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SUMMARY – The objective of this investigation is the study of the effects of fish meal (FM) in lamb diets on growth performance, carcass characteristics, and subcutaneous fatty acid (FA) composition. Twenty-five lambs (21 ± 2 kg) were assigned to five dietary treatments (5 animals per treatment). In all treatments, lambs were offered 200 g dry matter (DM) of oat hay and *ad libitum* amounts of concentrate. For lambs of the control diet, the concentrate was a mixture of barley, soybean meal (SBM) and mineral/vitamin supply. The concentrates for the other groups contained FM at 5 or 10%. Moreover, two strategies were developed to feed diets containing FM: FM diets were offered for 55 days before slaughter or during the whole experiment (105 d). All the concentrates were isonitrogenous (160 g of crude protein per kg DM). Dry matter intake and average daily gain were not affected (P>0.05) by FM feeding. Carcass traits and organ weights were neither affected (P>0.05) by FM feeding nor by feeding strategy except for the dressing percentage, which was higher for FM diets than for the control diet (P<0.05). FM feeding did not affect carcass adiposity or subcutaneous lipids' FA composition. Water holding capacity was not affected by FM feeding but pH decreased (P<0.05) with FM diets. In these experimental conditions, FM could replace SBM as a protein source but did not affect carcass or FA composition.

Keywords: Lambs, fish meal, growth, carcass composition, fatty acid profile.

***RESUME –** "Effets de l'incorporation de farine de poisson dans l'alimentation des agneaux sur les performances de croissance, la composition des carcasses et la teneur du tissu adipeux sous-cutané en acides gras". L'objectif de ce travail est l'étude des effets de l'incorporation de la farine de poisson (FP) dans l'alimentation des agneaux sur les performances de croissance, la composition des carcasses et la teneur du tissu adipeux sous-cutané en acides gras. Vingt-cinq agneaux de race Barbarine (21 ± 2 kg) ont été répartis en cinq lots de 5 animaux. Dans tous les lots, les agneaux recevaient 200 g de foin d'avoine et de l'aliment concentré à volonté. Pour les agneaux du lot témoin, l'aliment concentré est un mélange d'orge, de tourteaux de soja et de complément minéral et vitaminique. Les concentrés des autres groupes contenaient 5 et 10% de FP. En outre, deux stratégies ont été adoptées avec l'usage de la FP : application de ces régimes pendant les derniers 55 jours avant abattage ou durant toute la période expérimentale (105 j). Tous les concentrés sont iso-azotés (160 g de protéines brutes par kg MS). L'ingestion de MS et le gain moyen quotidien n'étaient affectés ni par le régime alimentaire ni par la durée d'application de ces régimes (P > 0,05). Les caractéristiques des carcasses et le poids des différents organes étaient similaires dans tous les lots, exception faite pour le rendement en carcasse qui était significativement supérieur dans les lots FP par rapport au lot témoin (P < 0,05). L'incorporation de la FP de poisson n'a affecté ni l'adiposité des carcasses ni la composition des lipides sous-cutanés en acides gras. La capacité de rétention de l'eau n'a pas été affectée par l'ingestion de FP, mais le pH a diminué (P < 0,05) avec ce facteur nutritionnel. Dans ces conditions expérimentales, la FP peut remplacer le tourteau de soja en tant que source protéique mais elle n'a pas affecté la composition des carcasses et celle des acides gras.*

***Mots-clés :** Agneaux, farine de poisson, croissance, qualité de carcasse, acides gras.*

Introduction

The protein degradation is an important concept in ruminant feeding. The rich feed in undegradable proteins in the rumen (UDPR) resulted in an increase in amino acids flux in the intestines resulting in a body weight (BW) rise without excessive adiposity (Thériez and Brun, 1978; Vipond *et al.*, 1989). Fish meal (FM) is considered a source of UDPR, which is used in replacing highly degradable protein sources (Hussein and Jordan, 1991). FM is also rich in poly-unsaturated fatty acids (PUFA) particularly the n-3 fatty acids considered as very healthy nutrients (Mandell *et al.*, 1997; Ponnampalam *et al.*, 2001, 2002). On the other hand, Tunisian people, taking conscience of health problems in relationship with fat consumption avoid the fat meat and prefer the lean lamb meat. Furthermore, FM as a protein source is less expensive than the soybean meal (SBM) in Tunisia, so its incorporation in animal diet may have triple aim: (i) a substitution to SBM; (ii) a source of UDRP; and (iii) a source of PUFA.

The objective of this investigation is the study of effects of the amount and duration of FM incorporation in lamb diets on growth performance, carcass characteristics, and subcutaneous fatty acid (FA) composition.

Material and methods

Animals and diets

Twenty-five lambs (21 ± 2 kg) were assigned to five dietary treatments (5 animals per treatment). In all treatments, lambs were offered 200 g dry matter (DM) of oat hay and *ad libitum* amounts of concentrate. For lambs of control diet, the concentrate was a mixture of barley, SBM and mineral/vitamin supply. The concentrates for the other groups contained FM at 5 or 10%. Moreover, two strategies were developed to feed diets containing FM: FM diets were offered for 55 days before slaughter or during the whole experiment (105 d). Experimental feeds characteristics are reported in Table 1.

Table 1. Chemical and fatty acid (FA) composition of the experimental feeds

	Hay	Concentrate		
		Control	FM 5%	FM 10%
Dry matter (%)	83	86	86	86
Organic matter (% DM)	93.7	91.6	90.2	88.9
Crude protein (% DM)	4.9	15.4	16.0	16.1
Crude fiber (g/kg DM)	32.8	9.0	8.5	8.0
Ash (% DM)	6.3	5.8	7.3	8.6
Energy (forage units/kg DM)	0.60	0.96	0.95	0.94
FA composition (% of total FA)				
C16:0		27.9	28.7	29.9
C18:0		3.0	3.1	4.4
C18:1		26.0	20.4	24.4
C18:2		33.2	27.5	27.6
C18: 3 n-3		2.5	2.6	2.7
C22:6 n-3		0.08	0.13	0.48

Measurements

Lamb BWs were recorded at slaughter. After slaughter, all organs were weighed, carcasses were stored 24 h at +4°C and then weighed. Tails were then removed and each carcass was split longitudinally in halves. The left half-carcass was cut into 6 joints, which were dissected in fat, muscles and bones. Samples of *longissimus dorsi* (LD) muscle (6^{th} to 13^{th} rib) and samples of subcutaneous fat were moved for meat quality, chemical analysis and FA composition.

Laboratory analysis

The ultimate pH was measured 24 h *post mortem* with an Orion 9106 penetrating probe. Water holding capacity (WHC) was measured as cooking loss in muscle samples aged in plastic bags at 4°C until 72 h *post mortem* (Boccard *et al.*, 1981).

The FA composition of the subcutaneous fat was analysed after extraction and methylation with K-OH on chromatograph (HP-5890) equipped with a flame ionisation detector and split (1:24) injector. Separations were performed using a HP-FFAP capillary column (25 cm × .2 mm i.d. × .3 µm).

Statistical analysis

A one-way analysis of variance for diet effect on growth, body composition and meat quality using GLM procedure in SAS (1989) was applied. Then, the test Duncan was used to compare diet mean effects (α = 0.05). Furthermore, The following contrasts were used to compare the effects of the different diets:

(i) Control *vs* FM – control diet *vs* FM diets.
(ii) FM 5% *vs* FM 10% – effect of concentration of FM.
(iii) FM 5% 55 *vs* FM 5% 105 – effect of duration of FM 5%.
(iv) FM 10% 55 *vs* FM 10% 105 – effect of duration of FM 10%.

Results and discussion

Lambs were fed restricted amounts of oat hay (0.2 kg/lamb/day), in revenge they had concentrate *ad libitum*. Dry matter intake (DMI) of concentrate was similar for all treatments. Average daily gain (ADG) tended to decrease with increasing duration of FM application but it was not affected (P > 0.05) by diet treatment (Table 2). Due to the similar DMI and ADG, feed efficiency (grams of DMI per gram of gain) was not improved by the inclusion of FM in the diet. All concentrates used in this trial contained 160 g CP/kg, the recommended level for growing lambs (INRA, 1988); so protein requirements of lambs were satisfied and they were not the limited factor for the lamb growth. Similar results were found by Hussein and Jordan (1991) in two lambs trial growth where soya bean was partially or totally replaced by FM. On the other hand, the high proportion of barley in the diet could explain this absence of significant response when FM rich source of UDPR replaced SBM, a highly degradable protein source. Furthermore, the high levels of barley could reduce ruminal pH resulting in a probable depression of CP degradation of SBM, which may have values close to those of FM. It was shown that CP degradation of SBM was markedly reduced by a depression in ruminal pH (Loerch *et al.*, 1983). As another explanation of the absence of response to FM supplementation is the depression of ruminal microbial protein synthesis by FM feeding (Hussein *et al.*, 1991). So, the reduced quantities of microbial protein synthesis in the rumen may counterbalance the great quantities of protein escaping ruminal degradation when FM replaced SBM.

Table 2. Effect of FM content in concentrate on lamb growth and carcass weight

	Control	FM 5%		FM 10%		p	C1†	C2†	C3†	C4†
		55	105	55	105					
DMI (g/day)										
Hay	0.2	0.2	0.2	0.2	0.2	ns	ns	ns	ns	ns
Concentrate	1.0	0.9	0.9	1.1	1.0	ns	ns	ns	ns	ns
Initial BW (kg)	19.5	20.0	21.3	21.8	21.0	ns	ns	ns	ns	ns
ADG (g/day)	120	115	104	111	109	ns	ns	ns	ns	ns
Final BW (kg)	31.9	31.9	32.1	33.2	32.3	ns	ns	ns	ns	ns
EBW (kg) ††	26.4	26.8	26.9	27.9	28.2	ns	ns	ns	ns	ns
Carcass (kg)	14.1	14.8	14.9	15.7	15.7	ns	ns	ns	ns	ns

†C1: control *vs* FM; C2: FM 5% *vs* FM 10%; C3: FM 5% 55 *vs* FM 5% 105; C4: FM 10% 55 *vs* FM 10% 105.
††EBW: empty body weight.

Carcass traits and organs weight were affected (Table 2) neither by FM feeding nor by feeding strategy except for the dressing percentage, which was higher for FM diets than control one (P < 0.05). Mean weights of skin, head, gut and liver were 4082, 1602, 2015 and 511 g respectively. The weight of offal components was not different between groups slaughtered at the similar BW, despite the difference in feed quality. This suggests that the weight of most offal components depend more on weight at slaughter rather than on the diet composition.

Muscle, fat and bone weights and proportions were not significantly affected by FM feeding (Table 3). So, carcass adiposity was not affected by dietary treatment. Lambs had the same EBW and carcass weight and composition, given they were slaughtered at the same weight; these parameters depend on slaughtering BW (Colomer-Rocher and Espejo, 1972; Atti *et al.*, 2003).

Table 3. Effect of FM content in concentrate on tissues weight (g) and proportions and meat characteristics

	Control	FM 5%		FM 10%		p	C1†	C2†	C3†	C4†
		55	105	55	105					
Muscle (g)	7234	7483	7297	8034	8363	ns††	*	ns	ns	ns
Muscle (%)	53.2	52.8	52.0	53.0	52.28	ns	ns	ns	ns	ns
Bone (g)	2607	2531	2353	2730	2823	ns	ns	ns	ns	ns
Bone (%)	19.1	17.9	16.8	18.2	17.6	ns	ns	ns	ns	ns
Fat (g)	3425	3727	4014	4004	4456	ns	ns	ns	ns	ns
Fat (%)	25.0	26.4	28.4	25.8	27.5	ns	ns	ns	ns	ns
pH	5.70	5.57	5.63	5.49	5.59	ns	ns	ns	ns	ns
WHC (%)	7.1	5.7	6.2	5.5	5.9	ns	ns	ns	ns	ns

†C1: control vs FM; C2: FM 5% vs FM 10%; C3: FM 5% 55 vs FM 5% 105; C4: FM 10% 55 vs FM 10% 105.
††Not significant (p>0.05); *: significant (p<0.05).

Water holding capacity was not affected by FM feeding but pH decreased (P < 0.05) with FM diets (Table 3). Fish meal feeding did not affect FA composition; furthermore, subcutaneous lipid didn't contain *n-3* FAs. FM did not affect carcass and FA composition (Table 4), while positive results in relationship with FM use were mentioned concerning the augmentation of *n-3* FAs in lambs (Ponnampalam *et al.*, 2001, 2002) and in beef (Mandell *et al.*, 1997).

Table 4. Effect of fish meal (FM) content in concentrate on subcutaneous lipid fatty acid composition (%)

	Control	FM 5%		FM 10%		p	C1†	C2†	C3†	C4†
		55	105	55	105					
C14	3.8	4.9	4.1	3.7	4.54	ns	ns	ns	ns	ns
C16	22.2	22.5	23.4	23.5	24.0	ns	ns	ns	ns	ns
C16:1	4.2^{ab}	5.1^{a}	3.9^{b}	3.7^{b}	3.8^{b}	*	ns	ns	ns	ns
C17	4.2	4.2	3.8	4.1	3.5	ns	ns	ns	ns	ns
C18:0	10.6	10.4	12.1	11.6	11.2	ns	ns	ns	ns	ns
C18:1	45.1	43.1	44.0	44.8	44.2	ns	ns	ns	ns	ns
C18:2	2.7^{a}	2.4^{ab}	2.1^{b}	2.2^{ab}	2.0^{b}	*	**	ns	ns	ns
CLA††	0.36	0.43	0.34	0.29	0.32	ns	ns	ns	ns	ns
C18:3	0.17	0.17	0.13	0.12	0.15	ns	ns	ns	ns	ns
SFA††	41.8	42.9	44.3	43.9	44.3	ns	ns	ns	ns	ns
PUFA††	3.2^{a}	3.0^{ab}	2.6^{b}	2.6^{b}	2.5^{b}	ns	ns	ns	ns	ns
PUFA/SFA	0.18	0.07	0.06	0.06	0.06	*	**	ns	ns	ns
UFA††	55.1	53.7	52.6	53.5	52.6	*	**	ns	ns	ns
UFA/SFA	1.3	1.3	1.2	1.2	1.2	ns	ns	ns	ns	ns
DFA††	65.7	64.1	64.7	65.0	63.8	ns	ns	ns	ns	ns
MUFA††	51.9	50.8	50.0	50.9	50.1	ns	ns	ns	ns	ns

†C1: control vs FM; C2: FM 5% vs FM 10%; C3: FM 5% 55 vs FM 5% 105; C4: FM 10% 55 vs FM 10% 105.
††CLA: conjugated linoleic acid; SFA: saturated fatty acids; PUFA: polyunsaturated fatty acids; UFA: unsaturated fatty acis; DFA: desired fatty acids; MUFA: monounsaturated fatty acids.
a,b: Means in the same line with different superscripts are significantly different (p<0.05); **p<0.01; *:p<0.05; ns: not significant (p>0.05).

In conclusion and in these experimental conditions, it is possible to substitute FM, local Tunisian product, to soya bean as protein source for growing ruminants, but it didn't reduce carcass adiposity and didn't increase *n-3* fatty acids proportion, so it didn't improve dietetic quality.

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