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Fatty acid composition of llama muscle and internal fat in two Argentinian herds

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Abstract

Coronary heart disease and a number of other diseases have been shown to increase with consumption of foods high in saturated fat and cholesterol. However, increased consumption of $n-3$ fatty acids reduces the incidence of these diseases. Llama meat has been reported as having a lower fat content, lower saturated fat content, and a higher $n-3$ fatty acid content than beef, and hence may serve as a more healthy alternative of animal protein. To assess these claims a study was undertaken in Argentina in which llama meat from two farms was analyzed to determine its composition. On average the lama meat had lower cholesterol (52.8 vs 67 mg/100 g) and fat (12.6 vs 20.6%) content than that reported for beef. The muscle fat of castrated males was lower in saturated fatty acids (42.6 vs 45.7%) and cholesterol (44.1 vs 63.7%), and higher in $n-3$ fatty acids (1.2 vs 1.0%) than non-castrated males. As castration appears to substantially improve llama meat quality, additional studies to confirm this appear warranted.

Keywords: Llama; Fatty acids; Lipids; Meat; $n-3$ fatty acids

1. Introduction

There is growing consensus that the dietary habits adopted by Western societies over the past century have contributed to an increased risk of coronary heart disease (CHD), hypertension, diabetes, and cancer (Leaf and Weber, 1987). Consequently, changes in human diets, particularly in terms of fat intake, have become a major interest in nutrition research (Simopoulos, 1998; Lichtenstein, 1999).

CHD is the single largest killer disease in America, causing one in every five deaths. The cost implication of CHD in the USA was projected at $ 299 billion for 2001 (American Heart Association, 2001). Clinical data strongly support a relationship between the incidence of CHD and consumption of cholesterol and saturated fatty acids (SFAs) (American Heart Association, 1991). Other experiments have demonstrated an inverse relationship between the incidence of CHD and consumption of foods rich in $n-3$ fatty acids (Kromhout et al., 1985; de Lorgeril et al., 1994; Leaf and Kang, 1998; Iso et al., 2001).

Consumption of fish and fish products would provide a more balanced fatty acid diet. For many people, however, increasing their intake of oil-rich fish is not readily accepted as a means of ingesting $n-3$ fatty acids because of taste preferences, and hence for these populations fish and fish products can be excluded as a significant $n-3$ source (Hargis and Van Elswyk, 1993; Buttriss, 1999).

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The American Heart Association (2000) recommended eating fish and only lean cuts of beef, veal, pork or lamb, and also suggests eating emu, buffalo and ostrich muscle as these are very low in total fat, saturated fat and cholesterol. Although not mentioned by the American Heart Association, South American Camelids are another group of animals that have been theorized as providing similar benefits. South American Camelids are members of the Camelidae family which consists of four species: llama, alpaca, vicuña and guanaco. Of these, only the first two have been domesticated, and they are best known for the fiber they produce.

Fatty acid composition and cholesterol content of llama meat has received little attention compared to other meats, and very little has been published. Perez et al. (2000) reported on the carcass composition of naturally reared llamas, but did not discuss fat content or composition, or cholesterol content. Gallinger et al. (1995) evaluated llama meat from a rheological standpoint and found the hindquarter to be tougher than the forequarter, without discussing composition. Garcia et al. (2003) compared fat and cholesterol content of vicuña, chicken and fish. It was reported that intramuscular fat of vicuña varied from 1 to 5% depending upon cut, with cholesterol content varying from 45 to 55 mg/g of muscle. Gauly and Boruke (2000) found alpaca and llama muscle to contain 0.2% cholesterol, with fat content for alpaca ranging from 1.1 to 7.2%, and llama from 1.2 to 4.8%. The authors, however, did not indicate the type of meat cut from which these data were obtained.

As minimal information on llama muscle composition is available, a study was undertaken to characterize llama meat. Fat content and composition, as well as cholesterol content of *longissimus dorsi* muscle and kidney fat were determined. The goal was to provide data which could be used to determine if llama meat offers any nutritional advantages, and whether or not more extensive studies should be initiated to fully characterize llama meat.

2. Materials and methods

2.1. Farm and animal selection

Two Argentine farms were selected to provide llamas. One was in the Province of Buenos Aires (35°S latitude, 62°W longitude) in the region known as the humid pampas, the other was in the foothills of the Andes, in Neuquen province (39°S latitude, 71°W longitude). These locations were chosen to provide animals which had been living under moderate weather conditions and eating lusher pastures (Buenos Aires), and animals which had been living under more extreme weather conditions and eating lower quality pastures (Neuquen). The Buenos Aires pasture was comprised primarily of white clover (*Trifolium repens*), high festuca (*Festuca arundinacea*), cebadilla criolla (*Bromus unioloides*) and medicagos (*Medicago* spp.). The main vegetation in the Neuquen pasture was cespitose gramineous (*Stipa* spp.) and dwarf shrubs known as "cushion", with the more important one being neneo (*Mulínum spinósum*). Other species consumed by the Neuquen llamas were coirones (*Stipa* spp. and *Festuca* spp.) and rosa mosqueta (*Rosa moscheta*). The Buenos Aires pasture can be characterized as being high in protein and low in fiber, with 1 ha able to support one cow. The Neuquen pasture has a high dry matter and a low protein content, with 30 ha required per cow. Mean temperature and rainfall for these locations are 16.7 °C and 737 mm, and 15.2 °C and 552 mm, respectively. Six male llamas, ranging in age from 5 to 8 years, were randomly harvested from each farm. Half of the animals ($n = 3$) from the Neuquen farm had been castrated 8 months earlier, while none of the Buenos Aires animals were castrated.

2.2. Samples and measurements taken

Immediately following harvesting, internal fat and muscle fat were obtained for laboratory analysis. Fat around the kidneys was chosen to provide internal fat samples while sections taken across the width of the longissimus dorsi muscle between the 12th thoracic vertebra and first lumbar vertebra provided the muscle fat samples. Following collection the samples were refrigerated until analyzed. Measurements of fat covering, ribeye area and ribeye diameters (transverse and perpendicular) were obtained according to the procedure of Boggs and Merkel (1980), prior to sending the muscle samples to the laboratory. To provide additional comparisons, fat in the chest cavity and in the pelvic region was removed and weighed separately. These samples, however, were not sent to the laboratory for fat analysis.

2.3. Laboratory analyses

Cholesterol content, fat content, and fatty acid composition were determined. Each sample was defrosted then individually milled and mixed. Lipids were extracted from the samples according to the method described by Folch et al. (1957), with lipid content determined gravimetrically. Total lipids were converted to fatty acid methyl esters with the IRAM 5-560II method (Instituto Argentino de Racionalizacion de Materiales, 1982), which is equivalent to ISO 5508 (ISO, 1990). Fatty acid methyl esters were separated and quantified by an automated gas chromatograph (Model 6890, GC)[1] equipped with flame ionization detectors and a 30 m × 530 μm i.d. capillary column (Model HP-FFAP) (see footnote one). HP Chem Station was used to integrate peak areas.

Cholesterol was extracted according to the method of the Association of Official Analytical Chemists Procedure 941.09 (AOAC, 1995). The same equipment and procedures that were used for the fatty acids were used to quantify the cholesterol levels, except that a Model HP-1 methyl siloxane column was utilized.

2.4. Statistical analysis

The experimental unit was a llama which had been randomly selected from the two herds. Each variable was compared using the generalized linear model analysis of variance technique to assess treatment differences. When the F-value was significant ($P < 0.05$), differences in means were analyzed using Duncan's multiple-range test (SAS Institute Inc., 2002).

3. Results

3.1. Effects of castration

Pelvic fat and chest fat weights were both greater ($P < 0.05$) in the castrated animals, as was depth of cover. Total fat, however, was not significantly different. Ribeye area and relative diameters were unaffected by castration. Castration increased ($P < 0.05$) palmitic, linoleic and linolenic fatty acid contents of the kidney fat, and the linoleic fatty acid content of the muscle fat for the llamas from the Neuquen farm (Table 1). These differences led to a significantly higher $n-3$ content of the kidney fat and $n-6$ content of the muscle fat (Table 2). No significant differences in SFA or monounsaturated fatty acid (MUFA) contents were detected between castrated and non-castrated animals.

Since castration was found to significantly affect fat composition, the overall comparison between farms and fat types was limited to non-castrated animals. Although this reduced sample size, some significant differences were detected.

3.2. Comparison between farms

Myristic fatty acid content was higher ($P < 0.05$) in both fat types for the Neuquen animals, compared to the Buenos Aires animals (Table 1). Oleic fatty acid content was significantly higher in the Buenos Aires kidney fat, while arachidonic fatty acid content was significantly lower. Cholesterol content was not significantly different between farms for either fat type. The higher oleic fatty acid content in the Buenos Aires kidney fat led to a higher ($P < 0.05$) MUFA content for the Buenos Aires samples (Table 2). No significant differences in SFA, $n-6$ or $n-3$ contents were detected for either fat type between farms. Also, no significant differences in total fat content, depth of fat cover, ribeye area or relative diameters were detected between farms.

3.3. Comparison between fat types

For the Neuquen llamas, only three fatty acids were statistically different for fat types (Table 1). Palmitic and linoleic fatty acid contents were higher ($P < 0.05$) in the muscle fat than in the kidney fat, while stearic fatty acid content was higher ($P < 0.05$) in the kidney fat than the muscle fat. For the Buenos Aires llamas, myristic and arachidonic fatty acid contents were significantly greater in the kidney fat, than in the muscle fat. Cholesterol content was lower ($P < 0.05$) in the Buenos Aires muscle fat than in the kidney fat. The same relationship in cholesterol content was found with the Neuquen animals, however the difference was not significant. The significantly greater arachidonic

[1] Hewlet Packard Co., Wilmington, DE.

Table 1
Comparison of composition and cholesterol content of muscle and internal fat samples and total fat content between farms for different sample locations for non-castrated animals[a]

Variable	Variable	Total fatty acids (%)								Cholesterol (mg/100 g)	Total fat (%)
		C14:0	C16:0	C16:1	C18:0	C18:1	C18:2$n-6$	C18:3$n-3$	C20:4$n-6$		
Neuquen	Muscle fat	3.11	23.00 A[b]	3.87	19.63 B	33.13	3.11 A	0.86	0.28	63.67	
	Kidney fat	2.56	20.13 B	2.44	27.57 A	28.77	2.69 B	0.74	0.34	104.67	
	CR[c]	1.19	2.56	1.46	6.04	9.61	0.35	0.26	0.16	61.6	
Buenos Aires	Muscle fat	2.44 A	22.03	3.41	21.53	30.67	2.20	0.53	1.78 A	41.88 B	
	Kidney fat	1.78 B	19.78	3.32	23.20	34.10	2.69	0.78	0.20 B	114.20 A	
	CR	0.34	2.37	0.77	4.26	4.16	0.76	0.29	1.20	17.7	
Kidney fat	Neuquen	2.56 A	20.13	2.44	27.57	28.77 B	2.69	0.74	0.34 A	104.67	
	Buenos Aires	1.78 B	19.78	3.23	23.20	34.10 A	2.69	0.78	0.20 B	114.20	
	CR	0.60	2.68	0.99	5.31	5.21	0.68	0.29	0.13	37.9	
Muscle fat	Neuquen	3.11 A	23.00	3.87	19.63	33.13	3.11	0.86	0.28	63.67	11.60
	Buenos Aires	2.44 B	22.03	3.41	21.53	30.67	2.20	0.53	1.78	41.88	13.57
	CR	0.61	2.73	1.06	5.20	6.58	0.99	0.37	1.86	22.34	12.67
Kidney fat	Castrated	3.02	23.70 A	3.65	21.03	29.73	3.41 A	1.16 A	0.28	82.57	
	Non-castrated	2.56	20.13 B	2.44	27.57	28.77	2.69 B	0.74 B	0.34	104.67	
	CR	1.06	3.20	1.54	7.60	7.80	0.60	0.30	0.15	48.97	
Muscle fat	Castrated	3.57	24.23	5.22	14.80	34.10	3.61 A	1.06	0.24	44.07	16.3
	Non-castrated	3.11	23.00	3.87	19.63	33.13	3.11 B	0.86	0.28	63.67	11.6
	CR	1.30	3.22	2.15	4.94	6.13	0.21	0.24	0.17	40.83	16.0

[a] The bottom portion of the table shows the effect of castration with animals harvested from the Neuquen farm.
[b] Values followed by a different letter within data pairs are statistically different at the 0.05 level of confidence.
[c] Critical range for mean separation.

Table 2
Comparison of SFA and MUFA composition, omega-3 and omega-6 contents, fat deposition and ribeye area between farms for different sample locations for non-castrated animals[a]

Variable	Variable	Total fatty acids (%)				Pelvic fat (g)	Chest fat (g)	Depth of cover (mm)	Ribeye area (cm^2)	Relative diameter
		SFA	MUFA	$n-6$	$n-3$					
Neuquen	Muscle fat	45.74	37.00	3.39	0.96					
	Kidney fat	50.26	31.20	3.03	0.84					
	CR[b]	9.34	10.12	0.46	0.26					
Buenos Aires	Muscle fat	46.00	34.08	3.98 A[c]	0.63					
	Kidney fat	44.76	37.42	2.89 B	0.88					
	CR	3.58	4.66	0.82	0.29					
Kidney fat	Neuquen	50.26	31.23 B	3.03	0.84	866	809			
	Buenos Aires	44.76	37.42 A	2.89	0.88	665	453			
	CR	6.31	5.76	0.70	0.29	576	463			
Muscle fat	Neuquen	45.74	37.00	3.39	0.96			6.17	39.33	1.52
	Buenos Aires	46.00	34.08	3.98	0.63			6.25	46.00	1.51
	CR	4.26	7.14	1.10	0.37			6.85	15.73	1.08
Kidney fat	Castrated	47.75	33.39	3.68	1.26 A	1515 A	1378 A			
	Non-castrated	50.26	31.20	3.03	0.84 B	866 B	809 B			
	CR	9.42	8.66	0.68	0.30	285	498			
Muscle fat	Castrated	42.60	39.32	3.85 A	1.16			16.11 A	39.67	1.64
	Non-castrated	45.74	37.00	3.39 B	0.96			6.17 B	39.33	1.52
	CR	6.13	6.62	0.32	0.24			7.19	17.46	0.88

[a] The bottom third of the table shows the effect of castration with animals harvested from the Neuquen farm.
[b] Critical range for mean separation.
[c] Values followed by a different letter within data pairs are statistically different at the 0.05 level of confidence.

fatty acid content of the Buenos Aires muscle fat led to the $n-6$ content of the muscle fat being higher ($P < 0.05$) than the kidney fat (Table 2). The same relationship in $n-6$ content was observed in the Neuquen animals, however the difference was not significant. No statistically significant differences in SFA, MUFA or $n-3$ contents were detected between fat types.

4. Discussion

The most significant finding was the effect that castration had on fat composition, fat amount, fat cover and cholesterol content. Castration decreased the cholesterol content and increased the linolenic fatty acid content of the muscle fat. These changes are desirable from a health standpoint. On the negative side, castration increased fat cover and total fat content of the ribeyes. Since fat cover can be easily removed, this is not considered to be a significant limitation considering the advantage gained by improving fat quality. Since the number of animals sampled in this test was very limited, additional analyses should be undertaken to verify the findings.

Significant differences in fat composition detected between fat types for the non-castrated animals were not consistent between farms, although the ranking of the mean values generally was consistent. Neuquen kidney fat had a higher SFA content, although not significantly, than the muscle fat as would be expected, but this was not the case with the Buenos Aires animals. The difference between farms was more likely due to diet, or small sample size.

Differences between farms for the muscle and internal fat samples for the non-castrated animals proved inconsistent as well, with a number of relationships reversed between sample pairs. The inconsistencies are probably related to diet or small sample size, rather than to animal differences.

Table 3
Comparison of SFA and linolenic fatty acid contents of llama meat to that reported by other researchers for beef, pork, goats, sheep/lamb

Component	Llama		Beef		Pork	Goats	Sheep/lamb		Author
	Neuqen	Buenos Aires	Grain	Grass			Grain	Grass	
SFA	45.74	46.00	40.90	45.68	36.90	53.80	40.80	42.39	Banskalieva et al. (2000)
			41.63[a]	41.63[a]	37.64		46.44[a]	46.44[a]	Enser et al. (1996)
			42.41	39.39					Enser et al. (1998)
			48.06[a]	46.36					Fukumoto et al. (1995)
Linolenic	0.86	0.53	0.57	0.91	0.43	1.20	0.55	1.94	Banskalieva et al. (2000)
			0.59[a]	0.59[a]	2.38		1.17[a]	1.17[a]	Enser et al. (1996)
			0.52	1.23					Enser et al. (1998)
			0.40[a]	2.76					Fukumoto et al. (1995)
			1.07[a]	1.07[a]					USDA (1999)

[a] Diet unknown, samples were purchased from retail outlets.

4.1. Comparison with data from other studies

Since a comparison of llama meat with other meat in terms of fat composition was the objective of this study, a search of relevant technical literature was conducted to find appropriate data to which the llama results could be compared. The comparison is set out in Table 3.

The most comprehensive report was written by Banskalieva et al. (2000), who summarized a number of studies that had measured fatty acid composition of goat, sheep, lamb, beef and pork meat. Only the longissimus dorsi muscle samples listed by these authors were directly comparable to the llama results.

Differences in the two linolenic fatty acid values given by Banskalieva et al. (2000) for the sheep/lamb and the beef samples were attributed to diet, with the higher values associated with animals grazing on grass pastures, and the lower values with animals fed rations composed primarily of grain in a feedlot setting. Since the higher of the two beef values were actually pooled values obtained by combining those from steers pastured on grass, and bulls fed concentrates, the source of the data (Enser et al., 1998) was consulted. The linolenic fatty acid content of the muscle fat from steers pastured on grass was 1.23%, and from bulls fed concentrates was 0.52%. It is interesting to note, however, that the authors did not discuss the effects that castration may have had on their results, rather they attributed their findings solely to diet. This may or may not be correct.

The linolenic fatty acid content of the Neuquen and Buenos Aires llama muscle fat samples were 0.86 and 0.53%, respectively, with the castrated and non-castrated values being 1.06 and 0.86%, respectively. These compare favorably by Enser et al. (1998) for beef values in the bulls and are superior to that in pork, but inferior to the goat, grass fed sheep/lamb and grass fed steer samples.

In an earlier study, Enser et al. (1996) compared the fatty acid composition of beef, lamb and pork purchased in retail stores in England (Table 3). Considering these data, the Neuquen llama samples are superior to beef, while the Buenos Aires are not. Fukumoto et al. (1995) compared fatty acid composition of choice grade beef from retail stores to young grass fed steers. In this case the linolenic fatty acid content of the llama muscle was higher than that of the purchased beef, but not that of the grass fed steers.

SFA values reported by Banskalieva et al. (2000) are provided in Table 3. As was the case for the linolenic fatty acid values, some of the SFA beef values were pooled, so the original source of the data was consulted. Enser et al. (1998) found the muscle fat from the grass fed steers to have a SFA content of 42.4%, and from the bulls fed concentrates to be 39.4%.

The SFA values for the Neuquen and Buenos Aires farms were 45.7 and 46.0%, respectively, with the castrated and non-castrated animals having SFA contents of 42.60 and 45.74%, respectively. The llama SFA values were higher than those reported by others for beef, sheep/lamb and pork, but were less than those of goat meat.

The SFA values reported by Enser et al. (1996) for beef, lamb and pork purchased in retail stores and by Fukumoto et al. (1995) for choice grade beef and pasture-fed young steer muscle are shown in Table 3.

The llama meat had a lower SFA content than both of the Fukumoto beef samples, but had a higher SFA content than the beef and pork values reported by Enser. In those cases where the llama samples had higher SFA contents than those reported by others in various muscles, the difference was due to the higher stearic fatty acid content, not palmitic fatty acid content. In the case of the Banskalieva et al. (2000) goat samples and Fukumoto et al. (1995) pasture-fed young steer meat, the palmitic fatty acid values were 1.5 times those of the llama samples. Thus although the SFA values for llama meat do not compare favorably to the values reported by others for some meats, the ratio of palmitic and steric contents are very favorable since stearic acid is considered much less hypercholesterolemic than palmitic acid (Nelson, 1992; Katan et al., 1995), or not hypercholesterolemic at all (Bonanome and Grundy, 1988; Grundy, 1997).

The USDA Food Composition Resource List for Professionals (1997) presents data for ribeye steaks obtained between the 10th and 12th ribs, trimmed to a 0.125 mm fat covering. Linolenic content is listed as 1.07%, cholesterol content as 67 mg/100 g, and total fat content at 20.63%. The llama muscle samples did have lower linolenic values, but also had less total fat without trimming and a lower cholesterol content than the USDA values.

5. Conclusions

Although this study provides only limited information on the composition of llama muscle fat and internal fat it does indicate that additional studies should be undertaken to fully characterize llama fat. Indications are that consumption of llama meat would not provide significant advantages in terms of fatty acid composition compared to beef, would be inferior to lamb/sheep muscle, but would be superior to pork. One finding that warrants additional study is the effect castration has on fatty acid composition, as it appears to increase the $n-3$ content and lower the cholesterol content substantially.

The effect of diet on fat composition also warrants study. Results reported by others indicate cattle and sheep pastured on grass have a higher linolenic content in the fat than those fed a predominately grain diet. Some of these results could have been confounded by the effects of castration, and this needs to be examined in detail.

Llama muscle does appear to offer some advantages compared to beef in that fat and cholesterol contents are lower. This may warrant llama meat consumption, particularly by individuals with a history of health problems that can be addressed by eating foods lower in saturated fats and cholesterol.

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