.15	0.0001	0.0103	0.5898
18:1*n*-9	331^{A}	301^{B}	261^{C}	0.36	295	301	0.29	0.0001	0.1491	0.0835
20:1*n*-9	4.1^{a}	3.8^{b}	3.6^{b}	0.01	3.8	3.8	0.09	0.0147	1.0000	0.1605
Total MUFA	380^{A}	348^{B}	287^{C}	0.50	332^{b}	344^{a}	0.41	0.0001	0.0470	0.1688
18:2*n*-6	258^{B}	259^{B}	292^{A}	0.56	285^{A}	254^{B}	0.46	0.0001	0.0001	0.0603
20:2*n*-6	2.4^{C}	3.1^{A}	2.8^{B}	0.01	2.6^{b}	2.9^{a}	0.01	0.0001	0.0140	0.0515
20:4*n*-6	16.2^{C}	29.4^{B}	44.8^{A}	0.15	28.6	31.7	0.12	0.0001	0.0763	0.0265
Total *n*-6 PUFA	277^{B}	291^{B}	339^{A}	0.58	316^{A}	289^{B}	0.47	0.0001	0.0001	0.0042
18:3*n*-3	20.7^{A}	19.3^{B}	17.2^{C}	0.05	20.7^{A}	17.4^{B}	0.04	0.0001	0.0001	0.0801
20:5*n*-3 (EPA)	4.0^{C}	7.2^{B}	8.8^{A}	0.03	6.0^{B}	7.3^{A}	0.03	0.0001	0.0009	0.0623
22:5*n*-3 (DPA)	3.8^{C}	6.5^{B}	9.3^{A}	0.03	6.2	6.8	0.03	0.0001	0.0818	0.0675
22:6*n*-3 (DHA)	2.0^{C}	4.4^{B}	8.6^{A}	0.03	4.9	5.1	0.03	0.0001	0.6264	0.0995
Total *n*-3 PUFA	30.4^{C}	37.4^{B}	43.8^{A}	0.09	37.7	36.7	0.08	0.0001	0.3113	0.8960
Total PUFA	305^{C}	325^{B}	380^{A}	0.63	351^{A}	322^{B}	0.52	0.0001	0.0002	0.0088
Other	8.9^{B}	10.2^{A}	11.2^{A}	0.04	10.2	10.0	0.03	0.0001	0.7277	0.0516
n-6/*n*-3	9.16^{A}	7.82^{B}	7.79^{B}	0.15	8.48^{a}	8.03^{b}	0.13	0.0001	0.0148	0.0459
Δ^5/Δ^6-desaturase index	8.96^{C}	15.8^{B}	20.2^{A}	0.66	13.7^{B}	16.5^{A}	0.55	0.0001	0.0013	0.0801

FG, Fast-growing; MG, medium-growing; SG, slow-growing; SB, soybean; FB, faba bean; SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; DHA, docosahexaenoic acid; DPA, docosapentenoic acid; EPA, eicosapentaenoic acid.

[a,b] Means within a row followed by different superscript letters differ significantly ($p \leq 0.01$).

[A–C] Means within a row followed by different superscript letters differ significantly ($p \leq 0.01$).

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Table 7. Effect of chicken genotype and diet on skin and breast meat color attributes.

	Genotype (G)				Diet (D)			*p*-Value		
	FG	MG	SG	SEM	SB	FB	SEM	G	D	G*D
n	30	30	30		45	45				
Breast skin										
Lightness, L*	69.4^{B}	72.5^{A}	72.9^{A}	0.54	72.0	71.3	0.43	0.0001	0.3867	0.9164
Redness, a*	5.86^{A}	3.06^{B}	1.23^{C}	0.36	3.27	3.40	0.29	0.0001	0.9724	0.0924
Yellowness, b*	29.2^{B}	33.7^{A}	29.8^{B}	0.78	32.5^{A}	29.3^{B}	0.63	0.0001	0.0015	0.0738
Hue, H*	1.37	1.15	0.80	0.17	0.88b	1.31a	0.14	0.0581	0.0580	0.0992
Chrome, C*	29.8^{B}	34.0^{A}	29.8^{B}	0.76	32.8^{A}	29.6^{B}	0.61	0.0002	0.0009	0.0650
Breast meat										
Lightness, L*	57.6^{A}	54.5^{B}	55.8^{AB}	0.50	55.9	55.9	0.41	0.0002	0.8835	0.5693
Redness, a*	1.08	0.88	0.90	0.19	1.07	0.83	0.13	0.5106	0.1567	0.0615
Yellowness, b*	5.65^{A}	4.71^{A}	3.26^{B}	0.35	5.50^{A}	3.85^{B}	0.29	0.0001	0.0008	0.1356
Hue, H*	0.88	0.92	0.95	0.18	0.90	0.94	0.15	0.9550	0.8273	0.9425
Chrome, C*	5.89^{A}	4.88^{A}	3.60^{B}	0.32	5.43^{A}	4.12^{B}	0.26	0.0001	0.0003	0.0547

FG, Fast-growing; MG, medium-growing; SG, slow-growing; SB, soybean; FB, faba bean.

^{a,b} Means within a row followed by different superscript letters differ significantly ($p \leq 0.05$).

$^{A–C}$ Means within a row followed by different superscript letters differ significantly ($p \leq 0.01$).