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Influence of slaughter weight on the proximate composition and fatty acid profile of feedlot-fattened lamb meat

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ABSTRACT. The effects of slaughter weight (28, 32, 36, and 40 kg) on muscle composition and fatty acid profile were determined in an experiment using samples of the *Longissimus dorsi* (LD) of 20 ram lamb (½ Bergamacia and ½ Corriedale). Mean weight was 12.1 ± 1.05 kg at the beginning. Lambs were fed with a mixture of 30% corn silage, 35% soybean meal, 34% oat hay, and 1% vitamins and minerals, ad libitum. Samples of *Longissimus dorsi* muscle were analyzed for their content in moisture, ash, crude protein, total lipids, and fatty acid profile. Oleic acid (18:1n-9) was in greater concentration than other fatty acids in all samples investigated. The concentration of saturated fatty acids (SFA) increased ($p < 0.05$) with an increase in slaughter weight, while monounsaturated and polyunsaturated fatty acids (PUFA) decreased. Lambs slaughtered at either 28 or 36 kg had an n-6/n-3 ratio (2.9 and 2.85, respectively) close to the recommended for humans (4.0 maximum). The overall results showed that slaughtering lamb at 28 kg resulted in the best meat quality as shown by nutritional indexes for humans (PUFA/SFA and n-6/n-3 ratios) and concentrations of crude protein (16.02%) and total lipids (13.24%).

Key words: lamb carcass, meat compositions, slaughter weight, fatty acids.

RESUMO. Influência do peso de abate sobre a composição centesimal e perfil de ácidos graxos de carnes de cordeiros terminados em confinamento. Os efeitos do peso de abate (28, 32, 36 e 40 kg) sobre a composição centesimal e perfil de ácidos graxos foram determinados em um experimento com amostras do músculo *Longissimus dorsi* (LD), de 20 cordeiros (½ Bergamácia e ½ Corriedale). Os cordeiros com peso médio inicial de 12,1 ± 1,05 kg foram alimentados com uma mistura de 30% silagem de milho, 35% farelo de soja, 34% de feno de aveia e 1% de vitaminas e minerais, *ad libitum*. As amostras de Longissimus dorsi foram submetidas as análises de umidade, cinza, proteína bruta, lipídios totais e perfil de ácidos graxos. O ácido graxo majoritário em todas as amostras foi o oleico (18:1 n-9). A concentração de ácidos graxos saturados (AGS) aumentou ($p < 0,05$) com o peso de abate, enquanto os monoinsaturados e poli-insaturados (AGPI) diminuiram. Os cordeiros abatidos com 28 e 36 kg apresentaram razão n-6/n-3 (2,9 e 2,85, respectivamente) dentro das recomendações para humanos (máximo 4,0). Os resultados globais mostram que o abate de cordeiros com 28 kg resultou em melhor qualidade da carne como demonstrado por índices nutricionais para uso humano (AGPI/AGS e razão n-6/n-3) e concentrações de proteína bruta (16,02%) e lipídios totais (13,24%).

Palavras-chave: carcaça de cordeiro, composição da carne, peso de abate, ácidos graxos.

Introduction

Efforts to increase production and carcass quality while maintaining profitability of growing lamb have led to many studies in the last few years. There is increased interest in improving carcass quality in regards with human consumption of lamb meat. Research in meat quality are related with breed, age, sex, slaughter weight, and diet (McCLINTON; CARSON, 2000; PRIOLO et al., 2002; DÍAZ et al., 2003; VERGARA et al., 2005; MARINO et al., 2008; PERLO et al., 2008). It is logical to think that a combination of two or more of these factors could improve meat quality and result in a more nutritional product from a human health point of view. In fact, the development of new feeding and fattening systems for growing lamb is often based on factors such as protein content, and fatty acid profile in muscle tissue (ROWE et al., 1999; BOZZOLO; BOUILLIER-OUDOT, 1999; MADRUGA et al., 2008; VELASCO et al., 2004).

Polyunsaturated fatty acids (PUFA) concentrations in ruminant meat are low because of biohydrogenation in the rumen (WACHIRA et al., 2002; NUERNBERG et al., 2008). However, it is known that the fattening system affects the physical composition (muscle, fat and bone) of the carcass in ruminants (RHEE et al., 2000; SANUDO et al., 2000; YEOM et al., 2002; ELMORE et al., 2005; BESSA et al., 2008).

Lamb meat production is an economic alternative that is feasible for the majority of food production areas in Brazil. The purpose of this study was to determine the chemical composition and fatty acid profile of lamb slaughtered at four different body weights (28, 32, 36 and 40 kg) and to establish the best slaughter weight in relation to fatty acid profile and economic considerations.

Material and methods

Animals and diets

Samples of *Longissimus dorsi* (LD) muscles were taken from 20 ram lamb, left half carcass, between 12th and 13th rib, from a feedlot system (diet containing approximately 30% corn silage high moisture, 35% soybean meal, 34% oats hay grass, and 1% calcareous). The diet contained 20% CP and 2.70 Mcal kg^{-1} DM base and was formulated to meet NRC standards (NRC, 1985). The lamb (½ Bergamacia x ½ Corriedale) were fed from an initial weight of approximately 12.1 kg to a slaughter weight of either 28, 32, 36 or 40 kg live weight. The samples were provided by the Arenito Research Center, State University of Maringá, Paraná State, Brazil.

Muscle composition

Moisture, ash, and crude protein contents were determined as described by Cunniff (1998). Total lipids were extracted from muscle tissues using the method of Folch et al. (1957). Meat samples (10.0000 ± 0.0001 g) were homogenized with 90 mL of a chloroform-methanol (2:1, v v^{-1}) solution for 2 min. After blending, 30 mL of chloroform and 30 mL of deionized water were added, and the mixture was homogenized. A 0.58% aqueous NaCl solution was added to the homogenate to separate the chloroform from the methanol-water phase. The lipid extract was transferred into a 250-mL flask and the solvent evaporated under a stream of N_2. The lipid content was determined gravimetrically.

Trans-esterification and fatty acid composition

Methyl esters were prepared by transmethylation according to method 5509 of ISO (1978), using KOH 2 M in methanol and *n*-heptane. Fatty acid methyl esters (FAME) were analyzed using a Shimadzu 14A (Japan) gas chromatograph equipped with a flame ionization detector and fused silica capillary column (50 m x 0.25 mm and 0.20 mm of Carbowax 20 M). The column temperature was programmed at 10°C $min.^{-1}$ from 150 to 240°C. The injection port and detector were maintained at 220 and 245°C, respectively. The carrier gas was H_2 (1.2 mL $min.^{-1}$) and the makeup gas was N_2 (30 mL $min.^{-1}$). The split was 1/100. Identification of fatty acids was made by comparing the relative retention times of FAME peaks from samples with standards from Sigma (St. Louis, MO, USA).

Statistical analyses

Analyses were made in triplicate and the results were expressed as mean values ± standard deviations. Muscle composition, and fatty acid profile were compared using one-way analysis of variance (ANOVA). Data were processed using the Statistica 5.1 Software (STATSOFT, 1996) according to a randomized design. Significance was declared ($p < 0.05$) unless noted otherwise.

Results and discussion

Data on the moisture, ash, crude protein, and total lipids of the *Longissimus dorsi* muscle are presented in Table 1. Moisture, ash, and crude protein concentrations in the LD were lower for lamb slaughtered at 40 kg than for those slaughtered at 28, 32, and 36 kg. The only exception was ash content it did not differ for lamb slaughtered at 40 and those slaughtered at 36 kg. Lamb with the highest amount of fat had the lowest moisture content as previously reported by Rowe et al. (1999).

Table 1. Influence of slaughter weight on chemical composition of *Longissimus dorsi* muscle in lamb fattened in feedlot.

	Slaughter Weight (kg)			
Parameters	28	32	36	40
Moisture (%)	69.42 ± 4.34[a]	71.58 ± 2.65	67.97 ± 4.08[a]	59.09 ± 0.84[b]
Ash (%)	0.90 ± 1.65[a]	0.87 ± 0.05[a]	0.82 ± 0.04[a,b]	0.75 ± 0.05[b]
Crude Protein (%)	16.02 ± 0.25[a]	16.65 ± 0.73[a]	16.42 ± 0.24[a]	14.55 ± 0.84[b]
Total Lipids (%)	13.24 ± 0.34[b]	10.55 ± 0.43[c]	14.30 ± 1.91[b]	25.28 ± 1.86[a]

All results are means ± standard deviation of five samples in triplicates. Means in the same row followed by different letters are significantly different ($p < 0.05$) by Tukey test.

Mean values of fatty acids (Table 2) are presented as the percentage of the total fatty acid methyl esters. Palmitic (16:0) and stearic (18:0) acids were greater in the LD of lamb slaughtered at 28 and 40 kg compared to those slaughtered at 32 and 36 kg. Oleic acid (18:1 n-9) comprised the greatest proportion of monounsaturated fatty acids in the LD as previously reported by others researchers (SOTA et al., 1995; SANTOS-SILVA et al., 2002; DÍAZ et al., 2003) for growing lamb. Concentrations of both oleic acid (18:1 n-9) and linolenic (18:2 n-6) were greater in the muscle of lamb slaughtered at 28 kg compared to those slaughtered at heavier weights, except that there was no difference between lamb slaughtered at 28 and 36 kg for linolenic acid concentration.

Table 2. Profile of fatty acids in the *Longissumus dorsi* muscle of lamb slaughtered at four different weights.

Fatty Acids	Slaughter Weight (kg)			
(% of Total)	28	32	36	40
12:0	0.27 ± 0.03^{a}	0.31 ± 0.03^{a}	0.20 ± 0.01^{b}	0.15 ± 0.02^{c}
13:0	0.29 ± 0.04^{a}	0.35 ± 0.02^{a}	0.18 ± 0.02^{b}	0.10 ± 0.01^{c}
14:0	1.43 ± 0.17	1.53 ± 0.05	1.28 ± 0.11	1.42 ± 0.17
14:1 n-5	0.27 ± 0.04^{b}	0.37 ± 0.04^{a}	0.21 ± 0.01^{b}	0.15 ± 0.02^{c}
15:0	0.29 ± 0.05	0.33 ± 0.02	0.32 ± 0.03	0.34 ± 0.05
15:1 n-10	0.30 ± 0.02^{b}	0.39 ± 0.05^{a}	0.29 ± 0.04^{b}	0.16 ± 0.03^{c}
16:0	20.82 ± 0.07^{a}	17.85 ± 0.14^{b}	17.83 ± 0.23^{b}	20.58 ± 0.08^{a}
16:1 n-7	0.72 ± 0.08^{b}	0.76 ± 0.07^{a,b}	0.59 ± 0.03^{c}	0.79 ± 0.04^{a}
17:0	1.45 ± 0.02^{a}	1.36 ± 0.11^{a}	1.02 ± 0.12^{b}	0.88 ± 0.07^{c}
17:1 n-7	0.41 ± 0.05	0.31 ± 0.05	0.38 ± 0.05	0.32 ± 0.04
18:0	15.57 ± 0.31^{d}	21.23 ± 0.23^{c}	30.01 ± 0.31^{a}	24.76 ± 0.14^{b}
18:1 n-9	37.47 ± 0.47^{a}	35.57 ± 0.49^{b}	34.57 ± 0.11^{c}	35.88 ± 0.94^{b}
18:1 n-7	0.59 ± 0.05^{a}	0.56 ± 0.05^{a}	0.37 ± 0.04^{b}	0.21 ± 0.01^{c}
18:2 n-6	2.52 ± 0.29^{a}	2.19 ± 0.04^{b}	2.42 ± 0.22^{a}	1.84 ± 0.12^{c}
18:3 n-6	0.67 ± 0.08^{a}	0.45 ± 0.05^{b}	0.30 ± 0.03^{b}	0.41 ± 0.03^{b}
18:3 n-3	0.55 ± 0.07^{a}	0.49 ± 0.03^{a}	0.42 ± 0.06^{b}	0.53 ± 0.08^{a}
18:4 n-3	0.51 ± 0.04^{a}	0.50 ± 0.03^{a}	0.24 ± 0.03^{b}	0.48 ± 0.04^{a}
20:0	1.44 ± 0.08^{b}	2.11 ± 0.20^{a}	1.28 ± 0.17^{b}	1.20 ± 0.03^{b}
20:1 n-9	0.82 ± 0.07^{b}	1.34 ± 0.14^{a}	0.61 ± 0.09^{c}	0.50 ± 0.03^{c}
20:1 n-15	1.31 ± 0.16^{a}	0.69 ± 0.07^{c}	0.81 ± 0.07^{b}	0.65 ± 0.08^{c}
20:2 n-6	3.23 ± 0.38^{a}	2.43 ± 0.08^{b}	0.74 ± 0.08^{d}	1.11 ± 0.13^{c}
20:3 n-6	2.34 ± 0.27^{a}	2.05 ± 0.03^{a}	0.79 ± 0.07^{b}	0.83 ± 0.05^{b}
20:3 n-3	1.03 ± 0.12^{a}	0.55 ± 0.06^{c}	0.75 ± 0.09^{b}	1.08 ± 0.14^{a}
20:4 n-6	0.53 ± 0.03^{b}	1.27 ± 0.07^{a}	0.54 ± 0.04^{b}	0.56 ± 0.02^{b}
20:5 n-3	1.38 ± 0.16^{b}	0.65 ± 0.09^{c}	0.75 ± 0.07^{c}	2.12 ± 0.12^{a}
22:0	1.05 ± 0.18^{b}	0.94 ± 0.07^{b}	0.87 ± 0.09^{c}	1.20 ± 0.16^{a}
22:1 n-9	1.45 ± 0.19^{a}	1.43 ± 0.09^{a}	0.55 ± 0.08	0.28 ± 0.02^{c}
22:2 n-6	0.78 ± 0.06^{b}	1.20 ± 0.17^{a}	1.36 ± 0.16^{a}	0.80 ± 0.07^{a,b}
23:0	0.51 ± 0.08^{b}	0.79 ± 0.09^{a}	0.28 ± 0.04^{c}	0.67 ± 0.05^{a,b}
SFA[1]	43.12 ± 0.43^{d}	46.80 ± 0.37^{c}	53.27 ± 0.46^{a}	51.30 ± 0.30^{b}
MUFA[1]	43.34 ± 0.55^{a}	41.42 ± 0.54^{b}	38.38 ± 0.20^{c}	38.94 ± 0.95^{c}
PUFA[1]	13.54 ± 0.60^{a}	11.78 ± 0.24^{b}	8.35 ± 0.33^{d}	9.76 ± 0.29^{c}
n-3[1]	3.47 ± 0.22^{b}	2.19 ± 0.12^{c}	2.16 ± 0.13^{c}	4.21 ± 0.21^{a}
n-6[1]	10.07 ± 0.56^{a}	9.59 ± 0.21^{a}	6.15 ± 0.30^{b}	5.55 ± 0.20^{c}
PUFA/SFA[1]	0.31 ± 0.02^{a}	0.25 ± 0.01^{b}	0.16 ± 0.01^{d}	0.19 ± 0.01^{c}
n-6/n-3[1]	2.90 ± 0.45^{b}	4.38± 0.72^{a}	2.85 ± 0.54^{b}	1.32 ± 0.18^{c}

All resuls re means ± standard deviation of five samples in triplicates. Means in the same row followed by different letters differ ($p < 0.05$) by Tukey test. [1]Saturated fatty acids (SFA); monounsaturated fatty acids (MUFA); polyunsaturated fatty acids (PUFA); omega-3 fatty acids (n-3); omega-6 fatty acids (n-6).

Saturated fatty acids concentration increased with an increase in slaughter weight while monounsaturated and polyunsaturated fatty acids decreased (Table 2). The greatest concentration of polyunsaturated fatty acids was obtained with lamb slaughtered at 28 kg. Enser et al. (1996) found higher concentrations of polyunsaturated fatty acids in swine (19.86%) than in ruminants such as ovine and bovine, which averaged 5.88 and 4.86%, respectively.

Lamb slaughtered at 28 kg had the largest PUFA/SFA ratio (0.31), which is close to the value of 0.45 recommended by the HMSO (1994); a decrease in the PUFA/SFA ratio indicates less healthy foods, which are linked to a greater incidence of cardiovascular diseases (MARINO et al., 2008; GARCIA et al., 2008). The maximum n-6/n-3 ratio recommended by the HMSO (1994) is 4.0, which is close to the ratio obtained in the muscle of lamb slaughtered at either 28 or 36 kg (ratio of 2.9 and 2.85, respectively). Enser et al. (1996) compared the fatty acid profile in bovine, ovine and swine, and they found that the n-6 to n-3 ratio was lower in the muscle of ruminant (bovine, 2.1 and ovine, 1.3) than in that of non ruminant (swine, 7.2).

Conclusion

In conclusion, the overall results showed that slaughtering of lamb at 28 kg resulted in the best meat quality as shown by nutritional indexes for human (PUFA/SFA and n-6/n-3 ratios) and concentrations of crude protein (16.02%) and total lipids (13.24%).

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