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Feeding of Safflower (*Carthamus tintorius*) Cake in Small Ruminant Total Mixed Rations: Effects on Growth Traits and Meat Fatty Acid Composition

Research Article

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ABSTRACT

Little scientific information is available that has evaluated safflower (*Carthamus tinctorius*) cake as a substitute to conventional ingredients in small ruminants diet. The objective of this work was to evaluate the effect of feeding safflower cake in total mixed rations (TMRs) on lamb and kid growth rates, carcass traits and meat fatty acid composition. Two consecutive trials were conducted using *Comisana* breed lambs and *Garganica* breed kids. Animals were randomly allocated to two isocaloric and isonitrogenous TMRs formulated to meet or exceed nutritional requirements, and consisted of the control diet and an experimental diet contained safflower cake. Animals were slaughtered after the feeding trial which lasted 50 days and the carcass traits and meat quality were evaluated. In both slaughter trials, none of the parameters studied were ($P>0.05$) influenced by dietary treatments except for slaughter weight and cold-carcass dressing that were improved in lambs fed safflower. Feeding the safflower diet resulted in significantly lower saturated fatty acid (SFA) content in meat, as well as the n-6 / n-3 polyunsaturated fatty acid (PUFA) ratio and saturation, atherogenic and thrombogenic indexes, while total PUFA and monounsaturated fatty acids (MUFA) as well as the indices related to human health increased. These results suggest that including safflower cake in diet for small ruminants can produce meat with an improved meat lipid profile. As result, safflower maintained carcass yields with no detrimental effect on meat quality.

KEY WORDS carcase fatty acid composition, kid, lamb, meat, nutrition, safflower.

INTRODUCTION

Safflower (*Carthamus tinctorius*), grown as an oil crop, has been the subject of several studies conducted in southern Italy over the last 30 years (Corleto, 2009). The lack of use of the crop as an oil plant in Mediterranean environments is mainly due to the length of cropping cycle along with low seed yield potential (Vonghia *et al.* 1990; Cazzato *et al.* 2011). Recent agronomic research work had strongly recommended the adoption of safflower as a productive crop under semi-arid / rainfed conditions due to its environmental, nutritional and agronomic benefits (Velasco *et al.* 2005; Pinto *et al.* 2011). Safflower oil has high linoleic acid content (70%), which is a unique trait amongst oilseed crops (Pinto *et al.* 2011).

High oleic acid oils are highly appreciated for food and non-food applications because they reduce cholesterol concentrations with a much greater oxidative stability than oils with higher polyunsaturated oil levels (Yodice, 1990). Previous works demonstrated that the fatty acid composition of meat of beef cattle can be positively affected by dietary safflower (Bottger *et al.* 2002). Moreover, these modifications also increase anticarcinogenic properties and reduce plasma cholesterol and fatn content (Laudadio *et al*. 2012).

It was observed in lamb fed rations containing low quality grass hay or cereal straw, supplementation by safflower meal lead to higher live weight gain than conventional barley / urea supplementation (Dixon *et al*. 2003). In hay-fed lambs, it was found that adding up to 25% safflower meal resulted in improvements of intake, digestibility, feed efficiency, and body gain weight (Dessie *et al*. 2010). However, limited research is available regarding the effects of dietary safflower cake on the meat composition of small ruminant. The typical diet for finishing lambs and kids in Mediterranean countries is a corn-or barley-based concentrate supplemented with different forage sources (Tufarelli *et al*. 2012). Therefore, our objectives were to evaluate the effects of dietary safflower cake as an alternative feed ingredient on growth traits and meat fatty acid content of lambs and kids.

MATERIALS AND METHODS

Experimental animals and design

Two pelleted TMRs meeting the nutritional requirements of lambs and kids (NRC, 2007) were formulated to be isocaloric and isonitrogenous. The dietary treatments were: (1) the control diet containing corn as main ingredient, whereas (2) the experimental diet containing safflower cake as main ingredient replacing corn and part of soybean meal and wheat bran. Both diets were formulated to contain 180 g/kg CP and 9.4 MJ/kg DM of metabolizable energy (ME) estimated from NRC (2007) using feed analysis for each treatment.

A total of fourteen *Comisana* breed male lambs weighing 16 ± 0.5 kg (Mean±SEM) at weaning (40±3 days of age) and sixteen *Garganica* breed male kids weighing 12 ± 0.4 kg (Mean±SEM) at weaning (40±4 days of age) were randomly assigned (seven lambs per treatment and eight kids per treatment, respectively) to the control and safflower diets. Lambs and kids were housed in individual pens (1.7×0.95 m) and were initially fed 500 g/d (as fed basis) per head of their allocated TMR increasing to 3.5% of live body weight (NRC, 2007). After an adaptation period of seven days, the growth trial was started and lasted 50 days. The TMRs were supplied to lams and kids in two equal meals. Clean drinking water was available at all times. Pens were cleaned weekly. Body weight of each lamb was recorded weekly before feeding at 07:00 h. Feed to gain ratio was calculated as the ratio of weight gain to DM intake. At the end of the feeding period (50 days), all lambs and kids were weighed after 16 h feed deprivation and five lambs and five kids per treatment were selected based on their body weight and then slaughtered by exsanguination using conventional humane procedures (Sarvar *et al*. 2009).

Meat chemical analysis

Meat samples collected from were assayed for moisture (method 945.15), ash (method 967.05), and crude protein (method 990.03) by oven, muffle furnace, and Kjeldahl methods, respectively, as described in AOAC (2000). Total lipids were extracted according to the method of Folch *et al*. (1957).

In preparation for the analysis of fatty acid composition, samples of meat (5 g each) were freeze-dried from *Longissimus lumborum* muscle and then ground. Methyl heptadecanoate (No. 51633, Fluka, USA) was dissolved into n-hexane (1 mg/mL) as an internal standard. Methyl esters of the FA were prepared (Sukhija and Palmquist, 1988); samples (300 mg each) and 5 mL internal standard were incubated (2 h at 80 ˚C) with methanolic acetyl chloride in a total volume of 9 mL. After cooling to room temperature, 7 mL of 7% (w/v) K_2CO_3 was added with mixing, and then the organic phase was collected after centrifuging at 1500 g for 2 min at 4 ˚C.

FA methyl esters were fractionated over a CP-SIL883 column (100 m×0.25 mm i.d., film thickness 0.20 µm fused silica; Varian, Palo Alto, CA, USA) in a Shimadzu (Model 2GC17A) gas chromatograph with a Hewlett-Packard HP 6890 gas system and using flame ionization detection. Helium was used as carrier gas at a constant flow rate of 1.7 mL/min. The oven temperature was programmed as follows: 175 ˚C, held for 4 min; 175-250 ˚C at 3 ˚C/min; and then maintained for 20 min. The injector port and detector temperature were 250 ˚C. Samples (1 µL) were injected with an auto-sampler. Output signals were identified and quantified from the retention times and peak areas of known calibration standards. Composition was expressed as percentages of the total FA.

The atherogenic and thrombogenic indexes were calculated according to Ulbricht and Southgate (1991) as follows:

Atherogenic index= (C12:0+4×C14:0+C16:0) / [ΣMUFA + Σ(*n*-6) + Σ(*n*-3)]

Thrombogenic index= (C14:0+C16:0+C18:0) / [0.5 × ΣMUFA + 0.5 × Σ(*n*-6) + 3 × Σ(*n*-3) + Σ(*n*-3) / Σ(*n*-6)]

Statistical analysis

Data were analyzed using the GLM (General Linear Model) procedure of SAS (2000). The model included the fixed effect of diet (control and safflower) and species (lamb and kid). Differences between diets were analyzed with the use of Student's t-test.

RESULTS AND DISCUSSION

Theinitial weight of lambs and kinds within the different diets were similar (Table 1). However, diets including safflower cake resulted in a greater final weight in lambs (23.9 kg) compared to the control diet. The difference in final weight is reflected in a greater but non-significant (P>0.05) gain of lambs fed safflower cake during the experiment. Other researchers confirm that safflower byproducts can be an effective replacement in concentrate with no adverse affect on livestock performance compared to control diets (ZoBell *et al*. 2005).

The lambs' feed consumption was not affected in lambs experimental groups (P>0.05). Conversely, the average dry matter intake of kids was significant lower when fed safflower cake as compared with the control TMR (621 and 765 g/d, respectively; P<0.01).

These findings in feed intake of kids supported previous results in bulls individually fed oilseed byproducts as replacement of corn meal.

Feed to gain ratio was significantly improved in lambs and kids (P<0.05) in the safflower cake group. These results are in line with other studies reporting that feed conversion ratio is associated with higher weight gain. These findings are consistent with those of Nagalakshmi *et al.* (2011), who fed lambs concentrate-based diets supplemented with different oilseed byproducts and observed similar improvements.

The inclusion of safflower cake in TMR did not affect values of meat moisture, protein, lipid and ash in lambs and kids (Table 2).

Data found for moisture, protein and ash are in accordance with those reported by Ravi *et al*. (2000) using other oilseed byproducts in concentrate for lambs and by Srivastava *et al*. (1990), who evaluated the addition of different oilseed cakes in kid rations. The different lipid extraction methods and even the variability of the same method among laboratories impede the comparison of data regarding lipid levels in *Longissimus dorsi* muscles in small ruminants (Pinto *et al*. 2011).

In the present study, the dietary treatments significantly affected meat fatty acid profiles in lambs and kids (Table 3). Meat lipid profile can be manipulated by the inclusion of some agro-industrial byproducts in the diet depending on the energy value, the fatty acid composition and the fiber content of alternative feedstuffs (Vasta *et al*. 2007; Tufarelli *et al*. 2013).

Feeding safflower cake resulted in a significant reduction in SFA in lambs (P<0.05) and kids (P<0.01). On the contrary, a significant improvement in total MUFA was reported in kids fed the alternative feed byproduct compared to the control diet (P<0.01). In our study, the n-6 / n-3 ratio decreased in the meat of kids fed the alternative safflower cake diet.

These ratios are similar to those found by Vicenti *et al.* (2009) in the *Longissimus dorsi* muscle of other species when fed different seeds in the diet. An increasing UFA / SFA ratio was observed in the meat of lambs and kids fed diets including safflower cake (P<0.01). The n-6:n-3 and UFA / SFA ratio ratios are a commonly used criterion to express the nutritional value of lipid (Peiretti and Meineri, 2008).

Table 1 Effect diets on growth performance of lambs and kids fed diets containing safflower cake in TMR

Item	Lambs				Kids				
	Diets								
	Control		Safflo		Control		Safflower		SEM
Initial live weight, kg	16.2		16.0		12.0		12.1		1.24
Final live weight, kg	23.1		23.9		21.0		20.3		2.07
BW gain, g/d	163		188		182		168		31.0
Feed intake, g/d	960		874		765	A	621	B	74.0
Feed to gain ratio, g/g	5.88	a	4.65	b	4.24	a	3.69	b	0.645

a, b: the means within the same row with different letter, are significantly different (P<0.05).
A, B: the means within the same row with different letter, are significantly different (P<0.05).
TMR: total mixed ration; BW: body weight and SEM: standard error of means.

Table 2 Effect of diets on meat chemical composition (%) of lambs and kids fed diets containing safflower cake in TMR

Item	Lambs		Kids		
	Diets				
	Control	Safflower	Control	Safflower	SEM
Moisture	75.70	75.78	75.81	74.80	0.940
Protein	18.60	19.00	19.72	18.98	0.627
Lipid	3.93	3.27	3.17	3.73	0.977
Ash	1.31	1.24	1.08	1.00	0.061
Other	0.46	0.71	1.21	1.47	0.082

TMR: total mixed ration and SEM: standard error of means.

Table 3 Effect of diets on meat fatty acid composition (% on total fatty acid) and indexes related to human health of lambs and kids fed diets containing safflower cake in TMR

Item	Lambs				Kids				
	Diets								
	Control		Safflower		Control		Safflower		SEM
Σ SFA	48.50	a	46.74	b	44.73	A	38.65	B	0.913
Σ MUFA	42.89		44.45		47.82	B	54.54	A	1.163
Σ PUFA	8.52		8.81		7.43		6.80		0.672
Σ UFA	51.40	b	53.26	a	55.26	B	61.34	A	0.918
Total n-6	7.72		7.80		6.61		5.74		0.953
Total n-3	0.89		1.01		0.82		1.06		0.155
n-6 / n-3	8.67		7.72		8.05	a	5.55	b	0.651
UFA/SFA	1.05	B	1.40	A	1.24	B	1.58	A	0.059
Atherogenic index	1.02	A	0.93	B	0.58	a	0.50	b	0.043
Thrombogenic index	1.69	a	1.56	b	1.41	A	1.06	B	0.047

a, b: the means within the same row with different letter, are significantly different ($P<0.05$).
A, B: the means within the same row with different letter, are significantly different ($P<0.05$).
TMR: total mixed ration and SEM: standard error of means.
n-6 / n-3: PUFA n-6 / PUFA n-3 ratio and UFA / SFA: unsaturated fatty acid / saturated fatty acid ratio.

The use of safflower cake in TMR significantly improved the atherogenic and thrombogenic indexes of the *Longissimus dorsi* muscle of lambs and kids.

These results indicate that safflower cake inclusion in diets for small ruminants represents an interesting functional product that could be recommended in healthy balanced dietary treatment to limit human cardiovascular diseases, as also reported in meat rabbits (Peiretti and Meineri, 2008), bulls (Vicenti *et al*. 2009) and poultry (Laudadio and Tufarelli, 2010).

CONCLUSION

Inclusion of safflower cake in total mixed rations for growing and fattening small ruminants does not affect their growth performance, meat quality or lipid fatty acid profile. Moreover safflower, from a practical and economic point of view, represents a valuable alternative to conventional ingredients in countries where safflower cultivation is supported by environmental conditions.

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