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Fatty acid composition and oxidative stability of lambs' meat as affected by a bioflavonoid antioxidant and fat sources

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Abstract

A study was conducted to investigate the effects of a synthetic or natural antioxidant and fat saturation, in a standard feedlot diet, on fatty acid composition and oxidative stability of lamb. The four dietary treatments consisted of the same basal diet providing 187 g crude protein (CP), 355 g neutral detergent fibre (NDF), and 71 g ether extract (EE) per kg dry matter (DM), differing in fat source (30 g/kg of either saturated beef tallow or unsaturated soybean oil) and type of antioxidant included (125 g/t of either a synthetic or natural antioxidant). Eighty four S.A. Mutton Merino lambs weighing 27.6 ± 1.7 kg were divided into four groups and randomly allocated to four dietary treatments (n = 21 lambs/treatment) subdivided into 7 replicates/treatment (n = 3 lambs/replicate). After an adaptation period of 8 days, all lambs received complete diets for a further feeding period of 41 days. At termination of the study, seven lambs per treatment, weighing 45.1 ± 3.0 kg, were randomly selected and slaughtered. Loin chops from each carcass were used for fatty acid, colour (a^* values) and thiobarbituric acid reactive substance (TBARS) analysis. Meat colour was determined on days 0 and 7 after being stored at 4 ºC under fluorescent light. The malonaldehyde content per kg meat was determined on days 0, 7 and 90 after being stored at -18 ºC in the dark. It was found that dietary treatment had no effect on colour stability as depicted in a^* values. The malonaldehyde content per kg meat was higher on days 0 and 90 for the unsaturated soybean oil treatment. Beef tallow inclusion resulted in an increase in palmitoleic acid, where soybean oil inclusion resulted in an increase in linoleic and α-linolenic acids in both lean and subcutaneous fat tissue. Natural antioxidant inclusion in the diet only increased the palmitoleic acid content of subcutaneous fat. The results suggested that the fatty acid profile of lamb meat can be favourably manipulated by the source of fat included in the diet.

Keywords: Antioxidants, dietary fat saturation, feedlot lambs
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Introduction

In the last few decades there has been increasing interest in supplementary lipid sources in ruminant diets to increase the energy density of these diets and to improve the dietetic quality of the carcass and other ruminant products (Bauchart *et al*., 1996). Due to this demand, there has been an increased interest to find suitable and natural ways to positively manipulate the fatty acid composition of red meat (Wood *et al*., 2003).

Polyunsaturated fatty acids (PUFA) are perceived to be beneficial for human health as it decreases the possibility of coronary heart disease and type 2 diabetes (Wood *et al*., 2003). Despite lipid biohydrogenation, a proportion of dietary PUFA bypasses the rumen intact and is available for absorption and subsequently

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deposition in muscle and adipose tissue (Wood *et al*., 2008). The susceptibility of muscle tissue to lipid oxidation depends on a number of factors, the most important being the level of PUFA present in the particular muscle system (Buckley *et al*., 1995) and antioxidant levels (Jensen *et al*., 1997). In meat, mono unsaturated fatty acids (MUFA) are more resistant to oxidative modification than PUFA (Frémont *et al*., 1998).

The increasing preference for natural foods has pushed the food industry to include natural antioxidants in various products to delay oxidative degradation of lipids, improve quality and nutritional value of foods, and replace synthetic antioxidants (Velasco & Williams, 2011). Flavonoids are secondary plant metabolites derived from phenylalanine and acetyl co-enzyme A (Winkel-Shirley, 2001), which acts as an antioxidant (Ross & Kasum, 2007). The use of these naturally occurring bioflavonoids in animal diets is one of the most promising steps in improving meat quality because of its antioxidant properties.

The colour of meat is seen as the most important factor in purchasing decisions (Mancini & Hunt, 2005). This also applies in beef (Killinger *et al*. 2004). One way of improving colour and fat stability of meat, other than adding antioxidants directly to meat (Resconi, 2007), is to include antioxidants in animals' diets (Ripoll *et al*., 2011). Meat quality can be improved by incorporating natural antioxidants to animal diets, adding these compounds onto the meat surface, or by using active packaging (Velasco & Williams, 2011).

The aim of the study was to determine the effects of a bioflavonoid antioxidant and fatty acid saturation in a standard feedlot diet on oxidative stability and fatty acid composition of muscle and fat tissue of lamb meat.

Materials and Methods

Eighty four S.A. Mutton Merino lambs weighing 27.6 ± 1.7 kg were divided into four groups; each group was randomly allocated to one of four dietary treatments (n = 21 lambs/treatment). Each group of animals was further subdivided into seven replicates of three lambs per replicate. The four dietary treatments consisted of the same basal diet (187 g CP-, 355 g NDF and 71 g EE/kg DM) only differing in the fat source (30 g/kg of either saturated beef tallow or unsaturated soybean oil) and type of antioxidant included (synthetic antioxidant included at 125 g/t according to the supplier, and a natural antioxidant also included at 125 g/t to match the level of the synthetic antioxidant for a direct comparison). The synthetic antioxidant contained a combination of butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), ethoxyquin, and trisodium citrate. The natural antioxidant is a poliphenolic plant extract containing bioflavonoids (cathecin and gallo-catchecin) and pro-anthocyanidins (which generate the anthocyanidins delfinidin, robinetidin and fisetidin).After an adaptation period of 8 days, all lambs received full rations for a feeding period of a further 41 days.

At termination of the study, seven lambs per treatment, weighing 45.1 ± 3.0 kg each, were randomly selected and slaughtered. One loin chop from each carcass was overwrapped with oxygen-permeable polyvinyl chloride (PVC) meat stretch wrap in polystyrene trays and stored for 7 days at 4 ºC under fluorescent light for fresh meat stability studies. Meat colour (a^* values) was determined on days 0 and 7 post mortem. A second loin chop was vacuum sealed and stored for 90 days at -18 ºC in the dark for frozen storage stability studies. A 5 g sample of muscle tissue was then removed from the middle of each loin chop on days 0, 7 (stored at 4 ºC) and 90 (stored at -18 ºC) to determine the thiobarbituric acid reactive substance (TBARS; mg malonaldehyde/kg meat) content using the aqueous acid extraction method of Raharjo *et al*. (1992). Total lipid from muscle and subcutaneous fat samples were quantitatively extracted according to the method of Folch *et al*. (1957) using the third (day 0) loin chop. The extracted fat was stored in a polytop (glass vial, with push-in top) and frozen at -20 ºC under a blanket of nitrogen pending fatty acid analyses. The data was subjected to PROC ANOVA and analysed according to a 2 x 2 factorial arrangement of treatments and tested for significant differences using the General Linear Model (GLM) procedures of the SAS program (SAS, 1999). Tukey's honest significant difference (HSD) test was used to identify significant differences (P <0.05) between treatments.

Results and Discussions

All procedures conducted during this study were approved by the Interfaculty Animal Ethics Committee for Animal Experimentation at the University of the Free State (Animal Experiment No.

04/2010). The effect of dietary antioxidant and fat source on the fatty acid content of muscle and subcutaneous fat tissue of S.A. Mutton Merino lambs is presented in Table 1. Only the major fatty acids that differed significantly were included.

The inclusion of saturated tallow resulted in a higher (P <0.05) favourable palmitoleic acid (C16:1c9) content of both muscle and subcutaneous fat tissue, while unsaturated soybean oil had a similar response (P <0.05) on the favourable linoleic- and α-linolenic fatty acid content of the same tissue (C18:2c9 and C18:3c9, respectively). The MUFA content of the muscle tissue increased (P = 0.0112) within the tallow treatment, following the same trend as palmitoleic acid. According to Demeyer & Doreau (1999) ruminant lipid composition reflects the rumen metabolism of dietary fatty acids. As a consequence of this, the fatty acid composition of ruminant meat are mainly saturated and monounsaturated (Wood *et al*., 2008). However, the PUFA content of both muscle and subcutaneous fat tissue increased (P <0.05) with unsaturated soybean oil inclusion. This is in agreement with Aurousseau *et al*. (2004) who stated that the fatty acid composition of muscle and adipose tissue is mainly influenced by the fatty acid composition of the feed.

The type of antioxidant had little effect on the fatty acid composition of lamb muscle and subcutaneous fat tissue (Table 1) except for the exception of palmitoleic acid that increased (P <0.01) within the subcutaneous fat layer, following the inclusion of the natural antioxidant.

Table 1 The effect of dietary antioxidant and fat source on the fatty acid content of muscle and subcutaneous fat tissue of S.A. Mutton Merino lamb meat

Parameter (% of total fatty acids)	Fat source		Antioxidant		Significance (P-value)			CV[#]
	Tallow	Soybean oil	Synthetic	Natural	Fat source	Antioxidant	Interaction	
Muscle tissue:								
Palmitoleic acid	2.09[b]	1.71[a]	1.92	1.89	<.0001	0.6344	0.5244	10.2
Linoleic acid	5.09[a]	7.19[b]	5.98	6.23	<.0001	0.4059	0.5084	16.3
α-linolenic acid	0.61[a]	0.75[b]	0.66	0.70	0.0006	0.1696	0.6816	13.0
SFA[1]	49.20	48.64	48.90	48.94	0.2452	0.9250	0.5020	2.6
MUFA[2]	42.17[b]	40.32[a]	41.72	40.78	0.0112	0.1738	0.1715	4.3
PUFA[3]	8.40[a]	11.04[b]	9.38	10.06	0.0001	0.2560	0.4995	15.7
Subcutaneous fat tissue:								
Palmitoleic acid	2.21[b]	1.78[a]	1.91[a]	2.08[b]	<.0001	0.0056	0.4472	7.6
Linoleic acid	2.95[a]	4.90[b]	4.03	3.82	<.0001	0.3087	0.9512	14.1
α-linolenic acid	0.44[a]	0.65[b]	0.55	0.54	<.0001	0.8853	0.1661	13.0
SFA[1]	57.13	55.59	56.74	55.98	0.1808	0.5031	0.5815	5.3
MUFA[2]	37.89	37.33	37.50	37.72	0.5344	0.8090	0.2766	6.3
PUFA[3]	4.44[a]	6.85[b]	5.76	5.52	<.0001	0.3446	0.7896	11.6

[a,b] Row means with different superscripts differ significantly (P <0.05) within fat source or antioxidant means;
[#]Coefficient of variation (%); [1]Saturated fatty acids; [2]Mono-unsaturated fatty acids; [3]Poly-unsaturated fatty acids.

The effect of dietary antioxidant and fat source on the malonaldehyde content and colour (a* values) stability of S.A. Mutton Merino lamb muscle tissue is presented in Table 2. Oxidative stability and colour of lamb meat did not differ between antioxidant treatments. In contrast, the unsaturated soybean oil treatment resulted in a lower oxidative stability within the muscle tissue of loin chops (P <0.05) measuring a higher malonaldehyde content/kg of meat on day 0 and 90. This could be attributed to the fact that the higher level of polyunsaturated fatty acids present in the muscle tissue (Table 1) increased its susceptibility to lipid oxidation (Buckley *et al*., 1995). Dietary fat source did not affect (P >0.05) the colour of lamb meat as observed on day 0 and 7.

Table 2 The effect of dietary antioxidant and fat source on the malonaldehyde content and colour (a* values) stability of S.A. Mutton Merino lamb muscle tissue after refrigerated and frozen storage

Parameter (loin chop)	Fat source		Antioxidant		Significance (*P*-value)			CV[#]
	Tallow	Soybean oil	Synthetic	Natural	Fat source	Antioxidant	Interaction	
TBARS[1]:								
Day 0 (fresh)	0.11[a]	0.13[b]	0.13	0.12	0.0378	0.2969	0.6688	16.8
Day 7 (refrigerated)	0.22	0.21	0.19	0.24	0.8822	0.2450	0.2306	48.2
Day 90 (frozen)	0.14[a]	0.17[b]	0.14	0.17	0.0455	0.1291	0.5641	28.6
Meat colour[2]:								
Day 0 (fresh)	10.74	10.69	10.39	11.04	0.9064	0.1869	0.1389	11.7
Day 7 (refrigerated)	8.90	8.66	8.95	8.61	0.6850	0.5763	0.6833	18.3

[a,b] Row means with different superscripts differ significantly (P <0.05) within fat source or antioxidant means.
[#]Coefficient of variation (%); [1]Thiobarbituric acid reactive substance (mg malonaldehyde/kg meat), [2]a* values.

Conclusions

Results indicated that the fatty acid profile of lamb meat can be favourably manipulated, i.e. lower palmitoleic- and higher linoleic-, α-linolenic- and PUFA by the inclusion of an unsaturated lipid source (soybean oil) in the diet. However, unsaturated fat in the diet resulted in a lower oxidative stability of lamb muscle tissue with no effect on colour stability (P >0.05). With the exception of a higher palmitoleic acid content in subcutaneous fat tissue of lambs fed the bioflavonoid antioxidant, the type of dietary antioxidant seems not to affect the fatty acid composition and oxidative stability of lamb meat.

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References

Aurousseau, B., Bauchart, D., Calichon, E., Micol, D. & Priolo, A., 2004. Effect of grass or concentrate feeding systems and rate of growth on triglyceride and phospholipid and their fatty acids in the *m. longissimus thoracis* of lambs. Meat Sci. 66, 531-541.

Bauchart, D., Gruffat, D. & Durand, D., 1996. Lipid absorption and hepatic metabolism in ruminants. Proc. Nutr. Soc. 55, 39-47.

Buckley, D.J., Morrissey, P.A. & Grey, J.I., 1995. Influence of dietary vitamin E on oxidative stability and quality of pig meat. J. Anim. Sci. 73, 3122-3130.

Demeyer, D. & Doreau, M., 1999. Targets and procedures for altering ruminant meat and milk lipids. Proc. Nutr. Soc. 58, 593-609.

Folch, J., Lees, M. & Sloane-Stanley, G.H., 1957. A simple method for the isolation and purification of total lipids from animal tissue. J. Biol. Chem. 226, 497-509.

Frémont, L., Gozzélino, M.T., Franchi, M.P. & Linard, A., 1998. Dietary Flavonoids reduce lipid peroxidation in rats fed polyunsaturated or monounsaturated fat diets. J. Nutr. 128, 1495-1502.

Jensen, C., Engerg, R., Jakobsen, K., Skibsted, L.H. & Bertelsen, G., 1997. Influence of the oxidative quality of dietary oil on brioler meat storage stability. Meat Sci. 47, 211-222.

Killinger, K. M., Calkins, C. R., Umberger, W. J., Feuz, D. M. and Eskridge, K. M., 2004. Consumer visual preference and value for beef steaks differing in marbling level and color. J. Anim. Sci, 82, 3288-3293.

Mancini, R. A., & Hunt, M. C., 2005. Current research in meat colour. Meat Sci. 71, 100-121.

Raharjo, S., Sofos, J.N.S. & Schmidt, G.R., 1992. Improved speed specificity, and limit of determination of an aqueous acid extraction thiobarbituric acid-C_{18} method for measuring lipid peroxidation in beef. J. Agric. Food Chem. 40, 2182-2185.

Resconi, V., 2007. The effect of diet on vitamin E concentration, colour shelf life and lipid oxidation during simulated retail display in beef steaks from different production systems. Tesis Máster. Instituto Agronómico Mediterráneo de Zaragoza-España. (in Spanish).

Ripoll, R., Joy, M. & Muñoz, F., 2011. Use of dietary vitamin E and selenium (Se) to increase the shelf life of modified atmosphere packaged light lamb meat. Meat Sci. 87, 88-93.

Ross, J.A. & Kasum, C.M., 2007. Dietary flavoids: Bioavailability, metabolic effects and safety. Ann. Rev. Nutr. 22, 19-34.

SAS, 1999. SAS® User's Guide. Version 6.12. SAS Institute Inc., Cary, N.C., USA.

Velasco, V. & Williams, P., 2011. Improving meat quality thrue natural antioxidants. Chilean J. Agri. Res. 71, 313-322.

Winkel-Shirley, B., 2001. Flavonoid biosynthesis. A colourful model for genetics, biochemistry, cell biology, and biotechnology. Plant Phys. 126, 485-493.

Wood, J.D., Enser, M., Fisher, A.V., Nute, G.R., Whittington, F.M. & Richardson, R.I., 2003. Effects of diets on fatty acids and meat quality. Options Méditerranéennes, Series A. 67, 133-141.

Wood, J.D., Enser, M., Fisher, A.V., Nute, G.R., Sheard, P.R., Richardson, R.I., Hughes, S.I. & Whittington, F.M., 2008. Fat deposition, fatty acid composition and meat quality: A review. Meat Sci. 78, 343-358.