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Original article

Fatty acid composition of abdominal adipose tissue in broilers fed green-oak (*Quercus ilex*), cork oak acorn (*Quercus Suber* L.) based diets

Kaddour BOUDEROUA*, Ghalem SELSELET-ATTOU

Laboratoire de Technologie Alimentaire et Nutrition, Faculté des Sciences et Sciences de l'Ingénieur, Université de Mostaganem, BP 300, Mostaganem, Algeria

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Abstract — Male broilers, 30 for every diet, were fed for six weeks, diets containing 60% green oak (GO) and oak cork (CO) acorns compared to 60% corn (C). The body weight of the chickens fed the oak acorn-based diets was 25% lower than that of the controls (C). Abdominal adipose tissue (AAT) was twice heavier in the controls compared to broilers fed oak acorn-based diets. The total lipids of AAT were higher in the controls compared to the oak acorn fed chickens (34.4 against 15.3 g per 100 g of AAT in the CO). The palmitic and oleic acid proportions were comparable in the AAT of chickens fed with the different diets. The proportion of linoleic acid, obtained exclusively by the diets, was significantly higher in the chickens fed oak acorn-based diets (23%), compared to the controls (19%). Reciprocally, palmitoleic acid was present in a small proportion in chickens fed oak acorns (4 to 5%). The observed variation of the fatty acid content of abdominal fat of acorn-fed chickens requires further research on the precise nutrient digestibility of oak acorns before considering them as a potential feed.

lipids / lipogenesis / broilers / oak acorn / adipose tissue

Résumé — **Variation de la composition en acides gras des lipides du tissu adipeux abdominal chez des poulets nourris avec des régimes à base de glands de chêne vert (Quercus ilex) et de chêne liège (Quercus suber L.).** Des poulets mâles, 30 par régime, ont été nourris durant six semaines avec une alimentation à base de glands de chêne vert (GO) et de chêne liège (CO) en substitution au maïs (C). Les poids vifs des animaux ont été plus faibles de 25 % chez les poulets recevant GO et CO par rapport à ceux recevant l'aliment témoin C. De même, le poids du gras abdominal était deux fois plus élevé chez les poulets témoins C par rapport à ceux consommant GO et CO. Le tissu adipeux abdominal des animaux témoins contenait plus de lipides totaux que celui des poulets recevant les régimes GO et CO (34,4 g par 100 g de gras abdominal pour C vs. 15,3 pour CO). Les proportions

* Corresponding author: bouderoua.kad@voila.fr

d'acide palmitique et oléique ont été comparables dans le gras abdominal des poulets pour les trois régimes. En revanche, la proportion d'acide linoléique, apporté exclusivement par les régimes, a été significativement plus élevée dans le cas des poulets consommant les régimes à base de glands de chêne (23 %) par rapport aux témoins (19 %). Inversement, l'acide palmitoléique a été en faible proportion chez les poulets consommant des glands de chêne (de 4 à 5 %). L'interprétation des variations de composition en acides gras du tissus abdominal de poulets consommant des glands de chênes requiert une évaluation plus précise de la digestibilité des nutriments contenus dans les glands avant de pouvoir les considérer comme des aliments potentiels pour le poulet.

lipides / lipogenèse / poulet / gland de chêne / tissu adipeux

1. INTRODUCTION

Oak acorns, unexploited to date in Algeria, are raising interest due to their large availability (27% of the forest surface), and their resistance to drought. The idea to exploit them for livestock feeding and oil extraction has appeared in most Mediterranean countries as an energy source (47 to 60% starch [7]; 7% to 14.4% lipids [14]; some unsaturated fatty acids (UFA) similar to olive oil [14]). The major fatty acids (FA) in acorns are oleic (66.8%), palmitic (18.4%), linoleic (13.5%) and only 0.6% of linolenic acid, compared to 0.9% in corn [14]. During the past years, meat chickens have increased their growth rate but also their abdominal adipose tissue (AAT) content. This fat is mainly lost during meat preparation [18]. Feeding is one of the most important factors that can modify the quantity and the quality of lipids stored in chickens [13]. Indeed, the fatty acid composition of abdominal adipose tissue is modified by the composition of dietary lipids: tallow fat in the diet increases the proportion of C16:0 and C18:0 in chickens but dietary vegetable oil, increases that of polyunsaturated fatty acids (PUFA) [12].

The present study was undertaken to study the effect of a diet based on green oak (*Quercus ilex*) or oak cork (*Quercus suber* L.) acorn in substitution to corn on chicken growth performances and fatty acid (FA) composition of the abdominal adipose tissue.

2. MATERIALS AND METHODS

Ninety male day-old chickens (Hubbard-ISA broilers) were fed until 14 days with a standard diet, containing 3100 kcal·kg^{-1} and 22% of proteins. For each experimental diet, 30 broilers were raised in the 3 m^2 floor pens (30 chickens per pen). They had an initial body weight of 250 ± 25 g at 15 days of age. The experimental diets based on green oak (GO) and cork oak (CO) acorn and a control feed (C) were fed from 15 to 56 days of age (Tab. I). At 56 days of age, the chickens were weighed and slaughtered. Samples of AAT were immediately frozen in liquid nitrogen and stored at –80 °C until analysis. The liver was also weighed.

The lipids of abdominal adipose tissue were extracted by chloroform-methanol according to the Folch et al. method [3]. Triglycerides were purified using a silicic acid column according to a technique adapted by Hirsch and Ahrens [6]. Fatty acids of lipids were freed by saponification (KOH 2N), and then methylated by methanol. The methylic esters of FA were analysed by gas chromatography (PYEU chromatograph NICAM 789) using a column full of butane-diol-succinate at 215 °C under isotherm conditions.

A variance analysis of the dietary effect was applied to all the studied parameters [2]. It was followed by a mean comparison using the Newman and Keuls test.

Table I. Composition of the experimental diets (%).

Diet	Corn C	Green oak acorn GO	Cork oak acorn CO
Corn	60	–	–
Green oak acorn	–	60	–
Cork oak acorn	–	–	60
Soybean meal	31	31	31
Wheat bran	8	8	8
MVC	1	1	1
Calculated composition (%)			
Crude protein	20.9	19.9	18.6
Lipids	5.6	6.5	6.1
Ash	1.1	2.1	3.2
Moisture	11.0	12.3	13.9
Calcium	1.0	1.0	1.1
Phosphorus	0.4	0.3	0.4
Lysine	1.1	1.1	1.2
Sulphur amino acids	0.8	0.7	0.6
Fatty acid analysis of dietary lipids (expressed in % of the identified fatty acids)			
C16:0	15.0	13.5	19.8
C16:1	traces	traces	traces
C18:0	2.3	2.5	3.1
C18:1	33	69	67
C18:2	48.5	14.1	9.7
C18:3	0.7	0.6	traces

The crude fibre and crude ash contents obtained by Weende analysis were, respectively, 4.1% and 2.2% in GO and 5.8% and 2.7% in CO.
MVC: mineral vitamin premix, provided (in mg per kg of diet); vitamin E: 6; vitamin K_3: 0.80; vitamin B_1: 1; vitamin B_2: 3; Pantothenate of Ca: 6; vitamin B_6: 1.5; vitamin B_{12}: 0.006; folic acid: 0.2; nicotinic acid: 12; copper: 5; cobalt: 0.65; manganese: 65; zinc: 65; selenium:0.25, iron: 50; iodine:0.8; magnesium: 100.

3. RESULTS

Linoleic acid was much more concentrated in dietary lipids of the corn-based control feed (48.5%) than in acorn diets (11.9%). Oleic acid was twice more concentrated in acorn-based diets compared to the control feed (Tab. I).

Diets based on oak acorn reduced chicken growth (Tab. II) especially with the CO diet (by about 29% compared to the controls; $P < 0.01$). The same observation was made for eviscerated carcass weight.

The abdominal adipose tissue weight was roughly twice heavier ($P < 0.01$) in control broilers compared with those fed

Table II. Mean body weight and abdominal adipose tissue (AAT) characteristics of broilers fed acorn based and control diets.

Diet	Corn C	Green oak acorn GO	Cork oak acorn CO	SEM	Dietary effect[1]
Body weight (g)	2800[a]	2240[a]	1900[b]	12.76	**
Weight gain (g)	2500[a]	1900[b]	1700[c]	20.30	**
Eviscerated weight (g)	2100[a]	1600[b]	1300[c]	12.81	**
(% of body weight)	75[a]	72[a]	67[b]	3.72	**
Abdominal adipose tissue (g)	54.2[a]	27.5[b]	22.1[c]	3.16	**
(% eviscerated weight)	2.6[a]	1.7[b]	1.6[c]	0.54	*
Liver weight (g)	32.3	28.3	27.5	2.12	NS
(% eviscerated weight)	1.6	1.7	2.0	0.56	NS
Total lipids ($g \cdot 100\ g^{-1}$ AAT)	34.4[a]	19.8[b]	15.4[c]	0.20	**
Triglyceride ($mmol \cdot g^{-1}$ AAT)	3.45[a]	3.18[a]	1.99[b]	0.37	*
C14:0 (%)	0.91	0.90	0.81	0.35	NS
($g \cdot 100\ g^{-1}$ of AAT)	0.34[a]	0.10[b]	0.11[b]	0.22	*
C16:0 (%)	28.70	27.01	30.08	1.30	NS
($g \cdot 100\ g^{-1}$ of AAT)	7.94[a]	4.41[b]	3.71[c]	0.69	**
C16:1 (%)	7.11[a]	5.03[b]	4.01[c]	1.22	**
($g \cdot 100\ g^{-1}$ of AAT)	1.98[a]	0.79[b]	0.49[c]	0.38	**
C18:0 (%)	7.01	8.01	7.05	1.16	NS
($g \cdot 100\ g^{-1}$ of AAT)	1.87[a]	1.31[b]	0.93[c]	0.57	**
C18:1 (%)	37.21	36.01	35.04	1.67	NS
($g \cdot 100\ g^{-1}$ of AAT)	10.25[a]	5.74[b]	4.33[b]	0.63	**
C18:2 (%)	19.05[a]	23.02[b]	23.02[b]	1.05	*
($g \cdot 100\ g^{-1}$ of AAT)	*5.26*[a]	3.65[b]	2.83[b]	0.68	**
Unsat Index[2]	1.30[a]	1.35[b]	1.36[b]	0.62	*

Each value is the mean of 30 chickens (body characteristics) or 5 chickens (fat analysis). Fatty acid expressed as % of the identified fatty acids.

[1] ANOVA, *: $P < 0.05$; **: $P < 0.01$; NS: non significant. Mean values within a line having different superscripts are not significantly different.

[2] Index of unsaturation according to Girard et al. [4], calculated as: 1(C16:1+C18:1) + 2(C18:2)/(C16:1+C18:1+C18:2).

oak acorn. The level of total lipid in abdominal adipose tissue was significantly higher ($P < 0.01$) in C fed chickens than in those fed oak acorns, especially CO (34.4 vs. 15.4 $g \cdot 100\ g^{-1}$ of AAT). However, no significant effect of the diet on liver weights was measured (Tab. II). High concentrations of palmitic and linoleic acids (in g per 100 g of AAT) were observed in AAT of control chickens compared to those fed GO and CO diets ($P < 0.01$). Comparatively to other fatty acids, palmitoleic and stearic acid levels were low, but more significantly higher in control chicken adipose tissue than in the

AAT of chickens fed the oak-based diets ($P < 0.01$). The same tendency was noticed for palmitoleic acid expressed as a percentage of identified FA. Palmitic and oleic acids were found in comparable proportions in the three diets.

4. DISCUSSION

The low body and gain weights obtained with acorn-based diets, especially CO, were attributed to a lower concentration and maybe to the availability of amino acids (especially of sulphur amino acids) that were not corrected in the formulae. According to Grisoni et al. [5], the maximal chicken growth is reached at 20% of protein. Indeed, protein concentration of acorns is low [1, 17], compared to corn [8]. It is also possible that tannin, a major anti nutritional factor in acorns [17], makes amino acids less available for chickens [9]. A more careful evaluation of the real content and digestibility of nutrients from acorns is necessary to evaluate their nutritional value for production.

A low digestibility of energy in GO and CO diets could explain the observed low fat deposition. Discussion of the fatty acid utilisation is impaired by the large BW differences observed between birds fed the different diets. As a consequence lipid synthesis and deposition are reduced, and TL content (% of AAT) varies in the same manner as the AAT weight. Acorn-fed broilers exhibited a fat deposition similar to that of genetically lean chickens [10].

Birds fed the corn-based control diet had live body weight and abdominal fat deposition and their adipose tissue fatty acid composition was similar to those mentioned in the literature [11, 15], with high contents in oleic acid synthesized from dietary starch and linoleic acid stored from dietary linoleic acid. In the abdominal fat pad, palmitic, stearic and oleic acid proportions are independent of the fatty acid composition of the ingested diet although their composition varies widely. In bird liver, saturated fatty acids are synthesised from dietary starch, then stearic acid is desaturated into oleic acid. The only difference is for the linoleic acid content which is higher in birds fed oak acorn diets than in those fed a corn diet: 23 vs. 19% of AAT, respectively. Could this result be compared to those obtained with sunflower oil? [16]. In fact, the present results could be better explained by a higher hepatic lipogenesis in birds fed corn compared to acorns. Broilers fed oak acorn diets would be starch and energy deprived, and dietary linoleic acid would be directly deposited in adipose tissue.

Finally, oak acorn diets give decreased growth of chickens but also an abdominal fat deposition. The observed variation of the fatty acid content of their abdominal fat requires further research on the precise digestible nutrient content of oak acorns before considering them as a potential feed for chickens.

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