Fatty acid profile and meat quality of lambs fed Crambe pie

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Abstract – The Crambe pie resulting from obtaining biodiesel, can be a potential ingredient for animal feed. The objective of this study was to evaluate the effect of Crambe pie inclusion in lamb diets on meat quality. Thirty-two female lambs, fed with 4 experimental diets with different levels of Crambe pie (0%, 4%, 8% and 12%) were used. After slaughter, the *Longissimus* muscle was collected. Color, weight loss by cooking (WLC), and shear force (SF) values were obtained, chemical composition and fatty acids profile determined. The activities of enzymes Δ9 desaturases, elongases and atherogenicity index were determined. Color, WLC and SF of meat were unchanged. There was a cubic effect of Crambe pie inclusion on the ether extract in meat. Increasing levels of Crambe pie in diet decreased the content of oleic, palmitoleic and the estimated activity of Δ9 desaturase16. The atherogenicity index was not changed. The use of Crambe pie up to 12% in the diet of sheep does not affect the physical properties of meat, but it has influence on fatty acids profile without affecting the atherogenicity index.

Key Words – nutrition, coproduct, meat

I.INTRODUCTION

The Crambe (*Crambe abyssinica*) is an oilseed used for production of biodiesel and its co-products (meal or pie) used as protein and lipid source in the diet of ruminants. There is need for recycling of these co-products in order to maintain the chain of sustainable biodiesel and reduce the impact they have on the environment.

The content of ether extract make this an attractive oilseed feed, given that nutrition is a factor that significantly affects the qualitative and quantitative properties of meat. The crambe is a vegetable rich in monounsaturated fatty acids. Increasing the proportion of polyunsaturated fatty acids in the diet makes it possible to increase the unsaturation and reduce the content of saturated fatty acids in ruminant meats [4]. There is also the benefit of reducing some fatty acids that have hypercholesterolemic effect.

Another important aspect is the fact Crambe pie has large amounts of erucic acid, which can demonstrably affect the quality of the meat and its fatty acid profile. The erucic acid (C22:1) is a monounsaturated fatty acid present in crambe; an anti nutritional factor considered to cause deleterious effects to the animal when present in excess [8].

In addition to physical and chemical characteristics of meat, some mathematical indices can be used to estimate the enzymatic activity (desaturases and elongases) and atherogenicity index [10, 13], as a complement to assess potential problems in the composition of meat that could affect the health of those who consume it.

The present study aimed to evaluate the parameters of meat quality of lambs fed with increasing levels of dietary crambe pie.

II.MATERIALS AND METHODS

The test was conducted in the Department of Animal Science, Federal University of Lavras. All experimental procedures were approved by the Ethics Committee on Animal Use. Thirty two female lambs were used (F1 Dorper x Santa Inês) with a mean age of 87 ± 9 days, weighing 17.1 ± 2.80 kg, confined for 118 days, fed with 4 experimental diets with different levels of Crambe pie (0% , 4%, 8% and 12%) in a randomized block design (4 initial weights) with 8 replication per treatment. The lambs were fed with diets based on oat hay (Tifton), corn, soybean meal, soybean hulls, limestone, mineral supplement and Crambe pie in the different experimental levels. The crude protein (CP%) level of diets was 15.96. Each lamb was fed individually and consumption of food was measured daily by weighing the food provided and orts, which were analyzed in the laboratory to determine the dry matter intake. Throughout the experimental period, lambs were weighed periodically to calculate the average daily weight gain. At the end of the experimental period (118 days) the lambs were weighed to obtain the slaughter weight, and were slaughtered after 16 hours of fasting, with the removal of solid food. Feed conversion was determined considering the amount of dry matter intake by daily weight gain. The carcasses were chilled for 24 hours at 3ºC. The *Longissimus lumborum* samples were collected and subsequently, color measurements were performed using a Minolta CM-700 (Konica Minolta, Japan). A total of 5 readings were taken on each steak and averaged to obtain lightness (*L**), redness (*a**) and yellowness (*b**). Uncooked meat samples were lyophilized and moisture (M), crude protein (CP), ether extract (EE) and ash, were determined [2]. The CP was quantified by the Kjeldahl method, the EE was extracted by Soxhlet method and ash in the oven at 600ºC. Weight loss by cooking (WLC) was performed in triplicate [11]. The measurement of shear force was conducted for assessment the tenderness in *Longissimus* [1]. The extraction lipid of the *longissimus lumborum* samples to determine the fatty acid profile was performed [6]. The activities of enzymes Δ9 desaturases and elongases were determined as mathematical calculation [10]. The atherogenicity index (AI) was calculated, as an indicator for the risk of cardiovascular disease [13]. The data were analyzed by regression procedure of SAS (Statistical Analysis Software), Proc REG, evaluating linear, quadratic and cubic effect.

III.RESULTS AND DISCUSSION

Lambs showed a significant decrease in dry matter intake with increasing dietary crambe pie (ranging from 814 to 698 g/day), but showed no differences in slaughter weight, daily weight gain and feed conversion (Table 1). This is probably due to the fact of increased energy density due to crambe pie, by increasing ether extract content (4.1, 5.6, 6.7 and 7.8% for diets with 0, 4, 8 and 12% of Crambe pie, respectively).

Some chemical parameters (ether extract, crude protein, ash and moisture) and physical properties (color, cooking weight loss and shear force) of meat were unaffected by inclusion of Crambe pie in the diet (Table 2). There was a cubic effect of increasing levels of crambe pie in diet on the ether extract in meat. Possible explanation may be due to changes in in dry matter intake by lambs, which fell as crambe pie increased although, by increasing the level of ether extract in diet, to some extent, has allowed increased EE in meat at 8% level. However, high dietary EE can limit the extent of feed intake by the animals, which at higher levels also limits EE in meat [7]. The proportion of lipids found was high, compared to some studies [12], whereas the fat content of sheep meat can vary from 2.0 to 4.0%. This is likely because females were used, and the physiology and metabolism of these tend to deposit more amount of fat [5].

Table 1- Dry matter intake and performance of lambs in treatments with increasing levels of crambe pie

Item	Crambe pie (%)				SEM[6]	P<F[7]
	0	4	8	12		
DMI[1]	814	802	727	698	33,1	0,05
SW[3]	35,8	36,1	33,8	33,8	1,1	0,31
DWG[4]	163	163	153	160	8,1	0,80
FC[5]	5,14	5,17	5,14	4,94	0,165	0,75

[1]Dry matter intake (g/day); [3]Slaughter weight (kg); [4]Daily weight gain (g/day); [5]Feed Conversion; [6]Standard Error of the Mean; [7]Probability (P<F).

Table 2- Physical and chemical properties of the *Longissimus lumborum* muscle from lambs fed diets containing Crambe pie

Item	Crambe pie (%)				P<F
	0	4	8	12	
*L**	41.2	43.0	41.2	42.7	0.6
*a**	8.4	8.9	8.2	8.8	0.8
*b**	16.0	15.2	15.0	15.2	0.6
WLC	25.1	24.8	20.8	21.8	0.6
SF	3.9	4.6	3.8	4.1	0.2
EE[a]	9.33	5.21	8.16	4.7	0.01
CP	21.92	22.71	22.07	21.79	0.69
Ash	2.4	2.57	2.50	2.64	0.13
M	62.74	62.74	64.54	65.84	0.46

[a]$Y=9.33-3.037x-0.624x^2-0.035x^3$; *L**:luminosity; *a**:redness; *b**:yellowness; WLC:weight loss by cooking(%); SF:shear force(kgf); EE:ether extract(%); CP:crude protein (%); ash:(%); M:moisture (%);

The increase in Crambe pie was effective in increasing linearly ($P<0.05$) the levels of fatty acids anti-iso pentadecanoic (C15:0), erucic (C22:1), arachidonic (C20:0), γ-linolenic (C18:3), the sum of the polyunsaturated and omega 3 and 6, and conjugated linoleic acid (CLA) (C18:2 C9, T11) (Table 3, 4 and 5).

Table 3 Composition of saturated fatty acids of *Longissimus lumborum* muscle from lambs fed diets containing different levels of Crambe pie

FA	Crambe pie (%)				P<F
	0	4	8	12	
C14:0	2.5	2.5	2.5	2.7	0.6
C15:0	0.2	0.2	0.3	0.3	0.02[a]
C16:0	22.3	21.3	20.7	20.2	0.1
C18:0	19.4	20.3	19.4	21.7	0.3
C20:0	0.2	0.3	0.5	0.6	0.007[b]

[a]ŷ=0.232+0.008x (R^2=0.95); [b]ŷ=0.220+0.37x (R^2=0.95); FA: fatty acids; C14:0 Myristic; C15:0 anti-iso pentadecanoic; C16:0 Palmitic; C18:0 Stearic; C20:0 Arachidonic.

Table 4 Composition of monounsaturated and polyundaturated fatty acids *Longissums lumborum* muscle from lambs fed diets containing different levels of Crambe pie

FA	Crambe pie (%)				P<F
	0	4	8	12	
C16:1C9	1.90	1.90	1.70	1.50	0.02[a]
C18:1C9	39.10	38.30	34.90	33.00	0.003[b]
C22:1	0.70	1.10	2.77	3.77	0.004[c]
C18:3n6	0.03	0.06	0.06	0.08	0.01[d]
C18:3n3	0.20	0.23	0.26	0.29	0.07
CLA	0.45	0.56	0.68	0.73	0.03[e]

[a]ŷ=1.95–0.034x (R^2=0.96); [b]ŷ=39.63-0.54x (R^2=0.95); ŷ=0.456+0.45x (R^2=0.96); [d]ŷ=0.034+0.0037x (R^2=0.91); [e]ŷ=0.46+0.024x (R^2=0.98); FA: fatty acids; C16:1,C9 Palmitoleic; C18:1, C9 Oleic; C22:1 Erucic acid; C18:3, n6 γ-Linolenic; C18:3, n3 α-Linolenic; CLA: conjugated linoleic acid (C18,2,C9,T1).

Probably the acid C15: 0 ante-iso was produced by ruminal process of the biohydrogenation because the presence of this fatty acid in the Crambe pie could not be detected. It is noteworthy that the C15: 0 present in meat may have a cytotoxic action, and should receive the same attention as CLAs regarding the likely effects on the health of those who consume the meat [9]. The increase in amount of erucic acid with increasing inclusion of Crambe pie in the diet is explained by the fact that this ingredient contain large amounts of this fatty acid (50.55%). However, the level of erucic acid was within the range (5%), established by the Council Directive of the European Communities, between 0.7 and 3.77, and is not detrimental to the health of those consuming the product. The increase in polyunsaturated is due to the increase in EE in the diet of lambs, which also resulted in an increase in its relations with saturated and monounsaturated (Table 5). The explanation for the increase of CLA might be an incomplete biohydrogenation of linoleic acid (C18: 2 cis-cis-9 12) by ruminal microbes, then yielding CLA, which was absorbed and deposited into muscle, or the action of Δ9-desaturase enzyme [7].

Table 5 Mean values of sums and ratios of saturated fatty acids (SFA), monounsaturated (MUFA), polyunsaturated (PUFA), ω6 and ω3 *Longisimus lumborum* muscle of lambs fed diets containing different levels of Crambe pie

FA	Crambe pie (%)				P<F
	0	4	8	12	
Σ SFA	47.7	47.8	46.7	48.5	0.77
Σ MUFA	51.5	51.3	51.3	49.7	0.64
Σ PUFA	2.2	2.4	3.1	2.8	0.02[a]
PUFA/SFA	0.05	0.05	0.07	0.06	0.04[b]
MUFA/SFA	1.09	1.08	1.11	1.03	0.66
PUFA/MUFA	0.04	0.05	0.06	0.06	0.01[c]
ω 6	0.05	0.07	0.07	0.09	0.03[d]
ω 3	0.20	0.23	0.26	0.29	0.08
Σ ω 3,6	0.24	0.30	0.33	0.38	0.04[e]
Σω6/Σω3	0.23	0.30	0.29	0.33	0.26

[a]ŷ=2,25+0,067x (R^2=0.67); [b]ŷ=0.048+0.0014x(R^2=0.55); [c]ŷ=0.044+0.01x (R^2=0.77); [d]ŷ=0,049+0,003x (R^2= 0.92); [e]ŷ=0,24+0,012x (R^2=0.99). FA: fatty acids;

Crambe pie inclusion decreased (*P* <0.05) the content of oleic (C18:1 C9), palmitoleic (C16:1 C9) (Table 4) and the estimated activity of Δ9 desaturase 16 (Table 6). The atherogenicity index was not affected by the treatments (*P*> 0.05) (Table 6). This result is consistent to the observed decrease of the palmitoleic acid content (C16: 1 C9). Thus, it may be that the lower activity of the enzyme Δ9 desaturase 16 has caused a reduction in the levels of palmitoleic acid in the lipid fraction of the *longissimus lumborum* muscle. The values found for the AI ranged from 0.57 to 0.64. This index was independent of diet, although presenting a slight tendency to be reduced (P = 0.078) by increasing crambe pie inclusion in diet. The AI relate the pro-and anti-atherogenic acids, and indicates the potential for stimulating platelet aggregation, indicating that the lower the value of AI, the greater the amount of anti-atherogenic fatty acids present in fats and hence the greater the potential to prevent the onset of coronary heart disease.

Table 6 Activities of Δ9desaturase 16 (Δ9D16) and Δ9desaturase 18 (Δ9D18) enzymes, elongase (elong) and atherogenicity index (AI) of intramuscular fat from lambs fed with different levels of Crambe pie

AG	Crambe pie (%)				P<F
	0	4	8	12	
Δ9D16	2.01	1.96	1.77	1.6	0.02[a]
Δ9D18	20.4	21.4	20.4	22.7	0.32
Elong	70.8	71.7	70.8	71.5	0.78
AI	0.64	0.62	0.59	0.57	0.08

[a] $\hat{y} = 2.04 - 0.035x$ ($R^2 = 0.96$); FA: fatty acids,

VI.CONCLUSION

It can be concluded that the use of Crambe pie, up to 12% in diet of the lambs, reduces the lipid portion of the meat and affects the profile of fatty acids, which may improve the proportion of CLA, without modifying the physical properties of the meat and atherogenicity index. Despite promoting increased erucic acid in the meat, the use of up to 12% crambe pie in the diet of lambs hardly compromises the health of those who consume the product.

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