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Citrus pulp and wheat straw silage as an ingredient in lamb diets: effects on growth and carcass and meat quality

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Abstract

Twenty "Merinizzata Italiana" lambs were introduced to two experimental diets. Ten animals (five males and five females, control group) received the traditional diet that is supplied by farmers in southern Italy, which comprised of oat hay ad libitum and commercial concentrate. The second group (the same number of lambs, silage group) received citrus pulp and wheat straw silage ad libitum and 70% of the commercial concentrate supplied to the control group. The animals were slaughtered after 80 days of feeding and carcass and some meat quality parameters were measured. No differences were observed for live weight between treatments, and carcass weights were similar for the two diets, but with obvious differences between sexes. Animals on silage produced carcasses with a better muscular conformation and with a lower fatness score ($P < 0.05$). Subcutaneous fat colour was influenced by sex, being lighter in the female carcasses ($P < 0.05$). Dissection of different anatomical parts showed a higher percentage of lean and a lower proportion of fat in silage samples compared to control ones. Ultimate pH was highly affected by sex being higher in the samples from male lambs ($P < 0.01$), but was unaffected by diet treatment. Diet tended to affect meat shear force value which was lower in the silage samples, although, samples from all the animals were extremely tender. Meat from silage samples had a higher water content ($P < 0.05$). Overall, in our experimental conditions, the use of citrus pulp silage seemed to be economically convenient for producing animals with substantially unmodified carcass and meat quality characteristics.

Keywords: Citrus pulp; Lamb; Carcass quality; Meat quality

1. Introduction

Citrus pulp is a by-product widely available in Mediterranean countries and its cost is relatively low compared to its nutritive value (Guessous et al., 1989). This by-product contains a relatively high amount of pectin and soluble carbohydrates, and for this reason dried citrus pulp has been used to replace cereals in ruminant diets (Bhattacharya and Harb, 1973; Hadjipanayiotou and Louca, 1976). However, citrus pulp has also some roughage-like characteristics (Ben-Ghedalia et al., 1989) and low amount of nitrogen (Lanza, 1982).

Although, most of the studies regarding citrus pulp concern the dried product, the process of drying is expensive and often inconvenient, and for this reason, the use of dried citrus pulp is uncommon. In this experiment, we chose to ensile citrus pulp, since, this

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practice is simple, cheap and can be easily performed by the farmer. Due to the high moisture content of citrus pulp, ensiling losses are high and can have a high impact on the farm environment. To avoid these problems, citrus pulp was ensiled together with chopped wheat straw which limits ensiling losses and gives to the silage the characteristics of a good and cheap substitute for farm forages.

The objective of this experiment was to evaluate the effects of replacing the forage and 30% of the concentrate of a traditional Mediterranean diet with citrus pulp silage on lamb growth and carcass and meat quality.

2. Materials and methods

2.1. Animals, diets and slaughter procedures

This trial involved 20 "Merinizzata Italiana" lambs, half male and half female, born on the same farm within a 3-day period and weaned at 63 days of age. After weaning the lambs were divided into four (male and female separately) groups and were allotted in collective pens (five animals per pen), and introduced to the two experimental diets. The first diet (control) was a traditional diet of sheep farmers of southern Italy and was based on oat hay supplied once daily on an ad libitum basis and a commercial concentrate. The concentrate was supplied twice daily on the basis of the hay consumption of the previous day in a way that the ratio hay/concentrate was always 30/70. The second diet (silage) was based on citrus pulp silage supplied ad libitum once daily and the same commercial concentrate of the control group supplied twice daily. The concentrate supplied to the silage group was always 70% of the concentrate supplied the same day to the control group. The silage was a mixture of citrus (orange) pulp and wheat straw chopped to a particle size of about 2.5 cm in a ratio 80/20. The silage was fed to animals 60 days after ensiling.

Refusals of hay (control group) and citrus pulp (silage group) were collected once daily before the addition of fresh feed and weighed to determine voluntary intakes of groups. Subsamples from each treatment group were bulked and stored for chemical analyses. Water was always available.

Feed offered and refused were analysed according to AOAC (1995). Fibre fractions (Goering and Van Soest, 1970) were also determined. Feed energy was calculated according to INRA (1988).

The lambs were weighed weekly during the feeding trial. All the animals were slaughtered at 150 days of age after a 100 km truck journey, and spending one night in lairage without feed but with access to water. The animals were slaughtered after electrical stunning and the carcasses were classified for muscular conformation and for fatness using a 15-point scale (EEC, 1992). The hot carcasses were weighed and chilled for 24 h in a chilling chamber set at 3°C.

2.2. Post-rigour measurements

Twenty-four hours post-mortem, the carcasses were removed from the chilling chamber, and the colour was measured in the subcutaneous fat of the tail with a Minolta CR 200 colour meter in CIE (1986) colour space (L^*, a^*, b^*). The carcasses were split and the right side was weighed and sectioned into commercial cuts according to Preziuso et al. (1999). The right proximal pelvic limb (sample cut) was removed from each carcass, and was dissected according to the guidelines of the ASPA (1991) to determine the percentage of lean, fat and bone. From the left side longissimus dorsi muscle was excised for instrumental meat quality determination data. Ultimate pH was measured with an Orion 9106 penetrating probe after calibrating with two buffers (7.00 and 4.00). Meat colour was determined on chops 2.5 cm thick which were stored for 1 h on a polystyrene tray and overwrapped with polyethylene film at 4°C to allow blooming; Hue angle and chroma were also calculated.

Water holding capacity was measured as cooking loss according to Boccard et al. (1981). Weighed samples were immersed, in plastic bags, in a bain-marie at 75°C until the internal temperature of the meat reached 75°C, as monitored with a probe. The bags were then placed under cold running water for 30 min. The cooked meat was patted dry with paper towels and reweighed. The cooked samples were also used for shear force determination. Three cores (1.25 cm diameter) were removed from each sample parallel to the muscle fibre axis and sheared perpendicular to this axis using an Instron 4411 equipped with a Warner Bratzler shearing device. The cross-head speed was 100 mm/min.

For chemical analysis, raw meat was finely minced and vacuum packed. All samples were kept at −35°C until analysis. AOAC (1995) methods were used for moisture (39.1.02), fat (39.1.05) and ash (39.1.09) determination. Protein was estimated by difference.

2.3. Statistical analysis

A completely randomised design was used for this experiment. Data were analysed by ANOVA with a model including diet and sex effects, their interaction and experimental error. Single animals were considered as experimental units.

3. Results and discussion

The chemical characteristics of feeds offered and consumed are shown in Table 1.

Animal performance and slaughter data are in Table 2. Live weight at slaughter and empty body weight (live weight at slaughter minus gut contents) were obviously affected by sex, being higher ($P < 0.01$) in the males but were unaffected by diet treatments. The same pattern was observed for the carcass weight which was higher in the males but was unaffected by diet. Daily live weight gain was also affected by sex ($P < 0.05$) but unaffected by diet. Carcass conformation was significantly influenced by diet ($P < 0.05$) being higher in the animals of the silage group and tended to be higher in the females compared to the males. Lambs on silage also showed a significantly ($P < 0.05$) lower carcass fatness score. The differences in the carcass characteristics could be due to a different pattern of ruminal volatile fatty acid production. Hadjipanayiotou and Louca (1976) reported that citrus pulp promotes acetate fermentation. Also, the higher consumption of concentrate in the control group, could have promoted a higher propionate fermentation which could account for a higher fat deposition. The diet did not influence carcass fat colour which was instead influenced by sex. The carcasses from females had higher L^* values than the carcasses from males ($P < 0.05$). Lightness is the value that indicates reflection and could have been affected by fatty acid composition (Prache et al., 1990). A difference in the fatty acid composition could have influenced fat colour because unsaturated fatty acids are less reflective than saturated ones. Lambs fed the silage diet had a higher influence of pelvic limb ($P < 0.01$) as percentage of the carcass and a lower influence of steaks ($P < 0.05$) (Table 3). Preziuso et al. (1999) suggested that differences in these proportions could be due to difference in carcass weights. However, in our case the carcass weights were similar within each sex. Kidney fat and pelvic fat incidence were higher in the control group ($P < 0.01$). The possible higher ruminal propionate linked to the higher concentrate consumption is probably the reason for these differences. Although, the influence of pelvic limb on carcass weight was higher in silage lambs, the weight of the hind leg was not influenced by diet and as expected was influenced by sex ($P < 0.05$). The pelvic limb from silage lambs tended to have a higher proportion of lean compared to control lambs and the

Table 1
Chemical characteristics of the feeds (% DM basis)

	Hay		Silage		Concentrate
	Supplied	Consumed	Supplied	Consumed	
Dry matter	87.56	86.88	26.64	24.40	88.56
Crude protein	4.91	5.46	8.08	8.47	18.04
Ether extract	1.44	1.53	2.32	2.38	2.96
Ash	8.15	8.10	7.60	7.67	8.37
Neutral detergent fibre	61.11	58.30	47.26	44.56	25.89
Acid detergent fibre	38.92	37.04	31.02	27.75	12.19
Acid detergent lignin	5.28	4.83	4.57	4.24	3.26
Meat FU (no./kg DM)	0.556	0.582	0.784	0.734	0.995

Table 2
Effects of the experimental treatments on animal performance and slaughter data

	Control		Silage		Significance			S.E.M.[a]
	M	F	M	F	D	S	D × S	
Initial weight (kg)	22.88	19.88	23.00	20.44	NS	**	NS	0.459
Final weight (kg)	43.80	37.54	43.52	35.52	NS	**	NS	1.200
Daily weight gain (g)	261	220	256	188	NS	*	NS	11.400
Concentrate consumption (g DM/day)	940	890	655	621				
Hay/silage consumption (g DM/day)	285	271	372	344				
Feed cost for 1 kg BWG (Euro)	1.22	1.37	0.97	1.24				
Slaughter data								
Empty body weight (kg)	35.79	30.64	34.90	29.62	NS	**	NS	0.879
Carcass weight (kg)	20.36	17.70	19.98	17.07	NS	*	NS	0.565
Dressing percentage (%)	56.72	57.69	57.12	57.15	NS	NS	NS	0.400
Carcass conformation	6.4	7.6	7.8	8.2	*	NS	NS	0.256
Carcass fatness	9.8	10.6	9.0	9.8	*	*	NS	0.213
Fat lightness (L^*)	72.37	76.67	74.73	75.08	NS	*	NS	0.583
Fat redness (a^*)	4.49	4.12	4.26	4.36	NS	NS	NS	0.199
Fat yellowness (b^*)	7.06	8.28	6.99	8.39	NS	NS	NS	0.337

[a] S.E.M. = standard error of the mean.
NS = not significant.
* $P < 0.05$.
** $P < 0.01$.

Table 3
Proportions of carcass joints and tissue composition of the hind leg

	Control		Silage		Significance			S.E.M.[a]
	M	F	M	F	D	S	D × S	
Half carcass weight (kg)	9.59	8.14	9.22	7.92	NS	*	NS	0.281
Percentage of								
Hind leg	29.66	30.27	31.88	31.07	**	NS	NS	0.281
Shoulder	17.91	17.25	19.22	18.17	NS	NS	NS	0.373
Steaks	16.22	14.91	13.92	14.80	*	NS	*	0.293
Neck	9.54	8.35	9.39	9.52	NS	NS	NS	0.221
Brisket	11.86	12.06	11.32	11.51	NS	NS	NS	0.279
Lumbar region	7.58	8.37	7.61	7.42	NS	NS	NS	0.199
Abdominal region	4.63	4.93	4.81	4.96	NS	NS	NS	0.137
Kidney	0.65	0.61	0.78	0.63	NS	NS	NS	0.037
Kidney fat	1.59	2.73	0.93	1.58	**	**	NS	0.183
Pelvic fat	0.36	0.53	0.22	0.33	**	**	NS	0.033
Dissection of hind leg								
Leg weight (g)	2838	2450	2897	2438	NS	*	NS	89.0
Lean (%)	67.35	67.49	69.97	68.59	NS	NS	NS	0.479
Fat (%)	11.52	12.76	10.17	11.87	NS	NS	NS	0.435
Bone (%)	21.13	19.75	19.86	19.54	NS	NS	NS	0.255

[a] S.E.M. = standard error of the mean.
NS = not significant.
* $P < 0.05$.
** $P < 0.01$.

Table 4
Instrumental measurements and chemical analysis (% wet basis) of the muscle longissimus dorsi

	Control		Silage		Significance			S.E.M.[a]
	M	F	M	F	D	S	D × S	
pH	5.81	5.62	5.72	5.64	NS	**	NS	0.027
Lightness (L^*)	42.99	42.86	41.17	43.67	NS	NS	NS	0.611
Redness (a^*)	18.51	18.32	18.48	18.23	NS	NS	NS	0.336
Yellowness (b^*)	10.79	11.11	9.63	10.52	NS	NS	NS	0.285
Chroma	21.43	21.44	20.88	21.05	NS	NS	NS	0.381
Hue angle	30.26	31.31	27.41	29.99	NS	NS	NS	0.604
Cooking loss (%)	15.54	12.43	11.21	12.87	NS	NS	*	0.565
Warner Bratzler shear force (kg F cm^{-2})	2.34	2.15	1.73	1.93	NS	NS	NS	0.114
Moisture	72.93	72.92	73.82	73.58	*	NS	NS	0.161
Protein	23.29	22.97	22.90	22.53	*	*	NS	0.099
Ether extract	2.68	3.01	2.13	2.81	NS	NS	NS	0.155
Ash	1.11	1.11	1.15	1.08	NS	NS	NS	0.011

[a] S.E.M. = standard error of the mean.
NS = not significant.
* $P < 0.05$.
** $P < 0.01$.

percentage of fat tended to be higher in the control lambs (Table 3).

Ultimate pH (Table 4) was highly influenced by sex, being higher in the male lambs ($P < 0.01$). This difference could be due to the higher susceptibility of males to stress compared to females. Nevertheless, the mean values were within an acceptable range for both sexes. L^*, a^*, b^* and chroma values for lean meat were unaffected neither by diet treatment, nor by sex. However, hue angle tended to be wider in control lambs showing that the silage samples were closer to a purpled red colour (Hue = 0). Cooking losses tended to be higher in control samples. Differences in cooking losses are often due to differences in muscle fat content (Solomon et al., 1980). In this case, the difference in cooking loss could be due to the difference in muscle moisture percentage between treatments. Meat toughness, as measured by Warner Bratzler shear force, was very low in all groups, indicating very tender meat, even though the samples of the control group tended to have higher values of shear force.

Meat chemical analysis (Table 4) showed higher values of moisture for the silage samples ($P < 0.05$). The difference in moisture percentage could account for Warner Bratzler shear force difference. Intramuscular fat tended to be higher in the control samples and in accordance with the results of carcass fatness and kidney fat. However, the differences were not significant in this case. As known and reported, meat from female lambs tended to be fattier than meat from males.

Considering that the lambs on silage received only 70% of the concentrate which the control group received, and considering the very low cost of the citrus pulp silage, this result would appear to be of great interest because it could create a real economic benefit to the farmer. The reduction of concentrate supplementation in the silage group has indeed permitted a consistent reduction of the feeding cost per kg of body weight gain which was about 20% lower in the males consuming silage compared to the males consuming hay (and a higher proportion of concentrate). For the females the gap was narrower (about 10%) but still consistent. Since, the animals were allotted in collective pens a statistical analysis of these data were impossible.

4. Conclusions

The results of this experiment indicate that citrus pulp silage can replace the roughage and partially replace the concentrate of a traditional diet for growing lambs. The lambs, indeed, maintained similar growth rates compared to those given the traditional diets, and the feeding cost per kg of body weight gain was lower in the experimental diet for both males and females. Carcass and meat quality were not affected by treatments and thus, the silage diet could represent an economic advantage for producers.

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