INTRA-MUSCULAR FAT AND FATTY ACID COMPOSITION OF ALPACA (*VICUGNA PACOS)* MEAT

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Abstract – Alpacas produce lean carcasses with minimal fat content. However, there is little available information on the health benefits and fatty acid (FA) composition of their meat. This study investigated the intra muscular fat (IMF) and FA content of alpaca meat from three muscles, the *m. longissimus thoracis et lumborum* (LL); *m. semimembranosus* (SM) and *m. biceps femoris* (BF). Fifty alpacas evenly distributed across three ages (18, 24 and 36 months) and two genders (castrated males and females) were grazed together for four months on coastal pasture of NSW Australia. Animals were slaughtered in two groups and after chilling for 24 hours samples were taken from each of the three muscles, diced and frozen at - 20˚C until analysis. IMF levels were within previously reported ranges for alpaca meat (LL = 0.71 ± 0.06 %) although lower than other species, supporting previous claims that alpaca meat has a low fat content. IMF in the LL increased with age as expected ($P < 0.05$). Younger animals had higher concentrations of polyunsaturated fatty acids (PUFA) than older animals ($P < 0.05$). Further research into the effects of FA, especially high PUFA levels in alpaca meat, is required to determine if there are any negative side effects on meat and eating quality.

Key Words – alpaca, intra-muscular fat, fatty-acid, meat quality.

I. INTRODUCTION

Alpaca meat production and consumption is growing in Australia [1]. However little is known about meat quality parameters and fat composition. It has been reported that fat contributes to a small proportion of alpaca carcass weight, resulting in very lean carcasses requiring minimal trimming [1]. However, as there is minimal fat on an alpaca carcass, it is important to investigate the fatty acid composition to establish meat quality parameters and nutritional values for this meat.

Fatty acids (FA) have been extensively studied in common livestock species such as lamb, beef and pork [2] and are known to have nutritional benefits, affect lipid oxidization of meat and aid in eating quality [2,3]. Different proportions of fatty acids including saturated fatty acids (SFA), unsaturated fatty acids (USFA) and polyunsaturated fatty acids (PUFA) are required for a healthy diet. The majority of FA can be synthesized by the human body. However, essential omega 3 fatty acids including eicosapentaenioc (EPA) and docosahexaenoic acid (DHA) need to be absorbed through either diet or supplementation [2]. Red meat has been shown to be a good source of EPA and DHA and, given the lean nature of alpaca meat, determining the fatty acid composition of fat within the muscles will aid in determining the health benefits of this meat.

Previous research into fatty acid composition of alpaca meat in South America suggests that alpacas have higher levels of polyunsaturated fatty acids (PUFA) and lower levels of monosaturated fatty acids (MUFA) in comparison to other camelids such as llamas [4,5]. PUFA are high in omega 3 which are beneficial for human health due to their links to reduced cardiovascular disease, reduced inflammation, and reductions in cholesterol levels [3]. However, they are also associated with increased levels of lipid oxidization which can result in negative flavor /aromas [2] which have a negative effect on eating quality.

Although IMF and FA content in lamb and beef has been shown to change over time and can be manipulated through nutrition and genetics [3, 6], little is known about the fatty acid composition of alpaca fat [4], especially under Australian

conditions and between genders and across ages. Therefore, the aim of this study was to investigate the IMF and fatty acid composition of three muscles across three age groups (18, 24 and 36 months of age) and two genders (castrated males and females).

II. MATERIALS AND METHODS

The data presented in this paper was part of a larger project and an in-depth account of experimental design and slaughter techniques is published elsewhere [1]. Briefly, 50 huacaya alpacas evenly distributed across three age groups (14, 20, 32 months) and two genders (females and castrated males) were grazed on coastal summer pastures on the south coast of New South Wales, Australia for four months. The animals were slaughtered in two groups (n = 25 / group), two weeks apart. After chilling (average chiller temperature 4.3˚C and humidity 90.3 %) for 24 hours, a 40 gram sample was taken for IMF and FA analysis from the caudal section of the *m. longissimus thoracis et lumborum* (LL); *m. semimembranosus* (SM) and *m. biceps femoris* (BF), diced and frozen at -20˚C until analysis.

IMF and FA analysis was conducted using methods described previously [7]. Prior to analysis samples were freeze dried and ground using a FOSS Knifetech™ 1095 sample mill. IMF analysis for crude fat content was conducted using a FOSS Soxtec 2050. A 3 g freeze dried sample was extracted in a tin with 85 ml hexane for 80 minutes in the Soxtec machine. The tin was then removed from the machine, dried for 30 minutes at 105˚C and weighed.

In brief the FA analysis consisted of 10 mg samples of freeze dried material being added to an 8 ml tube with 2 ml methanol:toluene (4:1 v/v) containing C19:0 internal standard. FAs were methylated (FAME) with 0.2 ml acetyle chloride drop–wise whilst vortexing and heating to 100˚C for 1 h. Once cooled the reaction was stopped by adding 5 ml of 6 % K_2CO_3, whilst vortexing, prior to being centrifuged for 10 minutes to separate the solution. The upper toluene layer containing the FAME were transferred into a glass vial and sealed for subsequent analysis by gas chromatography as described elsewhere [8].

The IMF data was analysed using linear mixed models (LMM) with fixed effects of animal age, and gender with the random effect of slaughter day and random error. FA data was analysed using LMM with fixed terms of animal age, animal gender and random terms including: slaughter day, machine detector side, date of analysis and random error. The above models were fitted using Genstat 14th edition [9].

III. RESULTS AND DISCUSSION

The highest levels of IMF were found in the LL (0.71± 0.06 %), followed by the BF (0.66± 0.04 %) and SM (0.62 ± 0.03 %). These levels are higher than Chilean studies, which found 25 month alpacas to have only 0.49 % IMF in the LL [5], but are lower than LL IMF values from Peru where 18 – 24 months had IMF values of 2.1 % [4]. These differences may be due to genetic and nutritional variation [6] between countries which may resulted in animals in Peru receiving a higher plane of nutrition for a longer period of time, depositing more fat through the LL muscle. Furthermore, the percentage of IMF in the LL increased with animal age as expected. Youngest animals had the smallest percentage (0.56 %) followed by 24 month (0.64 %) and the 36 month animals had the largest at 0.94 % ($P < 0.05$). These findings support previous literature stating that alpacas produce very lean carcasses and meat, which has health benefits (low fat content) and reduced wastage from trimming but also raises the question of potential side effects during processing of these lean carcasses [1].

Of the proportion of fat found within the LL muscle, a large percentage were unsaturated fatty acids (USFA; Table 1). In addition the SM muscle had a larger overall total amount of FA followed by LL, and BF (Table 1). All three muscles had a similar omega 3: 6 ratios (Table 1). The SM had a larger amount of health claimable FA (ALA, EPA, DPA, & DHA) in comparison to the BF and LL (Table 1). These differences could be attributed to differences in muscle function and fibre types [3]. Further investigation is required to determine the proportion of FA to IMF content and to determine

the effects of finishing animals under different pasture conditions to determine if and/or by how much the level and composition of fat changes in alpaca meat.

Table 1 Overall predicted means and standard errors (mean ± s.e.) for fatty acids (mg/ 100g meat) from the *m. longissimus thoracis et lumborum* (LL); *m. semimembranosus* (SM) and *m. biceps femoris* (BF) of alpacas.

Fatty acid	LL	SM	BF
C18:3n-3 (ALA)	11.51 ± 0.45	20.15 ± 1.44	17.96 ± 0.48
C20:5n-3 (EPA)	15.09 ± 4.69	24.08 ± 1.38	23.15 ± 1.77
C22:5n-3 (DPA)	6.78 ± 2.06	10.44 ± 0.52	11.32 ± 0.85
C22:6n-3 (DHA)	0.9 ± 0.22	1.34 ± 0.12	1.28 ± 1.03
EPA+DHA	15.99 ± 1.41	25.42 ± 0.43	24.43 ± 1.92
ΣPUFA	84.86 ± 1.41	145.8 ± 2.53	137 ± 9.3
ΣMUFA	164.51 ± 1.05	206.44 ± 1.1	189.43 ± 1.04
ΣUSFA	235.57 ± 1.04	365.1 ± 8.23	342.1 ± 8.87
Omega3: Omega 6	0.66 ± 0.01	0.65 ± 1.02	0.68 ± 0.01
PUFA:SFA	0.39 ± 0.01	0.52 ± 0.01	0.58 ± 0.02
ΣTotal	503.21 ± 1.04	702.75 ± 1.07	466.38 ± 1.03

[A]PUFA = polyunsaturated fatty acids, MUFA = monounsaturated fatty acids, USFA = unsaturated fatty acids, Omega 3: Omega 6 = ratio of omega 3 fatty acids to omega 6 fatty acids, PUFA: SFA = ratio of PUFA: SFA, total = sum of all FA detected in sample.

There were significant age differences detected in the LL, SM and BF muscles (Tables 2, 3, & 4). In the LL levels of health claimable FA including EPA, DPA, and DHA declined with age ($P < 0.05$; Table 2). This indicates that the proportion of healthy FA and PUFA decrease as the animal gets older and predisposes younger animals with higher PUFA content to increased lipid oxidization which can have negative aromas and affect eating quality. Hence, a balance between higher PUFA levels and low oxidization needs to be reached potentially with the addition of vitamin E to the diet to reduce the levels of oxidization [7].

Table 2 Fatty acids (predicted means ± standard errors (mean ± s.e.) with significant differences between age in the *m. longissimus thoracis et lumborum* (LL) of alpacas.

FA	18 mth	24 mth	36 mth	P - value
C20:5n-3 (EPA)	16.97 ± 4.72 ^{A}	14.31 ± 4.72 ^{B}	13.98 ± 4.72 ^{B}	0.005
C22:5n-3 (DPA)	7.33 ± 2.07 ^{A}	6.21 ± 2.07 ^{A}	6.8 ± 2.07 ^{B}	< 0.001
C22:6n-3 (DHA)	1.12 ± 0.23 ^{A}	0.68 ± 0.22 ^{B}	0.9 ± 0.22 ^{C}	0.011
ΣPUFA	4.54 ± 0.34 ^{A}	4.32 ± 0.34 ^{B}	4.46 ± 0.34 ^{A}	0.002
Omega3: Omega 6	0.67 ± 0.02 ^{AB}	0.69 ± 0.02 ^{A}	0.63 ± 0.02 ^{B}	0.02
PUFA:S FA	0.45 ± 0.02 ^{A}	0.4 ± 0.02 ^{A}	0.31 ± 0.02 ^{B}	< 0.001
ΣTotal	677.9 ± 1.05 ^{A}	442.31 ± 1.05 ^{B}	555.02 ± 1.05 ^{C}	< 0.001

*Different letters across the same row indicate statistical differences between means.
[A] PUFA = polyunsaturated fatty acids, SFA = saturated fatty acids, Omega 3: Omega 6 = ratio of omega 3 fatty acids to omega 6 fatty acids, PUFA: SFA = ratio of PUFA: SFA, total = sum of all FA detected in sample.

In addition, FA in the SM and BF including MUFA, USFA, omega 3: 6 and total FA decreased at 24 months and then increased to an equal or greater value than the 18 month animals, by 36 months of age (Table 3 and 4). The reason for this is not well understood and requires further investigation, especially as the trend occurs between both hindleg muscles.

Table 3 Fatty acids (predicted means ± standard errors (mean ± s.e.) with significant differences between age in the *m. semimembranosus* (SM) of alpacas.

FA	18 mth	24 mth	36 mth	P - value
ΣMUFA	195.78 ± 1.12 ^{A}	190.95 ± 1.11 ^{A}	235.1 ± 1.11 ^{B}	0.012
ΣUSFA	350.7 ± 14.45 ^{A}	332.2 ± 13.45 ^{A}	397.9 ± 13.69 ^{B}	0.004
Omega3: Omega 6	0.68 ± 1.03 ^{A}	0.7 ± 1.03 ^{B}	0.6 ± 1.04 ^{A}	0.004
ΣTotal	696.45 ± 1.08 ^{AB}	647.42 ± 1.08 ^{A}	768.93 ± 1.08 ^{B}	<0.001

*Different letters across the same row indicate statistical differences between means
[A]MUFA = monounsaturated fatty acids, USFA = unsaturated fatty acids, Omega 3: Omega 6 = ratio of omega 3 fatty acids to omega 6 fatty acids, total = sum of all FA detected in sample.

Table 4 Fatty acids (predicted means ± standard errors (mean ± s.e.) with significant differences between age in the *m. biceps femoris* (BF) of alpacas.

FA	18 mth	24 mth	36 mth	P - value

ΣMUFA	168.01 ± 1.07 ^{A}	171.4 ± 1.07 ^{A}	234.86 ± 1.07 ^{B}	<0.001
ΣUSFA	324.2 ± 15.5 ^{A}	316 ± 13.97 ^{A}	391 ± 14.03 ^{B}	<0.001
Omega3: Omega 6	0.7 ± 0.03 ^{A}	0.69 ± 0.02	0.5 ± 0.03 ^{B}	0.004
PUFA: SFA	0.63 ± 0.03 ^{A}	0.61 ± 0.03 ^{A}	0.5 ± 0.03 ^{B}	0.005
ΣTotal	574.21 ± 1.05 ^{A}	565.1 ± 1.04 ^{A}	699.94 ± 1.04 ^{B}	0.014

*Different letters across the same row indicate statistical differences between means

AMUFA = monounsaturated fatty acids, USFA = unsaturated fatty acids, Omega 3: Omega 6 = ratio of omega 3 fatty acids to omega 6 fatty acids, PUFA: SFA = ratio of PUFA: SFA, total = sum of all FA detected in sample.

Across the LL muscle females had higher (P < 0.05) levels of DPA (7.07 ± 2.07) and DHA (1.03 ± 0.22) than males (6.49 ± 2.07; 0.78 ± 0.22 respectively). However, males (0.69 ± 0.02) had a higher and more favorable omega 3: 6 ratio than females (0.63 ± 0.02). This trend continued into the hindleg muscles with males having higher (P < 0.05) levels in the SM (0.7 ± 1.04) and BF (0.7 ± 0.02) compared to females (0.61 ± 1.04; 0.64 ± 0.02 respectively). Males also had higher levels of health claimable ALA FA (21.15 ± 1.5) in the SM compared to females (19.14 ± 1.51). This trend was also seen in the BF muscle, but at lower levels in males (18.65 ± 0.89) and females (16.29 ± 0.89). However, females (0.61 ± 0.03) had higher PUFA: SFA ratios in the BF compared to males (0.53 ± 0.03; P < 0.05). In summation, the variability in FA changes with age and between genders and could be due to genetic differences between animals and physiological differences in muscles.

IV. CONCLUSION

Alpaca meat has low IMF values which increase with age. Younger animals have larger proportions of PUFA which decrease with animal age. Females have higher levels of DPA, and DHA in the loin, whilst males had higher and more favourable levels of omega 3: 6 ratio in the in LL, SM and BF muscles. Further investigation into the effects of high PUFA: SFA ratios need to be determined to ensure there a balance between healthy fatty acid composition and the effects of lipid oxidization is minimised. Changes in the amount of fat and FA composition also need to be determined when alpacas are fed under different production systems.

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