Anim. Res. 52 (2003) 271–285

DOI: 10.1051/animres:2003020

Original article

Use of whole barley with a protein supplement to fatten lambs under different management systems and its effect on meat and carcass quality

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Abstract — This study involved 53 Talaverana-breed lambs fattened until reaching a slaughter weight of 28 kg. After weaning at 45 days of age, the lambs were divided into four study groups. The lambs of two of the groups were fattened at pasture, while those of the other two groups were kept on a drylot. One group at pasture and another on the drylot received a commercial fattening concentrate. The other two groups received whole barley with a protein supplement. Drylot lambs displayed better carcass dressing, greater carcass fatness, higher carcass conformation values and a superior refrigerated carcass weight than lambs fattened at pasture. Lambs fattened with concentrate displayed better carcass dressing, higher carcass compactness and less digestive tract development (due to a lower proportion of stomach and digestive content) than those fed barley. The fat colour of lambs fattened at pasture was lighter (greater L*) than that of the drylot lambs, and the lambs fed concentrate exhibited a higher redness index (a*) than those fed barley. The *longissimus dorsi* (LD) muscle was used to evaluate meat quality. The lambs fattened at pasture displayed a lower lightness value, lower cooking losses and greater pleasantness scores in the sensorial analysis than drylot lambs. The lambs fattened at pasture presented lower values of fatty acids with an odd number of carbon atoms and monounsaturated fatty acids and higher linolenic acid (C18:3) levels than drylot lambs in both the intramuscular fat of the LD muscle and in subcutaneous fat. The lambs fed barley exhibited a higher proportion of fatty acids with an odd number of carbon atoms and lower C18:3 values than the lambs given the concentrate.

barley / pasture / lamb / meat quality / fatty acids

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Résumé — Utilisation de l'orge entière pour l'engraissement d'agneaux avec des systèmes d'élevage différents. Effets sur la qualité de la carcasse et de la viande. Cinquante trois agneaux de la race Talaverana ont été engraissés jusqu'à un poids d'abattage de 28 kg. Après le sevrage à 45 jours d'âge, les agneaux ont été divisés en quatre lots expérimentaux, deux ont été engraissés au pâturage et deux autres en bergerie. Un des deux lots de chaque système d'engraissement a été nourri avec un aliment concentré commercial, tandis que l'autre a reçu de l'orge entière avec un supplément protéique. Les agneaux élevés en bergerie ont présenté un rendement de carcasse supérieur, des carcasses plus lourdes (poids de carcasse froide), un état d'engraissement plus important et une meilleure conformation que les agneaux élevés au pâturage. Les animaux qui ont reçu l'aliment commercial ont eu un rendement et une compacité de la carcasse plus élevés que ceux nourris avec l'orge. En revanche, le poids du tractus digestif plein a été moins important, en raison d'une moindre proportion d'estomacs et de contenu digestif. La luminosité (L*) du gras chez les agneaux au pâturage a été plus élevée que celle des agneaux élevés en bergerie ; l'indice de rouge (a*) a été supérieur chez les animaux nourris avec l'aliment commercial. L'évaluation de la qualité de la viande sur le muscle *longissimus dorsi* (LD) a montré que la luminosité (L*) de la viande a été plus faible chez les agneaux au pâturage. De même, les pertes par cuisson ont été moindres. Lors de l'analyse sensorielle, les dégustateurs ont perçu cette viande comme plus agréable à consommer. Le gras intramusculaire (LD) et le gras sous-cutané des agneaux au pâturage ont présenté une plus petite quantité d'acides gras, soit à chaîne impaire, soit mono-insaturés, ainsi qu'une plus grande proportion d'acide linolénique (C18:3). En revanche, la quantité d'acides gras impairs a été plus importante alors que celle de C18:3 a été plus faible dans le gras des animaux nourris avec l'orge.

orge / pâturage / agneau / qualité de la viande / acides gras

1. INTRODUCTION

The present tendency in Spain is towards intensive lamb fattening operations based on consumption of concentrates. Nevertheless, it is possible to fatten lambs by taking advantage of natural resources, particularly in areas of native oak-wooded pastureland where grass is abundant. However, since pasture alone does not assure lambs a sufficient energy intake to reach an appropriate growth for slaughter before the summer drought, it is necessary to provide grazing lambs with an energy-rich feed supplement.

Whole cereal grains are the most economical feedstuffs for the stockbreeder to use as energy supplements. The kind of cereal provided may modify starch digestion [38] affecting fatness. Consumption of whole grains of barley by lambs fattened at pasture causes ruminal pH to rise, increasing the number of cellulolytic bacteria [24], which, in turn, favours the digestibility of the grass consumed and stimulates a greater intake.

The management system may affect lamb carcass and meat quality [8]. Lambs fattened at pasture generally display less fatness than drylot lambs, due to the metabolic modifications, that occur in lambs with exercise [2].

The management system affects some of the parameters that define meat quality such as water-holding capacity, colour and pH. Thus, as a result of exercise, lambs fattened at pasture present greater iron concentrations in muscle tissue [3] and their meat is therefore darker in colour than that of drylot lambs, a factor which may influence consumer acceptance.

The effect of diet with regards to the n-6/n-3 polyunsaturated fatty acid (PUFA) ratio has been noted by Mitchell et al. [25] who found that forage or grass-based diets contribute to high n-3 PUFA tissue concentrations while concentrate-based diets result in high n-6 PUFA concentrations.

These differences in fat composition contribute towards the characteristic meat flavours of animals fed grass or concentrate-based diets [21].

The aim of the present study was to determine the benefits of using whole barley with a protein supplement to fatten lambs under different management systems (pasture or drylot), and to study its effect on the productive characteristics of lambs and on carcass and meat quality when lambs are slaughtered at the live weight most common in our country.

2. MATERIALS AND METHODS

A total of 53 Talaverana-breed lambs were slaughtered at a pre-determined liveweight of 28 kg. The lambs lived with their mothers in a drylot until their weaning at 45 days of age at an average live weight of 14.3 kg. At that time, the lambs were randomly divided into four groups, two of which were fattened at pasture while the other two remained in the drylot. One group each of pasture and drylot lambs received a commercial concentrate while the other two groups were given whole barley with a commercial protein supplement. The latter constituted 14% of the barley ration, in order to ensure that the commercial concentrate and barley were isonitrogenous. Both barley and concentrate were available ad libitum to all lambs and, in addition, drylot animals had unlimited access to cereal straw. However, the complete diets were not isonitrogenous. Pasture was abundant (an average of 1 200 kg $DM \cdot ha^{-1}$ at the start of the study) and the stocking density was considered to be 7 lambs per hectare. An electrical fence facilitated lamb management. The mean chemical composition of the grass and that of the other feedstuffs consumed during the fattening period is presented in Table I. Cell wall fractionation analyses (NDF and ADF) were carried out following the method of Van Soest et al. [39], while all the remaining analyses were performed according to AOAC methods [1].

During the study, the lambs were weighed on a weekly basis. At the same time, commercial concentrate and supplemented barley intake was calculated by measuring the feed that the lambs had not consumed. The animals were transferred to an experimental abattoir on the same property when they reached the predetermined slaughter liveweight (W), and after a 16-h fast were weighed again (liveweight at slaughter, LWS) and slaughtered. The lambs from all four-study groups were slaughtered over a two-week period.

The dressing procedure followed the method of Colomer-Rocher et al. [10], obtaining stomach and intestine (full and empty) weights as well as those of the omental and mesenteric fats. Empty live weight (ELW) was calculated by subtracting digestive tract weight from LWS. Hot carcass weight (HCW) was recorded and refrigerated carcass weight (RCW) was obtained after 24 h at 4 ºC. Commercial dressings (CD) as well as fasting and refrigeration losses (FL, RL) were obtained from the previous data.

Fatness was determined by scoring the carcass as a whole as well as by evaluating

Table I. Chemical composition ($g \cdot kg^{-1}$ DM) of the feedstuffs consumed by the lambs.

	DM	OM	CP	Fat	NDF	ADF
Commercial concentrate	910.0	932.0	172.0	30.0	149.6	91.6
Barley	894.0	911.0	126.0	18.0	183.9	58.4
Protein supplement	893.0	826.2	446.0	514	197.2	127.5
Pasture grass	419.8	898.4	94.0	32.0	457.2	306.3

DM: dry matter; OM: organic matter; CP: crude protein; NDF: neutral detergent fibre; ADF: acid detergent fibre.

the quantity of kidney knob and channel fat (KKCF) and dorsal fat thickness, according to the method of Colomer-Rocher et al. [10]. A digital calibrator (Mitutoyo, UK) was used to calculate dorsal fat thickness at a point 4 cm from the carcass midline and 4 cm from the caudal edge of the last rib.

Carcass conformation was visually evaluated using a scoring system [10]. In addition, the carcass compactness index (RCW/L) was calculated by measuring the internal carcass length (L) [33].

The carcass was split using an electric saw and the left half of the carcass was dressed in accordance with the standardised method of Colomer-Rocher et al. [9]. The leg was considered the most appropriate cut to determine tissue composition. Leg muscle, bone and fat (subcutaneous, intermuscular and pelvic) were dissected following the Fisher and De Boer method [13].

A pH-meter (Schott-Gerate GMBH, Germany), equipped with a penetrating electrode and thermometer, was employed to determine pH in a cut in the *longissimus dorsi* muscle at 0 h and 24 h post mortem.

Colour was determined using the L* a* b* system [7] by means of a Minolta colorimeter (Chroma Meter CR-2000, Minolta Camera Co., Osaka, Japan). Nine colour evaluations were performed on the cut surface of the *longissimus dorsi* muscle at the level of the 13th thoracic vertebra while the subcutaneous fat of the tail root was evaluated through 12 determinations.

Water holding capacity (WHC) was measured using the modified Grau and Hamm [15] technique, as described by Sañudo et al. [35] in a central portion of the *longissimus dorsi* muscle. The results were expressed as the percentage of expelled liquid. Cooking losses were determined gravimetrically after a 15-min immersion in a 75 ºC water bath. Total collagen was calculated using the AOAC [1] method and the Hill [19] technique was used to obtain soluble collagen values.

As a result of the combinations between management system and feed types, four lamb groups were used for sensory analysis.

The left *Longissimus lumborum* (LD) muscle of twelve lambs in each group were taken at random for sensory analysis. Each one was split into eight steaks of 10 mm thick. The sensory analysis was carried out by twelve trained tasters of lamb meat in 4 sessions. In each session three LD per group were tested at random. The twenty-four meat samples per group were distributed among assessors. Each assessor tasted eight samples per session and in the same session one taster could not assess the same lamb.

The samples were cooked under conventional grill conditions to an internal temperature of 70 ºC. Screening and training of the assessor was broadly in line with those methods stated in ISO [20] trained in meat [11].

Sensory attributed analyses were the following: hardness, the force required to compress a piece of meat between molar teeth; springiness, the degree to which a product return to its original shape once it has been compressed between the teeth; juiciness, the juice liberated after compressing a piece of meat between molar teeth; pleasantness, the initial overall impression of the balance and fullness of a product. The meat was scored on a non-structured scale of 100 mm in length, on which the extremities represented minimum and maximum values.

Samples of the *longissimus dorsi* muscle and the associated subcutaneous fat were taken to determine the fatty acid composition of intramuscular and subcutaneous fat. These samples were vacuum-packed and frozen at –25 ºC for their posterior analysis.

Before fatty acid analysis, fat extraction was performed according to the method of

Hanson and Olley [17] and fatty acid methyl esters were prepared using the technique of Morrison and Smith [27]. Chromatographic analysis of the methyl esters was performed using a Perkin-Elmer gas chromatograph (Perkin-Elmer Corporation, USA) (equipped with a split–splitless injector and a flame ionisation detector) with a fused silica capillary column (0.25 mm internal diameter and 25 m long).

The mobile phase consisted of helium C-50 at a flow of 9 psig. Sigma reference standards were used to identify and quantify the fatty acids, and nonadecanoic acid (C19:0) was utilised as the internal standard; a Perkin-Elmer register-integrator (PE Nelson Corporation, USA) was employed.

Statistical results were obtained using an analysis of variance according to the model:

$$Y_{ijk} = \mu + M_{i(1...2)} + F_{j(1...2)} + MF_{ij} + \varepsilon_{k(ij)}$$

in which μ = arithmetic mean; M_i = effect of management system (pasture or drylot); F_j = effect of the type of feed (concentrate or whole barley with a protein supplement); MF_{ij} = interaction of the management system × type of feed and $\varepsilon_{k(ij)}$ = residual experimental error.

Sensorial data were analysed using an analysis of variance according to the model:

$$Y_{ijkl} = \mu + M_{i(1...2)} + F_{j(1...2)} + MF_{ij} + S_{k(1..4)} + \varepsilon_{l\,(kij)}$$

in which S_k = the effect due to session (four sessions) and $\varepsilon_{l\,(kij)}$ = the residual experimental error.

Differences between the means were analysed using the Newman-Keuls test.

Table II. Effects of the management system and type of feed on the carcass dressings, losses and the importance of the digestive tract.

	Pasture		Drylot		Management system (M)	Type of feed (T)	M × T	MSE
	Concentrate (n = 14)	Barley (n = 13)	Concentrate (n = 14)	Barley (n = 12)	Sig	Sig	Sig	
Feed consumption[1]	38.6	26.3	42.9	39.0				
Growth ($g \cdot d^{-1}$)	286	284	311	273	NS	NS	NS	1510.5
Pre-slaughter liveweight (W) (kg)	27.78	27.38	27.75	27.58	NS	NS	NS	0.92
Empty liveweight (ELW) (kg)	23.14	22.61	23.85	22.70	NS	***	NS	0.64
Refrigerated carcass (RCW) (kg)	12.49	12.14	13.02	12.24	*	***	NS	0.31
Commercial dressing (CD) (%)	44.97	44.36	46.92	44.37	*	***	*	1.97
Fasting losses (FL) (%)	7.62	6.84	5.07	6.71	**	NS	*	3.14
Refrigeration losses (RL) (%)	3.94	3.94	3.76	3.61	*	NS	NS	0.15
Digestive tract (%)								
Digestive[2]/ELW	22.25	23.71	21.47	24.64	NS	***	NS	2.94
Stomachs/ELW	3.60	3.89	3.34	3.91	NS	**	NS	0.21
Digestive content/ELW	10.90	12.82	10.43	13.33	NS	***	NS	1.89

In this and subsequent tables, Sig: significance; NS: non significant; *: $P \leq 0.05$; **: $P \leq 0.01$; ***: $P \leq 0.001$; M × T: interaction between the management system and the type of feed; MSE: mean square of the error; [1] Consumption of feed during the fattening period ($kg \cdot lamb^{-1}$); CD = (RCW × 100)/W; FL = (W – liveweight slaughter) × 100/W; RL = (hot carcass weight – RCW) × 100/hot carcass weight; [2] Full digestive.

3. RESULTS

The effects of the management system and type of feed on growth and intake, carcass dressings, losses and digestive tract development are shown in Table II. Feed intake was lower in lambs fattened at pasture than in drylot lambs, and also lower in lambs given barley than in those fattened on concentrate.

No differences in growth due to the management system or the type of feed were noted during the fattening period (46 days on average), in which lambs displayed a mean growth of 289 $g \cdot day^{-1}$. Commercial dressing values displayed a quantitative interaction ($P \leq 0.05$). The drylot lambs had higher values for commercial dressing than pasture lambs when fed concentrate, but was not different between the management groups that received barley.

Fasting losses (FL) displayed an interaction between the management system and type of feed ($P \leq 0.05$); these losses were always higher in lambs fattened at pasture than in drylot lambs and the differences were greater in lambs that received concentrate. Refrigeration losses (RL) were affected by the management system ($P \leq 0.05$), being higher in lambs fattened at pasture than in drylot animals.

The management system did not influence digestive tract components. However, lambs given barley displayed a higher entire digestive tract/ELW ratio ($P \leq 0.001$) than those, which consumed concentrate, mainly due to the greater percentage of digestive and stomach contents ($P \leq 0.001$ and $P \leq 0.01$, respectively) in the barley-fed lambs.

The effects of the parameters studied on fatness and carcass conformation are presented in Table III. Drylot lambs displayed greater dorsal fat thickness ($P \leq 0.001$) as well as a higher proportion of KKCF with regards to the right half-carcass and more omental fat in relation to the ELW ($P \leq 0.001$) than lambs fattened at pasture.

Visual conformation scores of the drylot lambs were higher than those of lambs raised at pasture ($P \leq 0.05$). Lambs fed concentrate presented greater carcass compactness ($P \leq 0.001$) than those fattened on supplemented barley.

Table III. Effects of the management system and type of feed on the carcass fatness and conformation.

	Pasture		Drylot		Management system (M)	Type of feed (T)	M × T	MSE
	Concentrate (n = 14)	Barley (n = 13)	Concentrate (n = 14)	Barley (n = 12)	Sig	Sig	Sig	Sig
Fatness (visual)	1.50	1.48	1.72	1.57	NS	NS	NS	0.11
Subcutaneous fat (mm)	1.90	1.72	2.89	2.35	***	NS	NS	0.40
KKCF (score)	1.80	1.73	1.88	2.04	NS	NS	NS	0.19
Right KKCF[1]	2.09	1.74	2.54	2.53	***	NS	NS	0.31
Omental fat/ ELW (%)	1.46	1.30	1.71	1.74	***	NS	NS	0.09
Mesenteric fat/ ELW (%)	1.68	1.52	1.59	1.68	NS	NS	NS	0.05
Conformation (visual)	1.50	1.42	1.81	1.55	*	NS	NS	0.09
Carcass Compactness (CC)	223.4	215.74	231.05	218.61	NS	***	NS	105.2

KKCF: kidney knob channel fat; [1] In % of right half carcass weight; ELW: empty live weight; CC: refrigerate carcass weight/internal carcass length.

Table IV presents the effects of the different treatments on leg tissue percentages. The proportions of muscle and fat were affected by the management system ($P \leq 0.01$ and $P \leq 0.001$, respectively), since the lambs fattened at pasture displayed a greater proportion of muscle and a lower percentage of fat than the drylot lambs.

The type of feed consumed did not significantly modify the percentage of fat and bone but did affect the proportion of muscle in the leg, which was higher in lambs which received barley than in those fed concentrate.

The effects of the different treatments on carcass fat and meat colour, as well as on pH, WHC, cooking losses and collagen are presented in Table V. The carcass fat of lambs fattened at pasture exhibited greater lightness ($P \leq 0.001$) than that of drylot lambs while other indexes were not affected by the management system. An interaction ($P \leq 0.05$) between the factors studied was seen with regards to the redness index (a*); this value was always higher in lambs fed concentrate than in those given barley, and the differences were greater in drylot lambs.

The colour of the *longissimus dorsi* muscle, which was not influenced by the type of feed consumed, was, however, affected by the management system: drylot lambs displayed greater lightness ($P \leq 0.05$) than lambs fattened at pasture. WHC, pH, total and soluble collagen values were not modified by the treatments. Cooking losses were higher ($P \leq 0.05$) in drylot lambs than in lambs fattened at pasture while the type of feed consumed did not influence these losses.

Sensorial analysis results indicate the session had an effect on the hardness ($P \leq 0.005$) and juiciness ($P \leq 0.01$), but did not affect the other parameters. Furthermore, the meat from lambs fattened at pasture showed higher pleasantness ($P \leq 0.01$) than the drylot lambs (Tab. VI).

Table VII indicates the percentage of fat and proportion of total fatty acids in intramuscular fat (m. *longissimus dorsi*) for the different treatments studied. The fatty acid composition of that fat was affected by the management system: drylot lambs presented a greater proportion of palmitic acid (C16:0) ($P \leq 0.001$) as well as of palmitoleic

Table IV. Effects of the management system and type of feed on the leg tissues.

	Pasture		Drylot		Management system (M)	Type of feed (T)	M × T	MSE
	Concentrate (n = 14)	Barley (n = 13)	Concentrate (n = 14)	Barley (n = 12)	Sig	Sig	Sig	
Proportion of tissues (%)								
Muscle	67.05	68.04	64.49	66.50	**	*	NS	6.86
Bone	20.69	19.99	20.61	20.06	NS	NS	NS	2.31
Fat	9.19	8.68	11.17	10.47	***	NS	NS	2.14
Subcutaneous fat	5.10	5.06	6.54	6.16	***	NS	NS	1.55
Intermuscular fat	2.43	2.28	2.76	2.76	***	NS	NS	0.25
Pelvic fat	1.61	1.30	1.81	1.51	NS	*	NS	0.23
Others	3.06	3.26	3.71	2.96	NS	NS	NS	2.39

Others: remaining tissues dissected (tendon, larger nerves...).

Table V. Effects of the management system and type of feed on the parameters related to the quality of the meat (m. *longissimus dorsi*).

	Pasture		Drylot		Management system (M)	Type of feed (T)	M × T	MSE
	Concentrate (n = 14)	Barley (n = 13)	Concentrate (n = 14)	Barley (n = 12)	Sig	Sig	Sig	
Fat colour								
L*	68.76	68.18	66.40	65.11	***	NS	NS	3.83
a*	5.34	4.75	5.87	5.06	NS	*	*	1.52
b*	8.61	7.78	7.84	7.63	NS	NS	NS	1.26
Meat colour								
L*	39.50	39.35	40.21	40.50	*	NS	NS	2.40
a*	17.20	16.67	16.87	16.85	NS	NS	NS	0.88
b*	4.09	3.62	3.66	3.65	NS	NS	NS	0.32
pH 0 h	6.52	6.49	6.43	6.41	NS	NS	NS	0.11
pH 24 h	5.59	5.75	5.70	5.73	NS	NS	NS	0.08
pH 0–24 h	0.94	0.74	0.72	0.67	NS	NS	NS	0.28
WHC (%)	17.1	16.8	17.3	18.4	NS	NS	NS	5.15
Cooking losses (%)	32.14	31.02	32.72	33.85	*	NS	NS	7.28
Total collagen (% DM)	5.30	5.24	5.11	5.17	NS	NS	NS	0.58
Soluble collagen (% total)	25.85	26.60	26.22	24.52	NS	NS	NS	17.0

WHC: water-holding capacity (expressed as percentage of expelled liquid).

(C16:1), oleic (C18:1) and linoleic (18:2) acids ($P \leq 0.01$) than their pasture-raised counterparts, which displayed a greater proportion of linolenic acid (C18:3). A quantitative interaction ($P \leq 0.05$) between the management systems and types of feed was observed for stearic (C18:0) and arachidic (C20:0) acids, whose values were always higher in lambs fattened at pasture. Although the differences between both management systems in stearic acids were higher in lambs fed whole barley whereas the differences in arachidic acids were greater in those fed concentrate.

The intramuscular fat of drylot lambs contained a greater proportion of fatty acids with an odd number of carbon atoms and monounsaturated (MUFA), in addition to a lower percentage of saturated fatty acids (SFA) ($P \leq 0.01$) than that of lambs fattened at pasture.

Lambs given barley presented a greater proportion of fatty acids with an odd number of carbon atoms ($P \leq 0.001$) than lambs fed concentrate. On the contrary, lambs which consumed barley had a lower proportion of linoleic (C18:2) acids ($P \leq 0.05$) than those fed concentrate.

Table VIII reflects the subcutaneous fat composition with regards to the fatty acids studied. Drylot lambs presented a lower proportion of stearic acid (C18:0) and SFA than that displayed by lambs fattened at pasture ($P \leq 0.01$). In addition, the subcutaneous fat of drylot lambs displayed a higher proportion of fatty acids with an odd number of carbon atoms ($P \leq 0.001$) than that of lambs fattened at pasture. The proportion of linolenic acid (C18:3) exhibited a quantitative interaction ($P \leq 0.01$) between management systems and types of feed; the levels of this fatty acid were higher in lambs raised at pasture than at drylot, the differences were greater in lambs that were fed whole barley.

Lambs fed barley displayed a higher proportion of fatty acids with an odd number of carbon atoms ($P \leq 0.001$) than lambs

Table VI. Effects of the management system and type of feed on the parameters related to the sensorial analysis of the meat (m. *longissimus dorsi*), as well as the effect of session on these parameters.

	Pasture		Drylot		Sessions (S)				Management system (M)	Type of feed (T)	M × T	Sessions	MSE
	Concentrate (n = 12)	Barley (n = 12)	Concentrate (n = 12)	Barley (n = 12)	S1 (n = 12)	S2 (n = 12)	S3 (n = 12)	S4 (n = 12)	Sig	Sig	Sig	Sig	
Sensorial analysis (scores)													
Hardness	41.78	35.29	38.20	39.39	39.89	42.38	37.79	34.61	NS	NS	*	*	171.5
Springiness	58.52	56.37	56.79	58.44	59.25	58.21	58.58	54.07	NS	NS	NS	NS	117.1
Juiciness	28.69	32.22	30.82	28.53	35.38	28.30	29.38	27.20	NS	NS	NS	**	141.3
Pleasantness	54.88	58.54	52.79	54.22	56.92	54.71	53.89	54.90	*	NS	NS	NS	93.9

Sensorial analysis (scores): from 1 to 100.

Table VII. Effect of the management system and type of feed on the fatty acid composition (percentage of total fatty acids) of intramuscular fat (m. *longissimus dorsi*).

	Pasture		Drylot		Management system (M)	Type of feed (T)	M × T	MSE
	Concentrate (n = 14)	Barley (n = 13)	Concentrate (n = 14)	Barley (n = 12)	Sig	Sig	Sig	
C 12:0	0.83	0.88	0.88	0.76	NS	NS	NS	0.32
C 14:0	3.68	3.47	3.58	3.34	NS	NS	NS	0.41
C 15:0	0.64	1.00	0.89	1.03	NS	*	NS	0.11
C 16:0	24.15	24.85	26.15	25.94	***	NS	NS	1.36
C 16:1	3.18	3.06	3.27	3.50	**	NS	NS	0.11
C 17:0	2.00	1.99	1.75	2.35	NS	*	*	0.16
C 17:1	0.32	0.48	0.43	0.83	***	***	*	0.04
C 18:0	15.81	17.03	14.8	14.37	***	NS	*	1.76
C 18:1 n-9	32.03	31.32	33.06	32.91	**	NS	NS	2.71
C 18:2 n-6	5.95	5.48	6.75	5.81	**	*	NS	0.61
C 18:3 n-3	3.19	2.30	1.44	1.48	***	*	*	0.51
C 20:0	3.60	2.36	1.88	1.94	***	NS	*	0.71
C 20:4 n-6	3.84	4.53	4.57	4.98	NS	NS	NS	0.93
C 22:0	0.76	1.23	0.54	0.76	NS	NS	NS	0.41
OFA	2.96	3.48	3.07	4.21	**	***	*	0.28
SFA	51.48	52.81	50.47	50.49	**	NS	NS	2.95
MUFA	35.53	34.86	36.76	37.23	**	NS	NS	3.33
PUFA	12.99	12.32	12.76	12.28	NS	NS	NS	3.00
PUFA/SFA	0.25	0.23	0.25	0.24	NS	NS	NS	0.001

OFA: odd fatty acids (15:0 + 17:0 + 17:1); SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids.

given concentrate. The PUFA/SFA ratio displayed a quantitative interaction ($P \leq 0.05$), with higher values ($P \leq 0.01$) observed in lambs fed concentrate than in those given barley although the differences were lower in the pasture lambs.

4. DISCUSSION

The lambs raised at pasture consumed less concentrate (10%) and barley (32%) than drylot lambs. The lower intake of feed may be compensated by a greater grass intake [30, 31] to achieve a growth rate similar to that of drylot lambs.

Pasture lambs consumed less barley than concentrate. This may be due to low appetence to barley in relation to grass. As indicated previously it is recognised that barley may enhance the digestion of forage matter and in turn stimulate intake, which most likely enabled these lambs to achieve a growth rate similar to that of the lambs fed concentrate [24, 31]. The forage consumed by the lambs fattened at pasture may reach 35% of the dry matter ingested, as Cañeque et al. [5] reported and which is corroborated

Table VIII. Effects of the management system and the type of feed on the fatty acid composition (percentage of total fatty acids) of subcutaneous fat.

	Pasture		Drylot		Management system (M)	Type of feed (T)	M × T	MSE
	Concentrate (n = 14)	Barley (n = 13)	Concentrate (n = 14)	Barley (n = 12)	Sig	Sig	Sig	Sig
C 12:0	1.06	0.96	1.20	0.97	NS	NS	NS	0.29
C 14:0	4.82	4.81	5.00	4.27	NS	NS	NS	0.73
C 14:1	0.41	0.73	1.18	1.31	***	NS	NS	0.27
C 15:0	1.24	1.57	1.53	1.59	NS	*	NS	0.10
C 15:1	0.28	0.37	0.80	0.58	***	NS	NS	0.12
C 16:0	26.42	27.10	27.00	27.23	NS	NS	NS	2.43
C 16:1	3.54	3.64	3.75	4.08	*	NS	NS	0.18
C 17:0	2.36	3.03	2.83	3.77	***	***	NS	0.25
C 17:1	0.53	0.70	0.69	1.36	***	***	**	0.09
C 18:0	16.36	17.1	13.83	14.21	***	NS	NS	3.07
C 18:1 n-9	35.12	32.97	35.02	35.12	NS	NS	NS	6.39
C 18:2 n-6	2.91	3.09	3.55	2.71	NS	*	**	0.25
C 18:3 n-3	1.66	1.57	1.51	0.68	**	*	*	0.40
C 20:0	3.27	2.34	2.10	2.11	***	*	*	0.54
OFA	4.42	5.68	5.84	7.29	***	***	NS	7.16
SFA	55.54	56.91	53.50	54.16	**	NS	NS	9.05
MUFA	39.88	38.42	41.44	42.44	**	NS	NS	0.92
PUFA	4.57	4.66	5.10	3.40	NS	**	**	7.16
PUFA/SFA	0.08	0.08	0.09	0.06	NS	**	**	0.008

OFA: odd fatty acids (15:0 + 15:1 + 17:0 + 17:1); SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids.

by the greater digestive tract development and the greater digestive content observed in these lambs.

Differences in feed intake were seen between drylot lambs given commercial concentrate and those which received barley with a protein supplement. In the latter case, the lower barley intake (9%) could not be compensated by a greater straw intake, since the lambs intake capacity for the latter is at most 15% of their barley intake, much lower than that for grass [5]. This led to the lower growth rate of these lambs, although differences with regards to the drylot lambs fed concentrate were not significant. Nevertheless, the greater development of the digestive tract and its greater content also indicates that drylot lambs fed barley consumed more straw than those fed concentrate.

Drylot lambs were of better commercial dressing than pasture lambs when all of them were fed concentrate. This finding was in agreement with those of other authors [6, 26], and may be due to differences in fatness [23], as seen in our study. Commercial dressings were higher in lambs that consumed concentrate than in lambs fed barley, not only because of their higher carcass weight but also due to the lower development of their digestive tract [18].

Drylot lambs exhibited greater fatness than pasture lambs, especially due to greater subcutaneous, KKCF, omental fat content and also more leg fat. These findings are confirmed by other studies in which the same management systems were compared [8, 26, 29]. Fundamentally they relate to the greater energy expenditure of pasture lambs, as well as metabolic modifications because of the exercise [2]. A lower energy intake in those lambs may also contribute to less fat.

The management system affected carcass colour, since lambs fattened at pasture exhibited greater lightness (L*), and thus a whiter colour, than drylot lambs. A low feed intake appears to increase the lightness of subcutaneous fat in addition to its firmness [37]. Carcass colour was also affected by the type of feed used. Lambs fed concentrate exhibited a higher redness index than those that received barley. Theriez et al. [37] also noted that the energy source may modify the redness index (a*), but did not affect the yellowness index (b*).

The colour of the *longissimus dorsi* muscle was slightly affected by the management system; drylot lambs displayed greater lightness than their pasture homologues. Colour differences between pasture and drylot lambs are probably due to their different physical activity levels [41], which condition iron muscle concentration [3] and not the quantity of the ration or the composition of the diet [28].

Although there was no effect of the management system on hardness, springiness and juiciness were detected in the sensorial analysis. The management system did affect the pleasantness score, which was higher for the meat of lambs fattened at pasture than for that of their drylot counterparts. This pleasantness score may be related to their diet [32], which in turn affects the fatty acid composition and thus the flavour. The latter is the sensorial component that influences eating satisfaction to the greatest degree. The taste panels identified a high correlation [14] between flavour intensity and the proportion of linolenic (C18:3) and linoleic (C18:2) (positive and negative, respectively) fatty acids. Proportions of linoleic and linolenic acids observed in our study clearly differed; the lambs that consumed grass displayed a greater percentage of the latter [22].

The preference of taste panel members for the meat of lambs fed feed or grass seems to depend on their previous experience [14]. The panellists in our study were accustomed to consuming lamb, which may have led them to prefer meat with greater flavour, such as that from lambs fattened at pasture.

The differences between sessions could be because they randomly allocated samples within treatment. Therefore, the session effect is caused by different assessors receiving different samples within the same treatment group on different days.

The intramuscular fat of the LD muscle of lambs fattened at pasture presented a higher proportion of stearic (C18:0), linolenic (C18:3) and arachidic (C20:0) fatty acids, but lower percentages of palmitic (16:0), oleic (C18:1) and linoleic (C18:2) acids than drylot lambs. Likewise, Rowe et al. [34] observed that the intramuscular fat of the LD muscle of lambs raised at pasture exhibited a greater concentration of long chain saturated fatty acids, in the form of stearic (C18:0) and arachidic (C20:0) acids, and of PUFA, linolenic (C18:3) and arachidonic (C20:4) fatty acids, but lower levels of oleic (C18:1) and linoleic (C18:2) acids than drylot lambs. Stearic (C18:0) and palmitic (C16:0) fatty acids are the two saturated fatty acids present in the greatest proportion in the intramuscular fat. The former increases in lambs raised at pasture but may be considered neutral with regards to cholesterol formation [16] while the latter decreases in pasture lambs but may elevate cholesterol levels under certain conditions [16]. This oleic acid/stearic acid ratio is also higher in drylot lambs than in their pasture counterparts, since this ratio usually rises as fatness increases [29].

The greater percentage of linolenic acid (C18:3) in fatty tissue samples from animals raised at pasture is attributed to the high concentration of this acid in grass [42]. Nevertheless, although a percentage of this acid is hydrogenated in the rumen, resulting in a greater concentration of stearic acid (C18:0), a large amount escapes from the rumen and is absorbed intact in the small intestine [36]. The importance of linolenic acid is its capacity to diminish the thrombocytic tendency of blood and the risk of suffering coronary diseases. On the contrary, linoleic acid, which predominates in concentrates, is present in a greater proportion in drylot lambs due to their higher feed intake of this diet [12].

Subcutaneous fat also reflects the type of feed consumed. That of lambs given barley displayed more fatty acids with an odd number of C atoms, than that of lambs fed concentrate [40]. This fatty acid composition may have contributed to more soft subcutaneous fat [4], although this was not observed when the carcasses were classified.

5. CONCLUSIONS

The use of whole barley with a protein supplement is an alternative for finishing lambs at low slaughter weights. Lambs fattened at pasture consumed less feed than drylot lambs, although pasture lambs showed a growth rate equivalent to drylot lambs with a reduction in feed costs due to their grass intake. Pasture lambs displayed less fatness than their drylot counterparts, which in turn was related to their grass intake and greater exercise level. Pasture lambs also received higher pleasantness scores in the sensorial analysis.

With regards to fatty acid composition of intramuscular and subcutaneous fat depots, drylot lambs exhibited a higher proportion of unsaturated and lower saturated fatty acids, although the percentage of linolenic acids (C18:3) was lower than in lambs fattened at pasture. Thus, from the consumer-health viewpoint, the fatty acid composition of lambs raised at pasture may be considered better than that of drylot lambs.

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