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Influence of feeding management on lipid content and fatty acid profile of adipose tissues and muscles in goats reared in the argan tree areas of Morocco

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SUMMARY – The characteristics of goat meat from the argan area, in the south western part of Morocco, was studied in 2 experiments. Each experiment was carried out on 3 groups of 6 male goats, reared either indoors or at grazing in the Argan forest and given or not a concentrate. The growth rate of the grazing goats receiving no energy supplementation was very low in the first experiment (34 g/d), but it was relatively high in the second one (64 g/d) with a higher availability of herbaceous vegetation. In both experiments, the weights of omental and perirenal adipose tissues were the lowest in the 2 groups of grazing goats. Goats from the argan area had the highest percentages of odd FA, branched-chain FA, and *n*-6 and *n*-3 polyunsaturated FA, but the lowest percentage of palmitic acid. The low fat content of goat meat from the argan area and the fatty acid profile give to their meat a more beneficial characteristic for health of consumers.

Key words: Goats, adipose tissues, muscles, lipids, fatty acid.

RESUME – *"Influence du système d'alimentation sur la teneur en lipides et le profil en acides gras des tissus adipeux et des muscles de caprins élevés dans l'arganeraie du Maroc". Les caractéristiques de la viande de chevreaux de la région de l'arganeraie, au sud-ouest du Maroc, a été étudiée, au cours de 2 expériences. Chaque expérience a été réalisée sur 3 lots de 6 chevreaux mâles, élevés soit en chèvrerie, soit au pâturage dans l'arganeraie, avec un complément énergétique ou non. En absence de complémentation énergétique, les chevreaux de l'arganeraie ont présenté des vitesses de croissance très réduites au cours de la 1ère expérience (34 g/j), mais plus élevées dans la 2ème expérience (64 g/j) avec une plus grande disponibilité en herbes. Dans les 2 expériences, les poids des dépôts adipeux omental et périrénal ont été les plus réduits chez les chevreaux de l'arganeraie. Les chevreaux de l'arganeraie ont les pourcentages en acides gras impairs, ramifiés et polyinsaturés* n-*6 et* n-*3 les plus élevés, et des teneurs en acide palmitique plus faibles. La faible adiposité des chevreaux de l'arganeraie et le profil en acides gras de leurs lipides confèrent à cette viande une caractéristique bénéfique pour la santé des consommateurs.*

Mots-clés : *Chevreaux, tissus adipeux, muscles, lipides, acides gras.*

Introduction

In the south-western region of Morocco, the Argan forest is important for goat breeding because of the ability of these animals to use argan tree products as feeds, which represent the main part of the diet when grass availibily is low (El Aich, 1995; Bousquet, 2000; El Aich *et al.*, 2003). The goat meat production makes up an important part of the incomes of goat farmers. During the dry periods the feed supply coming from argan tree forest is not sufficient to meet energy and nitrogen requirements for maintenance and growth. In these conditions, the goat farmers are forced, either to sell part of their livestock or to give purchased concentrate. In the north of Morocco goats for meat are often raised indoors, with diets rich in energy. To help the development of the goat husbandry in the argan areas growth and carcass characteristics of goats raised in this region have to be stated.

The aim of this work was to study the effects of concentrate supplementation both on goats reared indoor and on goats reared in the Argan forest. This first study was focused on the characteristics of goat meat and on the search for possible beneficial characteristics for human consumers.

Material and methods

Two experiments were conducted in the Argan forest of Morocco, between Essaouira and Tamanar, during 2 consecutives years (2001 and 2002). Each year, 18 entire male goats of local breed, aged 8-10 months, weighting about 10 kg were allocated in three groups. Two goups, raised in the Argan forest area, were compared to a third one raised indoor (ZP). The target slaughter weight was between 16 and 17 kg. The two first groups received either only some argan pulp (PP) or a mixed concentrate feed (PA) which was composed of barley (39%), wheat bran (18%) and argan pulp (43%), respectively in the first experiment, and of barley (54%), sunflower meal (18%) and argan pulp (29%) in the second experiment. Diet of ZP goats was based on barley (50%), wheat bran (30%), and beet pulp (18%), in the first experiment, and of barley (46%), sunflower meal (30%) and beet pulp (23%) in the second experiment. In the first experiment, the total distributed concentrate was about 377, 210 and 92 g per goat and 580, 397 and 106 g, in the second one, respectively for ZP, PA and PP groups. The intake of herbaceous plants and of shrubs was very low in the first experiment, but relatively high in the second one. The lipid content of *longissimus dorsi* muscle was determined according to the method of Bligh and Dyer (1959) and the fatty acid (FA) content was determined by following the method of Rule (1997). The FA were separated according to the chromatographic conditions described by Bas *et al.* (2003).

Results and discussion

In the first experiment, the target live weight of goats was reached in about 3 months for all the goats of groups ZP and PA. Their average daily gain (ADG) did not differ (Table 1). Contrarily, PP goats did not reach this target live weight neither in that period nor with 3 extra experimental months. In the second experiment, the ADG of goats raised in the Argan forest (PA and PP) were not significantly different. They were about 30% higher than that of ZP goats. In the two experiments, the weights of omental and of perirenal adipose tissues of PA and PP goats appeared similar and much lower (≅75%) than those of ZP goats. Between experiments, the weights of these adipose tissues were lower in the second experiment for ZP and PA goats but they were similar for PP goats, even when calculated to equivalent carcass weight. The muscle lipid content was about half for PA and PP goats than for ZP goats.

Table 1. Characteristics of goats

	Experiment 1			Experiment 2		
	ZP	PA	PP	ZP	PA	PP
Initial live weight (kg)	12.9[a] *(0.72)*††††††	12.8[a] *(1.35)*	12.3[a] *(1.18)*	10.6[a] *(0.51)*	10.4[a] *(0.42)*	11.1[a] *(0.78)*
Live weight at slaugther (kg)	16.7[a] *(0.47)*	16.1[a] *(1.00)*	13.0[b] *(1.08)*	15.9[a] *(0.37)*	15.6[a] *(0.50)*	16.3[a] *(1.43)*
Duration of the experiment (d)	90.3[a] *(5.72)*	90.3[a] *(5.72)*	199.7[b] *(54.7)*	111.0[a] *(14.2)*	98.0[b] *(0.0)*	99.0[b] *(0.0)*
ADG† (g/d)	54.2[a] *(10.8)*	54.3[a] *(15.5)*	34.3[b] *(8.2)*	51.5[a] *(7.3)*	72.7[b] *(13.1)*	64.3[ab] *(12.6)*
Hot carcass weight (kg)	7.9[a] *(0.51)*	7.3[ab] *(0.42)*	6.9[b] *(0.78)*	6.6[a] *(0.50)*	6.8[a] *(0.50)*	7.2[a] *(0.59)*
OM†† (g)	400[a] *(70.5)*	126[b] *(47.1)*	75[b] *(78.9)*	315[a] *(63.17)*	64[b] *(19.7)*	103[b] *(24.1)*
PR††† (g)	262[a] *(50.1)*	72[b] *(36.9)*	43[b] *(42.9)*	193[a] *(40.2)*	41[b] *(21.0)*	41[b] *(13.0)*
MU†††† (%)	2.6[a] *(0.76)*	1.7[b] *(0.66)*	1.4[b] *(0.47)*	2.6[a] *(0.78)*	1.1[b] *(0.18)*	1.1[b] *(0.29)*

†ADG: Average daily gain during the 12 weeks of the experiments for all goats.
††OM: Weight of omental adipose tissue.
†††PR: Weight of perirenal adipose tissue.
††††MU: Lipid content in muscle *longissimus dorsi*.
††††††Standard deviations in brackets.
[a,b]For an experiment, means within a row lacking a common superscript differ ($P < 0.05$).

Generally, fat of internal adipose tissues (omental and perirenal) and muscles of PA and PP goats had higher percentage of polyunsaturated FA (PUFA) than those of ZP goats (Table 2). As this increase of PUFA was relatively higher for *n*-3 PUFA than for *n*-6 PUFA, the *n*-6:*n*-3 ratio was the lowest in the adipose tissues and muscles of goats raised in the Argan forest. It could lead to a ratio *n*-6:*n*-3 < 5.0 in the daily diet, that could be beneficial against coronary heart desease (Wood and Enser, 1997). By contrast, the percentage of monounsaturated fatty acids (MUFA) was the lowest for PA and PP goats. This decrease of MUFA percentage was higher in muscles than in adipose tissues (-20.3% and -10.6%, respectively). Although $C_{18:1n9c}$ declined, internal adipose tissues and muscles of PA and PP goats had higher percentages of isomers of oleic acid (+73.6% and +28.1%, in adipose tissues and muscles, respectively) than ZP goats. Moreover, PA and PP goat tissues had more odd FA than ZP ones (+38.9% and +24.7%, in adipose tissues and muscles, respectively). Likewise, PA and PP goat tissues had more branched-chain FA (BRFA: *iso* and *anteiso*) than ZP ones (+37.1% and +19.2%, in adipose tissues and muscles, respectively). These higher percentages of odd FA and of BRFA could be derived from blood with their circulating FA synthetized by ruminal lipid microorganisms, in accordance with results of Bas *et al.* (2003) who found that with diets rich in neutral detergent fiber (NDF), the odd FA and BRFA percentages in bacteria, could be higher than 30% of their total FA. The adipose tissue and muscle lipids of PP goats, had most often higher percentages of stearic acid (+5.5% and +23.1%, respectively) but lower percentage of palmitic acid (-12.6% and -6.3%, respectively) than for ZP goats. In this way, the total saturated FA percentage did not differ in internal adipose tissues between the three groups of goats, but nevertheless it appeared to be higher in muscles of PA and PP goats than in ZP ones. The decrease in palmitic acid percentage was considered a positive factor for consumers health, because of atherogenic characteristics of this FA (Ulbricht and Southgate, 1991).

Table 2. Fatty acid composition of adipose tissues and of muscles of goats

	Adipose tissues†			Muscles		
	ZP	PA	PP	ZP	PA	PP
$C_{16:0}$	29.0^{a} *(4.1)*	24.1^{b} *(3.6)*	25.4^{b} *(4.1)*	20.3^{a} *(2.4)*	19.0^{b} *(3.3)*	19.0^{b} *(2.9)*
$C_{16:1}$	1.3^{a} *(0.23)*	1.3^{ab} *(0.54)*	1.5^{b} *(0.38)*	2.0^{a} *(0.36)*	1.8^{b} *(0.33)*	1.7^{b} *(0.31)*
$C_{18:0}$	33.1^{a} *(33.1)*	35.8^{b} *(35.8)*	35.0^{ab} *(35.0)*	14.5^{a} *(1.3)*	17.6^{b} *(1.6)*	17.9^{b} *(1.3)*
$C_{18:1n9c}$	20.9^{a} *(5.5)*	16.1^{b} *(3.0)*	14.8^{b} *(2.7)*	45.7^{a} *(3.4)*	33.4^{b} *(3.6)*	32.1^{b} *(4.8)*
$oC_{18:1}$††	3.8^{a} *(3.8)*	7.6^{b} *(7.6)*	6.6^{b} *(6.6)*	3.2^{a} *(0.6)*	4.4^{b} *(1.1)*	4.1^{b} *(0.6)*
Odd FA	3.6^{a} *(3.6)*	4.7^{b} *(4.7)*	5.0^{c} *(5.0)*	2.2^{a} *(0.52)*	2.8^{b} *(0.40)*	2.8^{b} *(0.61)*
BRFA††† (*iso + aiso*)	2.7^{a} *(0.62)*	3.1^{b} *(0.48)*	3.7^{c} *(1.11)*	1.1^{a} *(1.1)*	1.2^{ab} *(1.2)*	1.3^{b} *(1.3)*
n-6 PUFA††††	1.5^{a} *(0.69)*	2.6^{b} *(0.98)*	2.8^{b} *(0.73)*	6.0^{a} *(2.7)*	10.1^{b} *(3.2)*	11.2^{b} *(3.9)*
n-3 PUFA†††††	0.07^{a} *(0.07)*	0.45^{b} *(0.46)*	0.55^{b} *(0.55)*	0.80^{a} *(0.34)*	3.1^{b} *(1.4)*	3.3^{b} *(1.4)*

†Adipose tissues (omental and perirenal).
††$oC_{18:1}$: Other isomers of oleic acid.
†††BRFA: Branched-chain fatty acids.
††††*n*-6PUFA: Polyunsaturated fatty acids of the *n*-6 series, consisted of $C_{18:2n-6}$, $C_{18:3n-6}$ and $C_{20:4n-6}$ for the adipose tissues and $C_{18:2n6}$, $C_{18:3n6}$, $C_{20:2n6}$, $C_{20:3n6}$, $C_{20:4n6}$, $C_{22:4n6}$ for the muscles.
†††††*n*-3PUFA: Polyunsaturated fatty acids of the *n*-3 series, consisted of $C_{18:3n-3}$ for the adipose tissues and $C_{18:3-n3}$, $C_{20:3n-3}$, $C_{20:5n-3}$, $C_{22:5n-3}$, $C_{22:6n-3}$ for the muscles.
[a,b,c]Figures within a row lacking a common superscript differ (P < 0.05).

The PA and PP goats had very similar FA percentages in adipose tissues and muscles. The only significant difference between these two groups of goats concerned odd FA and BRFA. In internal adipose tissues of PA goats these FA contents were intermediate between PP and ZP ones. This difference between PA and PP adipose tissue FA percentages was 23% and 62%, for odd FA and BRFA, respectively. Thus, it was very difficult to distinguish goat meat from the two groups raised in the Argan forest by their FA profile. Nevertheless, more than 2/3 of the PA and PP goats could be distinguished by the following percentages of FA in the adipose tissues ($C_{16:0}$, $C_{18:1n9c}$, odd FA, BRFA, *n*-6 FA and *n*-3 FA), when 100% of the ZP goats could be easily distinguished from PP and PA by their FA profile of adipose tissues and of muscles.

Conclusion

In this study, it was shown that meat of the goats grazing at the Argan forest has some different characteristics in fat content and FA profile than that of goats fattened indoors. This difference in composition expressed on the one hand, a more intense ruminal activity, and on the other hand a diet richer in PUFAs. The higher content of PUFAs of the *n*-3 series and the lower percentage of palmitic acid in this meat, brought to the meat of goats which could graze in the Argan forest a favourable aspect for consumers health.

The energy supply of the goats which grazed in the Argan forest had a beneficial effect on growth rate, but had low effect on fat depot weights and on FA composition of adipose tissues and muscles. Thus, the main interest of this supply could be analysed in economic terms, when grazing resources were very low.

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