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Effects of polyethylene glycol in concentrate or feed blocks on carcass composition and offal weight of Barbarine lambs fed *Acacia cyanophylla* Lindl. foliage

Naziha ATTI[a]*, Hichem BEN SALEM[a], Alessandro PRIOLO[b]

[a]INRA-Tunisie, Laboratoire de Productions Animales et Fourragères, rue Hédi Karray, 2049 Ariana, Tunisia
[b]Università di Catania DACPA Sez di Scienze delle Produzioni Animali, Via Valdisavoia 5, 95123 Catania, Italy

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Abstract — The influence of concentrate or feed blocks with or without Polyethylene glycol (PEG, molecular weight 4000) on the carcass characteristics and weight of offal components of 25 Barbarine ram lambs offered *Acacia cyanophylla* Lindl. foliage was studied. The animals were divided into 5 equal groups and housed in individual pens for 74 days. All of the animals received 400 g oat hay and air-dried foliage of acacia ad libitum. Two groups were supplemented with 300 g concentrate with (C_{PEG}) or without (C) 20 g PEG. The other groups had free access to urea-containing feed blocks with (BU_{PEG}) or without (BU) PEG. One other treatment was a PEG-containing feed block without urea (B_{PEG}). PEG was used to preferentially bind *A. cyanophylla* condensed tannins (CT). At the end of the growth trial, the animals were slaughtered, offal components were weighed, left half carcasses were dissected and carcass tissues were weighed. At slaughter, body weight (BW) was the highest ($P < 0.01$) in the group receiving concentrate and PEG (35.4 kg). The animals on diets C, B_{PEG} and BU_{PEG} were slaughtered at similar BW (33.4, 31.8 and 32.1 kg, respectively) and those on BU had the lowest BW (27.8 kg). Dressing percentage was not affected by diet treatments. The weights of the head, feet, lungs, heart and abomasum were not affected by the diet. The diet significantly influenced the skin, testes, liver, kidneys and rumen weights. The animals fed concentrate had heavier skin (4485 g) and rumen (812 g) than those fed blocks (3773 and 720 g for the skin and rumen, respectively). The animals receiving BU had the smallest organs. On contrasting treatments plus/minus PEG, it was observed that PEG administration significantly increased the weight of all organs. PEG supply significantly increased ($P < 0.01$) testis weight (196 vs. 127 g with/without PEG). Due to treatment effects on slaughter BW and hence carcass weight, muscle, bone and fat weights were lower in the BU group compared to those in the other groups. In C, C_{PEG}, B_{PEG} and BU_{PEG} groups, there was no significant difference in body muscle weight. Indeed, the animals fed *A. cyanophylla* with feed blocks with PEG and without urea (B_{PEG} group) produced the same amount of muscle as those produced with PEG and urea-containing feed blocks or conventional diets (concentrate). The

* Corresponding author: belhaj.naziha@iresa.agrinet.tn

animals given feed blocks (more protein and less energy than the concentrate) were less fat (20.0%) than those receiving concentrate (24.7%). The use of acacia foliage and feed blocks without urea but containing PEG may be a useful solution to produce lean lamb in a more economic manner.

lamb / *Acacia cyanophylla* Lindl. / tannins / concentrate / feed blocks / polyethylene glycol / carcass quality / offal weight

Résumé — Incorporation dans le concentré ou les blocs alimentaires de polyéthylène glycol : effets sur la composition de la carcasse et le poids des abats chez les agneaux de race Barbarine nourris avec des feuilles d'*Acacia cyanophylla* Lindl. Les effets de la complémentation ou non de l'aliment concentré ou des blocs alimentaires (BA) avec du PEG sur les caractéristiques des carcasses et le poids des abats ont été étudiés sur 25 agneaux de race Barbarine alimentés avec une ration à base de feuillage d'*Acacia cyanophylla* Lindl. Les animaux ont été répartis en 5 lots homogènes. Logés en boxes individuels pendant 74 jours, tous les agneaux ont reçu 400 g de foin d'avoine avec du feuillage d'acacia à volonté. Deux lots ont été supplémentés avec 300 g de concentré avec (C_{PEG}) ou sans (C) 20 g de PEG. Deux autres lots ont eu libre accès aux blocs alimentaires contenant de l'urée avec (BU_{PEG}) ou sans (BU) PEG. Le dernier traitement a inclu un supplément sous forme de bloc alimentaire sans urée mais avec du PEG (B_{PEG}). A la fin de la période d'engraissement, les animaux ont été abattus, tous les organes pesés, les demi-carcasses disséquées et les différents tissus pesés. À l'abattage, le poids vif des animaux du lot C_{PEG} a été le plus élevé (35,4 kg), celui des animaux des lots C, B_{PEG}, et BU_{PEG} similaire (33,4, 31,8 et 32,1 kg, respectivement), et celui des animaux du lot BU le plus faible (27,8 kg). Le rendement à l'abattage n'a pas été affecté par le régime alimentaire, de même que les poids de la tête, des pattes, des poumons, du cœur et de la caillette. En revanche, le régime alimentaire a eu un effet significatif sur le poids de la peau, des testicules, du foie, des reins et du rumen. De ce fait, le poids de la peau et du rumen des agneaux recevant le concentré (4485 et 812 g) a été supérieur à celui des agneaux recevant les blocs alimentaires (3773 et 720 g), alors que les organes les plus légers ont été observés chez les animaux recevant le régime BU. L'effet du PEG, testé par la méthode des contrastes, a montré que l'administration de PEG augmentait le poids des organes. Ainsi, le poids des testicules a été significativement ($P < 0,01$) plus élevé chez les agneaux recevant le PEG que ceux n'en recevant pas (196 avec PEG vs. 127 g sans PEG). Étant donnés les effets du régime alimentaire sur le poids vif et par conséquent sur le poids de la carcasse, les poids des tissus musculaire, adipeux et squelettique ont été les plus faibles dans le lot BU. En revanche, dans les lots C, C_{PEG}, B_{PEG} et BU_{PEG}, la masse musculaire n'a pas été significativement différente. En conséquence, supplémenter des animaux ayant une alimentation à base de feuilles d'*Acacia cyanophylla* avec des blocs alimentaires sans urée mais contenant du PEG permet de produire une masse musculaire comparable à celle obtenue avec des blocs alimentaires contenant de l'urée et du PEG ou avec des régimes conventionnels (concentré). Les animaux supplémentés avec les blocs alimentaires (plus de protéines et moins d'énergie que le concentré) ont été relativement moins gras (20,0 %) que ceux supplémentés avec le concentré (24,7 %). L'utilisation de feuilles d'acacia avec des blocs alimentaires sans urée mais contenant du PEG permettrait de produire des agneaux non gras de façon plus économique.

agneaux / *Acacia cyanophylla* Lindl. / tannins / concentré / blocs alimentaires / polyéthylène glycol / qualité des carcasses / abats

1. INTRODUCTION

In arid and semi-arid regions of the Mediterranean area, particularly Tunisia, sheep feeding is based on natural resources, range land and stubble. The availability of such resources is uncertain. In good years, grazing is available during a short period (3 to 4 months) in the spring. Out of this season, the fattening operation is based on concentrate feeding. Grazing Barbary lambs reached slaughter age (6 months) with a higher weight and less fat than feedlot lambs fed on hay and concentrate [4, 5].

Furthermore, in feedlot conditions the food conversion efficiency is rather low which increases feed costs.

In order to overcome the problem of food availability and cost, several shrubs and agro-industrial by-products are used as alternative feed resources. *Acacia cyanophylla* Lindl. foliage and *Opuntia ficus indica* (cactus) are the plant species most established and their fodder potential is known [9, 10]. The limiting factor of *A. cyanophylla* is the presence of condensed tannins (CT). The beneficial effect of polyethylene glycol (PEG) supply on the nutritive value of CT-rich feeds has been reported in numerous papers [e.g. 15, 31, 34]. In a recent work, Ben Salem et al. [11] concluded that feed blocks, a solidified mixture of several agro-industrial by-products, were a good carrier of PEG to sheep fed *A. cyanophylla*. This means of administering PEG improved the nutritive value of *A. cyanophylla* and sheep growth. Studies on the effect of CT and their deactivation by PEG on intake, digestion and growth of ruminants are abundant, but information about the effects of these secondary components on the carcass quality of sheep is lacking. The objective of this work was to study lamb production on *A. cyanophylla* foliage supplemented by concentrate or feed-blocks with or without PEG in order to reduce (i) lamb production cost, feed blocks being less expensive than concentrate, and (ii) carcass adiposity via diet quality. Digestive aspects of diets and sheep growth have been reported previously [12]. This paper investigates the effects of these regimens on the carcass composition and offal weight of fat-tail Barbarine sheep.

2. MATERIALS AND METHODS

2.1. Animals and feeding

Twenty-five male Barbarine lambs aged 5 months were separated into 5 groups that were matched as closely as possible for live weight (29 (s.d. 2.6) kg) and housed in individual pens. Before the commencement of the experiment all of the animals were treated against internal and external parasites with Ivomec (MSD-AGVET®). The animals had free access to water, they received 400 g oat hay (6.7 MJ of metabolisable energy (ME) and 74 g crude protein (CP)·kg^{-1} DM), air-dried foliage of *A. cyanophylla* ad libitum (5.6 MJ ME and 153 g CP·kg DM^{-1}) and supplement. In two groups, the supplement was 300 g concentrate (10.5 MJ ME and 116 g CP·kg^{-1} DM), only concentrate in one (C) and concentrate plus 20 g PEG in the other (C_{PEG}). In the 3 others, supplements were feed blocks, which varied with group. Feed blocks contained urea without PEG (BU: 6.1 MJ ME and 235 g CP·kg^{-1} DM), in the first group and, PEG without urea in the second (B_{PEG}: 4.2 MJ ME and 101 g CP·kg^{-1} DM). In the third group, feed blocks contained both urea and PEG (BU_{PEG}: 5.3 MJ ME and 253 g CP·kg^{-1} DM). The animals were on trial for 74 days during which time the average daily DM intake of *A. cyanophylla* foliage varied between 300 and 500 g. At the end of the trial, the lambs were slaughtered.

2.2. Measurements at slaughter

Before slaughter, lamb body weights (BW) were recorded. After slaughter, omental and mesenteric fat (OMF) were removed, the weights of the different components of offal were determined: skin, head, feet, thoracic organs (heart, lungs + trachea) and viscera (digestive tract, spleen, liver and kidney). All fractions of the digestive tract (reticulo-rumen + omasum (rumen), abomasum, and intestine) were weighed full then empty after hand rinsing, in order to determine the weight of the digestive contents.

Conformation and fat scores of the carcass were visually determined according to photographic standards using a 15 point scale [16]. The second parameter was based on backfat thickness and fat distribution. Fat colour (white, yellowish or yellow) and persistence (hard, tender or oily) and lean colour (red or rosy) were assessed visually. Warm carcass weight (WCW) was recorded and then the carcasses were stored at +4 °C.

2.3. Carcass cutting and dissection

The cold carcass weight (CCW) was recorded 24 h post-mortem after storage at 4 °C. The fat tail was removed and weighed then the carcass was split longitudinally into two and the halves were weighed. The left half-carcass was cut into six joints (leg, lumbar region, flank, thoracic region, neck and shoulder) following the procedures of Colomer et al. [13]. Every joint was weighed and dissected. The first operation in the dissection process was the removal of subcutaneous fat. The muscles were then removed singly from the bones, finally inter-muscular fat was trimmed from the muscles and bones. Other tissues such as tendons, lymph nodes etc. were separated as waste. Pelvic fat was removed from the leg and kidney fat from the thoracic region.

2.4. Calculation and statistical analysis

Empty body weight (EBW) was calculated as the difference between BW before slaughter and the weight of digestive contents. Commercial and real dressing percentage (CDP, RDP) were calculated according to the following equations:

CDP (%) = 100 × WCW / BW

RDP (%) = 100 × CCW / EBW.

For each joint, the tissues were weighed individually; the sum of the weights of each tissue in all joints represents the weight of the tissue in the half carcass and was used for calculation of carcass composition. The carcass composition data were reported as percentages. The total tissue weight recovered after dissection was used as the divisor in the calculation of percentages of each tissue. Fat depots were presented as proportions of total carcass fat (TCF) as real values, and as carcass fat without fat tail (CFWFT) to facilitate comparison with results relative to thin tail breeds.

Statistical analysis was performed by analysis of variance using the GLM procedure of SAS [32]. The effects of dietary treatment on offal component weights, tissue weights, their proportions in EBW or in carcass, the different fat depot weights and their proportions in TCF were analysed according to the following model:

$$Y_{ij} = \mu + D_i + e_{ij}$$

(Y_{ij} = jth measure of the ith diet; μ = overall mean; D_i = effect of the ith diet (C, C_{PEG}, BU, B_{PEG}, BU_{PEG}); e_{ij} = error term). Differences between groups were evaluated by the Duncan t-test; significance was declared at $P < 0.05$.

The following contrasts were used to compare the effects of the different diets:

- ($C+C_{PEG}$) vs. ($BU+BU_{PEG}$): combined the effect of the method of supplementation and energy/protein supply from the supplement.
- (C+BU) vs. ($C_{PEG}+BU_{PEG}$): global effect of inclusion of PEG.
- BU_{PEG} vs. B_{PEG}: effect of including urea in blocks.
- BU_{PEG} vs. BU: effect of inclusion of PEG in blocks.
- C_{PEG} vs. C: effect of inclusion of PEG in concentrate.

3. RESULTS

3.1. Empty body weight, carcass characteristics and dressing percentage

BW at slaughter was affected by diet ($P < 0.05$). Almost all the contrasts, except

[BU_{PEG} vs. B_{PEG}] and [C_{PEG} vs. C] were significant. Indeed, BW was higher in groups receiving concentrate (34.4 kg) than in those receiving feed blocks (30.5 kg). Administering PEG in concentrate had no effect on BW, however, its incorporation in feed blocks improved BW (Tab. I). Animals given PEG-containing feed blocks (B_{PEG} and BU_{PEG}) were slaughtered at similar BW (31.8, and 32.1 kg, respectively) which was significantly higher than that of animals on the BU-diet (27.8 kg). This effect of the diet on BW was carried through to EBW and carcass weight (Tab. I). Dressing percentage was not significantly affected by the diet treatments, the mean CDP was 43.8% and the mean RDP was 53.2%.

Carcass conformation score was significantly affected ($P < 0.001$) by diet (Tab. I). and was higher in groups receiving concentrate (8.1) than in those receiving feed blocks (5.1). The contrast [C+C_{PEG} vs. BU+BU_{PEG}] was significant ($P < 0.001$). The contrast [BU_{PEG} vs. BU] was highly significant ($P < 0.01$) but the contrast [C_{PEG} vs. C] was not. In fact, administering PEG in feed blocks led to the largest improvement in carcass conformation score compared to PEG included in the concentrate. The BU-group had the lowest score conformation. The carcass fat score was affected ($P < 0.05$) by the diet treatment and contrasts [C+C_{PEG} vs. BU+BU_{PEG}] and [BU_{PEG} vs. BU] were significant. The fat score was the highest in C_{PEG} (Tab. I). Fat consistency and lean colour were not affected by the treatments. In all carcasses, the fat was tender and the lean rose. Fat colour was not the same in all groups; sheep receiving concentrate had more carcasses with white than yellowish fat whereas in sheep fed feed blocks the reverse occurred.

3.2. Offal weights

Weights of head, feet, lungs, heart and intestines were not affected by diet and all contrasts were not significant except for the presence of the PEG effect on intestine weight (Tab. II). Diet effect was significant for skin, testes, liver, kidneys, rumen and abomasum weights (Tab. II). Animals receiving BU had the smallest organs (Tab. II). The effect of PEG inclusion [C+BU vs. C_{PEG}+BU_{PEG}] was significant for all these organs increasing with PEG administration (Tab. II). The increase of skin, kidney and rumen weight due to PEG administration was particularly pronounced when this reagent was introduced in feed blocks. Animals fed concentrate had heavier skin and rumen than those fed blocks; the [C+ C_{PEG} vs. BU+BU_{PEG}] contrast was significant (Tab. II). The weight of the digestive tract contents was higher in the animals offered concentrate (6957 g) than in those given feed blocks (6428 g). The animals fed concentrate had more ($P < 0.05$) OMF than those offered feed blocks. The animals offered blocks had greater proportions of intestines ($P < 0.01$) and liver ($P < 0.05$) in EBW than those on the concentrate diet (4.73 and 1.66% vs. 4.21 and 1.53% respectively). Proportions of head and feet were affected ($P < 0.01$) by diet; these organs were higher with feed blocks than with concentrate and in animals receiving PEG than in other groups. Otherwise, sheep given PEG had the greatest testis proportion ($P < 0.01$) in EBW (0.74 vs. 0.52%). OMF proportion in EBW was the lowest in the BU group.

3.3. Carcass composition

3.3.1. Carcass joints

Weights of the leg, shoulder, thoracic and lumbar regions and fat-tail were significantly affected by diet ($P < 0.01$) and were higher in sheep receiving concentrate compared to those receiving feed blocks. Administering PEG led to increasing the weight of these organs, except for the fat-tail which decreased with PEG. As proportions of the carcass, joints had similar values on all diets (36, 18.5, 19, 10 and 10 for

Table I. Mean body weight (BW), empty body weight (EBW), cold carcass (CC), dressing percentage, carcass conformation and fat score of lambs on each treatment.

	C	C_{PEG}	BU	B_{PEG}	BU_{PEG}	S.E.	Significance
BW (kg)	33.4^{a}	35.4^{a}	27.8^{b}	31.8^{a}	32.1^{a}	0.58	*
EBW (kg)	26.5^{ab}	28.4^{a}	22.05^{c}	25.1^{b}	25.3^{b}	0.44	**
Carcass weight (kg)	14.4^{ab}	15.2^{a}	11.7^{c}	13.4^{b}	13.0^{bc}	0.24	***
CDP (%)	44.5	44.0	43.7	43.4	42.2	0.29	ns
RDP (%)	54.4	53.4	53.4	53.2	51.2	0.10	ns
Conformation score	7.4^{b}	8.8^{b}	2.8^{a}	6.0^{a}	6.6^{a}	0.24	***
Fat score	7.8^{ab}	9.2^{a}	3.0^{b}	6.2^{ab}	6.2^{ab}	0.37	*

Contrasts	C+C_{PEG} vs. BU+BU_{PEG}	C+BU vs. C_{PEG}+BU_{PEG}	BU_{PEG} vs. B_{PEG}	BU_{PEG} vs. BU	C_{PEG} vs. C
BW (kg)	***	**	ns	**	ns
EBW (kg)	***	**	ns	**	ns
Carcass weight (kg)	***	ns	ns	*	ns
CDP (%)	ns	ns	ns	ns	ns
RDP (%)	ns	ns	ns	ns	ns
Conformation score	***	**	ns	**	ns
Fat score	*	ns	ns	*	ns

In this and all other tables, C: group supplemented with concentrate; C_{PEG}: group supplemented with concentrate and PEG; BU: group supplemented with urea feed block; B_{PEG}: group supplemented with feed block containing PEG; BU_{PEG}: group supplemented with urea feed block containing PEG; S.E.: standard error; CDP: commercial dressing percentage; RDP: real dressing percentage.
^{a,b,c}: Means in the same line with different superscripts are significantly different ($P < 0.05$).
***: $P < 0.001$; **: $P < 0.01$; *: $P < 0.05$; ns: not significant ($P > 0.05$).

Table II. Mean fresh organ weights (g) of lambs on each treatment.

	C	C_{PEG}	BU	B_{PEG}	BU_{PEG}	S.E.	Significance
Head	1837	1788	1634	1767	1821	22.3	ns
Feet	699	735	656	687	674	12.1	ns
Skin	4275^{ab}	4694^{a}	3305^{c}	3807^{bc}	4206^{ab}	131.4	*
Testis	134^{a}	209^{b}	119^{a}	194^{b}	184^{b}	8.6	***
Heart + pericardic fat	138	155	120	167	138	5.4	ns
Liver	397^{ab}	445^{a}	365^{b}	410^{ab}	422^{a}	8.2	*
Lungs + trachea	510	481	447	486	508	15.8	ns
Kidneys	88	90	84	97	103	2.5	*
RRO	776^{ab}	848^{a}	686^{c}	801^{ab}	754^{bc}	13.4	**
Abomasum	146^{a}	181^{b}	144^{a}	166^{b}	175^{b}	4.9	*
Intestines	1088	1221	1079	1151	1196	22.8	ns
OMF	508^{ab}	632^{a}	309^{b}	500^{ab}	417^{b}	30.1	*

Contrasts	$C+C_{PEG}$ vs. $BU+BU_{PEG}$	$C+BU$ vs. $C_{PEG}+BU_{PEG}$	BU_{PEG} vs. B_{PEG}	BU_{PEG} vs. BU	C_{PEG} vs. C
Head	ns	ns	ns	ns	ns
Feet	ns	ns	ns	ns	ns
Skin	**	ns	**	ns	ns
Testis	ns	***	ns	**	**
Heart + pericardic fat	ns	ns	ns	ns	ns
Liver	ns	**	ns	*	*
Lungs + trachea	ns	ns	ns	ns	ns
Kidneys	ns	**	ns	**	ns
RRO	**	*	ns	ns	ns
Abomasum	ns	**	ns	*	*
Intestines	ns	*	ns	ns	ns
OMF	**	ns	ns	ns	ns

[a,b,c]: Means in the same line with different superscripts are significantly different ($P < 0.05$); ***: $P < 0.001$; **: $P < 0.01$; *: $P < 0.05$; ns: not significant ($P > 0.05$); RRO: Reticulo-rumen + omasum; OMF: Omental + mesenteric fat.

Table III. Mean weights of tissue (g) and as a percentage of whole carcass (CW) of lambs on each treatment.

	C	C_{PEG}	BU	B_{PEG}	BU_{PEG}	S.E.	Significance
Muscle (g)	3644^{a}	3871^{a}	2932^{b}	3519^{a}	3489^{a}	56.3	***
% CW	52.4	52.0	54.4	53.4	55.1	0.69	ns
Bone (g)	1466	1481	1274	1455	1436	26.2	ns
% CW	21.1^{bc}	19.9^{c}	23.6^{a}	22.1^{abc}	22.8^{ab}	0.42	**
Fat (g)	1679^{ab}	1900^{a}	1037^{c}	1426^{bd}	1232^{cd}	71.3	**
% CW	23.9^{ab}	25.4^{a}	19.1^{b}	21.5^{ab}	19.3^{b}	0.64	**
Contrasts	$C+C_{PEG}$ vs. $BU+BU_{PEG}$		$C+BU$ vs. $C_{PEG}+BU_{PEG}$		BU_{PEG} vs. B_{PEG}	BU_{PEG} vs. BU	C_{PEG} vs. C
Muscle (g)	***		**		ns	**	ns
% CW	ns		ns		ns	ns	ns
Bone (g)	*		ns		ns	ns	ns
% CW	***		ns		ns	ns	ns
Fat (g)	***		*		ns	ns	ns
% CW	**		ns		ns	ns	ns

[a,b,c]: Means in the same line with different superscripts are significantly different ($P < 0.05$); ***: $P < 0.001$; **: $P < 0.01$; *: $P < 0.05$; ns: not significant ($P > 0.05$).

Table IV. Fat depot proportions in dissectible carcass fat without fat-tail (% CFWFT) and in total carcass fat (% TCF) of lambs on each treatment.

	C	C_{PEG}	BU	B_{PEG}	BU_{PEG}	S.E.	Significance
Subcutaneous fat (g)	655 ^{a}	787 ^{b}	347 ^{c}	593 ^{a}	428 ^{c}	36.1	**
% CFWFT	54.3 ^{a}	57.1 ^{a}	46.1^{b}	54.4 ^{a}	44.9^{b}	1.05	**
% TCF	38.8^{ab}	41.6 ^{a}	32.8^{c}	41.0 ^{a}	34.4^{bc}	0.71	**
Inter-muscular fat (g)	440	481	316	380	431	21.1	ns
% CFWFT	36.9 ^{a}	34.5 ^{a}	43.6^{b}	36.1 ^{a}	45.3^{b}	0.83	**
% TCF	26.3^{ab}	25.2 ^{a}	31.0^{bc}	27.3^{bc}	35.2^{c}	0.82	**
Pelvic fat (g)	37	36	33	40	37	2.6	ns
% CFWFT	2.9^{ab}	2.6 ^{a}	4.6^{b}	3.9^{ab}	4.0^{ab}	0.22	ns
% TCF	2.1^{ab}	1.9 ^{a}	3.3^{b}	3.0^{ab}	3.1^{ab}	0.24	ns
Kidney fat (g)	71	86	42	59	55	6.41	ns
% CFWFT	5.8	5.9	5.6	5.7	5.7	0.34	ns
% TCF	4.2	4.3	4.0	4.3	4.3	0.19	ns
Tail fat (g)	953 ^{a}	1016 ^{a}	600 ^{b}	709 ^{b}	564 ^{b}	49.9	**
% TCF	28.6	27.0	28.9	24.4	22.9	0.78	ns

Contrasts	$C+C_{PEG}$ vs. $BU+BU_{PEG}$	$C+BU$ vs. $C_{PEG}+BU_{PEG}$	BU_{PEG} vs. B_{PEG}	BU_{PEG} vs. BU	C_{PEG} vs. C
Subcutaneous fat (g)	***	ns	ns	ns	ns
% CFWFT	***	ns	**	ns	ns
% TCF	***	ns	**	ns	ns
Inter-muscular fat (g)	***	ns	**	ns	ns
% CFWFT	*	ns	**	ns	ns
% TCF	***	ns	**	ns	ns
Pelvic fat (g)	ns	ns	ns	ns	ns
% CFWFT	**	ns	ns	ns	ns
% TCF	**	ns	ns	ns	ns
Kidney fat (g)	*	ns	ns	ns	ns
% CFWFT	ns	ns	ns	ns	ns
% TCF	ns	ns	ns	ns	ns
Tail fat (g)	***	ns	ns	ns	ns
% TCF	ns	*	ns	*	ns

[a,b,c]: Means in the same line with different superscripts are significantly different ($P < 0.05$); ***: $P < 0.001$; **: $P < 0.01$; *: $P < 0.05$; ns: not significant ($P > 0.05$).

leg, shoulder, thoracic and lumbar regions and the flank, respectively). They were not affected by the diet treatment and all contrasts were not significant, except for the contrast [C+C_{PEG} vs. BU+BU_{PEG}], which was significant for the fat-tail proportion ($P < 0.05$). Animals fed on concentrate had relatively bigger tails (7.5%) than those consuming feed blocks (5.7%).

3.3.2. Carcass tissues

Muscle and adipose tissue mean weights were significantly affected by the diet ($P < 0.01$). However bone weight was not affected by dietary treatments and [C+C_{PEG} vs. BU+BU_{PEG}] and [C+BU vs. C_{PEG}+ BU_{PEG}] contrasts were significant. Adipose tissue weight was bigger in the animals receiving concentrate than in those receiving feed blocks. Administration of PEG in the concentrate resulted in a little increase in muscle and fat weight, but PEG added to feed blocks led to an important ($P < 0.01$) increase in muscle, fat and bone weight (Tab. III). The proportion of the carcass muscle was similar for all diets (53.4%). Inversely, the proportions of fat and bone were affected by diet. Sheep given feed blocks were less fatty ($P < 0.01$; 20.0%) and had relatively more bone than those receiving concentrate (24.7%). The [C+C_{PEG} vs. BU+ BU_{PEG}] contrast was significant ($P < 0.01$). Sheep given concentrate were fatter; hence they had relatively more subcutaneous and less inter-muscular and pelvic fat than those fed feed blocks. Only the tail fat proportion was decreased by PEG supply. The proportion of kidney fat was not affected by the treatment (Tab. IV).

4. DISCUSSION

Differences in performances observed between animals receiving concentrate and those receiving feed blocks are associated with the method of supplementation combined to the energy/protein ratio from the supplement. In fact, the two concentrate treatments had the same energy and protein content. However, the three block treatments differed in protein content and had similar energy content (5.4 MJ·kg^{-1}) which was less than the concentrate (10 MJ·kg^{-1}). Hence the concentrate diet resulted in the heaviest lambs. Thus, the animals receiving these diets had the highest EBW and carcass weight. Introducing PEG in the concentrate also tended to slightly increase these traits. Adding PEG to urea feed blocks (BU_{PEG}) led to an increase of DM intake and feeding value of the diet [12] which resulted in an increase in BW, EBW and carcass weight with reference to the BU treatment which had the same energy and protein content. A similar tendency occurred with the B_{PEG} treatment, despite the fact that it contained less protein (101 g CP·kg^{-1}) than the BU treatment (235 g CP·kg^{-1}), it permitted a higher BW, EBW and carcass weight. PEG operated as a precipitating reagent to deactivate *A. cyanophylla* CT and hence to promote increased N availability to rumen micro-organisms and to the host animal. However, the BU lambs had the lowest EBW and carcass weight.

C_{PEG} animals had the best conformation score. This result may be related to the highest fat score, since it is difficult to discriminate between these parameters [22]. The increase in these parameters resulted from a BW increase. Numerous authors [1, 14, 18, 29, 30, 36] reported such a relationship.

Rumen weight was higher for sheep receiving concentrate with or without PEG and the PEG-containing feed block. This trend is associated with the feed intake level [7, 17, 20, 26], which was more elevated in C, C_{PEG}, B_{PEG} and BU_{PEG} groups [12]. Hence the digestive tract content, which is related to food intake, was heavier in those groups. On the contrary, these animals were heavier than BU animals. It is well established that, in young animals, some parts of the alimentary tract and particularly the rumen continue to develop as the animals become older and heavier [17, 20, 25, 33]. However, the weight of some other organs increased or tended to increase only by PEG supplementation (abomasum, intestines, liver and kidneys). Nutrients produced by fermentation of PEG-containing diets are probably important factors in changes in liver weight [27]. This phenomenon may explain the higher weight of the liver and other organs in sheep given PEG as compared to those fed control diets (i.e. without PEG).

The weight of offal components high in bone content and/or with a low metabolic activity (head, feet and lungs) varied slightly with diet. Since these components are early maturing parts [28, 35]; they are less affected by the dietary effects in growing animals [21].

The weight of most offal components was not different between groups slaughtered at a similar BW, despite the difference in feed level and quality. This suggests that the weight of most offal components depend more on weight at slaughter rather than on the intake level or diet composition.

It is worth noting that PEG supply increased the testis weight. It is well documented that testis weight is correlated to spermatozoa production [19, 24]. Therefore, it would be interesting to confirm these findings on animals given PEG in CT-rich feeds or in other feeds.

Due to the treatment effects on slaughter BW and hence carcass weight, body muscle, bone and fat weights were lower in the BU group compared to those in the other groups. In C, C_{PEG}, B_{PEG} and BU_{PEG} groups, there was no significant difference in body muscle weight. So for animals fed *A. cyanophylla*, supplementation by concentrate or feed blocks with PEG resulted in the same muscle quantity, whereas PEG added to concentrate did not act on the muscle quantity, but administered in feed blocks, this reagent increased muscle growth. Furthermore, including PEG in feed blocks without urea (B_{PEG} group) in animals fed *A. cyanophylla* led to the same amount and proportion of muscle as in those given *A. cyanophylla* and concentrate or feed blocks with urea. Indeed, supplementing animals fed *A. cyanophylla* with feed blocks with PEG and without urea (low in CP, B_{PEG} group) may have deactivated tannins; thus releasing proteins from protein-tannin complexes and enhancing protein synthesis. This quantity of protein seems to be sufficient to produce the same amount of muscle as that produced with PEG and urea-containing feed blocks or conventional diets (concentrate).

Body fat increased in weight (and proportions) in concentrate groups compared to feed block groups. Energy and protein contents [12] of diets containing concentrate (10 MJ and 116 g $CP \cdot kg^{-1}$ DM) or feed blocks (6 MJ and 101 or 235 g $CP \cdot kg^{-1}$ DM) partly explain the difference in body fat contents. Indeed, both PEG-containing feed block diets having the high ratio of protein to energy led to the same muscle weight and proportion but less fat than concentrate diets. Sheep given concentrate had relatively more subcutaneous and less inter-muscular fat. The subcutaneous fat deposition occurs late, hence its proportion increased when total body fat increased while for inter-muscular fat, an early maturing depot, the inverse occurred. This order of deposition has been confirmed in several breeds [2, 3, 6, 8, 23].

Referring to earlier studies on Barbarine lambs slaughtered at the same weight and age, animals used in the current experiment (fed *A. cyanophylla*) and supplemented with concentrate were less fatty (24.7%) than those kept in the feedlot and given oat-vetch hay ad libitum and concentrate (29.7%; [5]). This trend was expected since animals used in the current experiment were offered diets having a high ratio of protein to energy. However, the conventional fattening regimen is more expensive, needing more hay (0.6 to 1 kg $DM \cdot lamb^{-1} \cdot day^{-1}$) and more concentrate (0.6 $kg \cdot day^{-1}$). On the contrary, animals fed *A. cyanophylla* and supplemented with feed blocks were less fatty than those used in the previous work, and they have a fat level (20%) similar to lambs fed at pasture (20%, [5]). Hence, it may be possible to produce lean lambs without a problem of food availability, using *A. cyanophylla* foliage and feed blocks with PEG.

5. CONCLUSIONS

Using PEG-containing feed blocks as a supplement to animals fed *A. cyanophylla*, resulted in the same amount of muscle as that produced by lambs given concentrate as a supplement to *A. cyanophylla*. Furthermore and in conjunction with differences in energy content and protein to energy ratio, diets supplemented with PEG-containing feed blocks decreased carcass fatness by 40 $g \cdot kg^{-1}$ of side carcass. For animals fed *A. cyanophylla*, the use of feed blocks with PEG and without urea, may permit savings on urea use since it produced carcasses of similar composition to that produced by a regimen supplemented with feed blocks containing both PEG and urea.

Barbarine lambs given *A. cyanophylla* and concentrate or feed blocks with PEG had reduced carcass fatness compared to those fed a common diet (oat hay and concentrate). So finishing lambs on *A. cyanophylla* supplemented with either concentrate or feed blocks containing PEG produced less fat and hence were more economically efficient and addressed partially the problem of food availability. The use of feed blocks without urea but containing PEG for sheep fed acacia foliage may be of benefit to producers seeking to produce lean carcasses in a more economic manner.

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