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Meat and carcass quality from Peruvian llama (*Lama glama*) and alpaca (*Lama pacos*)

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Abstract

An experiment based on 20 llama males and 40 alpaca males reared in Peru has been carried out with the aim to evaluate the live growth performances, carcass quality, the nutritional characteristics of meat from animals slaughtered at 25 months of age, and to determine the physical and chemical parameters of meat obtained from these animals. The live body weights registered during the 25 months of the experiment were significantly lower in alpaca compared with llama. In llama carcasses were significantly higher both warm and cold carcass weight ($P<0.001$) but dressing percentage was higher in alpacas ($P<0.01$). The glycolityc fine-course was very similar both in llama and in alpaca muscle *Longissimus Thoracis et Lumborum*. Chemical composition of muscle *Longissimus Thoracis et Lumborum* taken from llama and alpaca carcasses was significantly different ($P<0.01$) in ash content; cholesterol content was significantly higher ($P<0.001$) in llama meat compared with alpaca.

Keywords: Llama; Alpaca; Meat quality; Carcass quality

1. Introduction

The increase in meat production from llama and alpaca and the improvement of their breeding systems represent the best strategy to avoid the poverty in the south americans populations living in the mountains of the Andean countries (Wheeler, 1993). In 1991, the total Andean alpaca population was estimated to be 2,811,612 animals, while the total llama population was estimated to be 3,227,412 (Wheeler, 1991). Beside this humanitarian purpose, alpaca and especially llama meat are actually required by an important part of the consumers coming from the richest countries, considering the nutritional value of these meats, due to their reduced fat and cholesterol contents (Kiesling, 1995), and also because llama and alpaca meat is an important source of protein for the Andean population (Pérez et al., 2000).

The breeding systems of south american camelids are absolutely not specialized, and for this reason we can find low reproductive efficiency, high mortality rate and consequently a reduced meat production in all the farms of the Andean countries in whichs llama and alpaca are reared (Flores Ochoa, 1982).

The present study has been carried out with the aim to evaluate the suitability of domestic south american camelids reared in Peru for meat production, trying to estabilish the nutritional characteristics of meat from llama and alpaca males slaughtered at the same age, and to determine the physical and chemical parameters of meat obtained from these animals.

2. Material and methods

The study was performed in Peru, in the experimental station of Arequipa, located at 4650 m above sea level in the district of Toccra, using 20 llama males and 40 alpaca males. Animals were reared in extensive conditions on pasture characterized by the following

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grassland varieties typical of the Andean highlands: *Lilaleopsis andina, Junnellia spp., Alchemilla diplophylla, Calamagrotis spp., Festuca orthophylla*.

Live body weight was registered at the birth of the animals, and then at the age of 6, 10, 13, 16, 19, 22 and 25 months.

All the animals were slaughtered at 25 months of age in a beef slaughter house, using the same methodologies applied in south America for beef cattle. The final body weight was registered directly in the slaughter house after 24 h food deprivation; the warm carcass weight was monitored 1 h after slaughtering, while the final carcass weight (cold carcass weight) was obtained 24 h later. The carcass dressing percentage was registered 1 h post mortem (warm dressing percentage) and also 24 h after slaughtering (cold dressing percentage), in all the carcasses obtained in this experiment. To determine the dressing percentage from each carcass we eliminated skin and coat, head (cut at the occipital-atlantoidal articulation), neck (cut at the last cervical and at the first thoracic articulation) and feet (cut at tarsal-metatarsal and carpal-metacarpal articulations), liver, heart, spleen, lungs, kidneys, trachea and all the digestive tracts.

After 24 h storage, the following measurements were made on all the carcasses: external length (from the base of the tail to the base of the neck), length of the hind leg (in the right side) and length of the front leg (in the right side). The front leg was separated from the thorax through the muscular insertion, and the hind leg was cut at the lumbo-sacral articulation, according to the cutting procedure previously described by Pérez et al. (2000).

Post mortem glycolysis was monitored by measuring the pH values at 1, 6, 12, 24, 48 and 72 h after slaughtering inserting a pH-meter probe (Portamess Knick mod. 910) into the muscle *Longissimus Thoracis et Lumborum* (LTL) 2.5 cm below the dorsal surface adjacent to the thirteenth vertebra (Polidori, Lee, Kauffman, & Marsh, 1999).

Samples weighing approximately 350 g were removed from LTL at the 8th rib, both from llama and alpaca carcasses, and water holding capacity was determined on this muscle at 1, 6, 12, 24, 48 and 72 h after slaughtering, according to the procedure described by Warner, Kauffman and Greaser (1997).

Chemical composition and cholesterol content of muscle LTL taken from llama and alpaca carcasses were determined using the methods described by Babiker, El Khidir, and Shafie (1990).

Data were analysed by the method of least squares using the general linear model procedures of the SAS (2001) and results were expressed as least square means.

3. Results

The live body weights registered throughout the trial (Table 1) were significantly lower in alpaca compared with llama; the difference between the two types of camelids was statistically significant at the birth of the animals ($P < 0.01$), and then from the sixth month of age to slaughter the difference became more significant ($P < 0.001$). The results of the final body weights obtained in this experiment for the llama males were much lower compared with the final body weights obtained using young and adult llama males in the study conducted in Chile by Pérez et al. (2000). This is probably due to a genetic difference in the kind of llamas reared in Chile and in Peru.

Warm and cold carcass weight were significantly ($P < 0.001$) higher in llama carcasses compared with alpaca carcasses; both the warm and the cold dressing percentage were significantly ($P < 0.01$) higher in alpaca than in llama carcasses. (Table 2). The length of the carcass was significantly ($P < 0.001$) bigger in llama than in alpaca (Table 2). The hind legs obtained from llama were significantly ($P < 0.01$) longer compared with the hind legs taken from alpaca. Similarly, the length of the front legs obtained from llama were significantly ($P < 0.001$) longer than alpaca front legs.

The results of pH measurements obtained at 1, 6, 12, 24, 48 and 72 h after slaughtering for the selected muscle are shown in Table 3. The pH values obtained in this experiment clearly indicate that the glycolytic process normally ends 24 h after slaughtering, both in llama and in alpaca muscles. No significant differences were found

Table 1
Live body weights (kg) at different ages (mean ± standard error)

Age (months)	Alpaca (n = 40)	Llama (n = 20)
Birth	5.99 ± 0.94[a]	7.15 ± 1.37b
6	20.19 ± 0.94a	28.13 ± 1.37c
10	27.99 ± 0.94a	36.78 ± 1.37c
13	37.19 ± 1.02a	46.93 ± 1.47c
16	40.35 ± 1.12a	55.77 ± 1.67c
19	41.05 ± 1.29a	56.29 ± 1.80c
22	42.87 ± 1.58a	59.43 ± 2.09c
25	46.07 ± 2.23a	63.18 ± 2.92c

[a] Different letters in the same row indicate significant difference (b: $P < 0.01$, c: $P < 0.001$).

Table 2
Carcass characteristics of alpaca and llama (mean ± standard error)

	Alpaca (n = 40)	Llama (n = 20)
Warm carcass weight (kg)	24.42 ± 1.53[a]	31.16 ± 1.93C
Cold carcass weight (kg)	23.28 ± 1.51a	29.96 ± 1.92C
Warm dressing (%)	55.69 ± 0.84a	52.37 ± 1.06b
Cold dressing (%)	53.23 ± 0.93a	50.53 ± 1.18b
Carcass length (cm)	71.15 ± 1.87a	130.37 ± 2.69C
Length of hind leg (cm)	66.93 ± 3.05a	74.61 ± 3.86C
Length of front leg (cm)	60.45 ± 1.55a	67.70 ± 1.96C

[a] Different letters in the same row indicate significant difference (b: $P < 0.01$, c: $P < 0.001$).

during the first 72 h after slaughtering in pH values determined in alpaca LTL compared with the same muscle taken from llama carcasses.

Chemical composition of muscle LTL taken from llama and alpaca carcasses is shown in Table 4. The difference between fat and protein contents in llama and alpaca muscle is not statistically significant, while ash content was significantly ($P<0.05$) higher in llama LTL compared with alpaca LTL. The most important result obtained considering meat chemical composition was the very low value of fat content, both in llama and in alpaca muscle, while protein content was similar to that one normally obtained in many other species of meat animals (Lawrie, 1985).

Cholesterol content was significantly higher ($P<0.001$) in llama meat compared with alpaca (Table 4); however, cholesterol contents determined both in llama and alpaca meat are lower than the values nomally determined in meat obtained from other species, such as beef, pork, mutton (Lawrie, 1985); the low lipidic fraction in meat obtained from south american camelids is very similar to the values determined in venison obtained from farmed red deer stags (Stevenson, Seman, & Littlejohn, 1992).

The values obtained for water holding capacity demonstrated a significant ($P<0.01$) difference between meat obtained from llama and alpaca at 48 and 72 h after slaughtering (Table 5), while during the first 24 h after the death of the animals the values were not significantly different. The gradual increase in water holding capacity obtained from alpaca meat during post mortem period, when pH value is declining, has been previously determined also in veal meat (Den Hertog-Meiscke, Klont, Smulders, & Van Logtestijn, 1997); in that case, the authors affirmed that the effects of the rate of pH decline on muscle protein denaturation and hence on water holding capacity were negligible. There are in fact many determinants of water holding capacity (Den Hertog-Meiscke, Van Laack, & Smulders, 1997): physiological factors (rate of post mortem pH fall, species, breed, muscle type), rearing conditions, slaughter method, etc.

Table 3
pH values for *Longissimus Thoracis Lumborum* muscle (mean ± standard error)

Time post mortem (h)	Alpaca ($n=40$)	Llama ($n=20$)
1	6.86±0.04a	6.85±0.05a
6	6.64±0.03a	6.62±0.03a
12	6.04±0.02a	6.06±0.02a
24	5.57±0.02a	5.60±0.01a
48	5.56±0.01a	5.57±0.01a
72	5.56±0.01a	5.55±0.01a

For each trait, same letters in the same row indicate no signicant difference.

Table 4
Chemical characteristics of *Longissimus Thoracis Lumborum* muscle (mean ± standard error)

	Alpaca ($n=40$)	Llama ($n=20$)
Moisture (%)	73.64±1.66[a]	73.94±1.87a
Fat (%)	0.49±0.01a	0.51±0.01a
Protein (%)	23.33±0.69a	23.12±0.88a
Ashes (%)	2.54±0.20a	2.43±0.25b
Cholesterol (mg/100 g)	51.14±2.01a	56.29±2.89C

[a] Different letters in the same row indicate significant difference (b: $P<0.01$, C: $P<0.001$).

4. Discussion

Carcasses obtained from llama were significantly bigger compared with those obtained from alpaca, therefore in the retailed cuts (hind legs, loin, etc.) it will be easier to produce a good amount of high quality meat from llama carcasses rather than from alpaca carcasses.

Chemical composition was similar in llama and in alpaca LTL muscle, except for the ash content: it will be very interesting to deepen in the future the knowledge about micro and macro elements contained in muscles coming from both the animals above mentioned, considering the accepted nutrient role of certain minerals (Lawrie, 1985).

The ultimate pH value is the result of pre-slaughter handling, post mortem treatments, and muscle physiology (Marsh, 1977; Thompson, 2002). The relation between fresh meat tenderness and ultimate pH value has been frequently debated (Purchas, 1990; Watanabe, Daly, & Devine, 1996); in beef and lamb meat, there is a curvilinear relationship between ultimate pH and tenderness, meat is more tender at the extremes (pH 5.4 and 7.4) of the range and less tender in the middle (pH 5.8–6.2) of the range (Dransfield, 1994). Both in llama and alpaca meat, the ultimate pH measured at 24 h after slaughtering is in the range 5.57–5.60; this range can be considered the usual one for most meat animals (Greaser, 1986).

Water holding capacity (WHC) is important for both consumers and processors; from the consumers' point of

Table 5
Water holding capacity (WHC) of *Longissimus Thoracis Lumborum* muscle (mean ± standard error)

Time post mortem (h)	Alpaca ($n=40$)	Llama ($n=20$)
1	49.09±2.08[a]	50.53±2.14a
6	49.18±2.01a	48.61±2.11a
12	49.30±2.51a	49.78±3.08a
24	51.17±3.01a	50.68±2.74a
48	52.80±2.77a	49.60±2.61b
72	53.76±4.11a	49.78±2.23b

[a] Different letters in the same row indicate significant difference (b: $P<0.01$).

view, WHC influences many quality traits such as nutritional value, appearance and palatability (Kauffman, Joo, & Schultz, 1994). For the processing industry, WHC greatly impacts the economic value of weight for fresh meat products and the yield in processed products: the more water remains in meat, the heavier weight of the meat, the better. Considering the possibility of using from llama and alpaca both fresh meat or processed meat (i.e. *charqui*), the values obtained in this experiment clearly demonstrated that WHC in llama and alpaca meat is not very high, compared with other species (Offer & Knight, 1988), creating in this way the right conditions for an easy transformation process to obtain a "dry" derived product much as the *charqui*, traditionally made in the Andean regions using both llama and/or alpaca meat (Bollati, Melo, Bulaschevich, & Boetto, 1994). Probably the WHC from llama and alpaca muscles could be greatly modified in the future, using appropriate feeding techniques to improve meat quality, especially in llama meat production.

5. Conclusions

Considering all the results obtained in the present experiment, we can affirm that llama could be better suited for meat production in the Andean countries than alpaca; the letter must be considered firstly an animal for fibre production, and only the discarded animals from this population can be easily used for meat production, as recently confirmed also in some european experiences in which these animals have been tested (Trabalza Marinucci, Reali, Haouet, & Olivieri, 1995). Moreover, the genetic selection necessary to improve fibre production in these animals is totally different from that one necessary to improve meat production (Frank, 1995; Lauvergne, 1993; Renieri, 1993). Therefore, considering the situation for people actually living in the Andean mountains regions, we can conclude that production of llama meat could represent a good opportunity to increase the income of local farmers, as indicated also in the results obtained by Delgado Santivañez, Valle Zaráte, and Mamani (2001), while alpaca must be still bred as a fibre animal rather than a meat animal, especially considering the high added value obtained in the richest countries by the alpaca natural fibre (Vinella, 1993).

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References

Babiker, S. A., El Khidir, I. A., & Shafie, S. A. (1990). Chemical composition and quality attributes of goat meat and lamb. *Meat Science*, *28*, 273–277.

Bollati, G. P., Melo, O. E., Bulaschevich, M. C., & Boetto, G. C. (1994). Low quality allowance supplementation in domestic South American camelids. In E. N. Frank, & C. Renieri (Eds.), *Actas primer seminario internacional de camelidos sudamericanos domesticos, 29 June–1 July 1994* (pp. 23–41). Argentina: Cordoba.

Delgado Santivańez, J., Valle Zaráte, A., & Mamani, C. (2001). Fibre quality of a Bolivian meat-oriented llama population. In M. Gerken, & C. Renieri (Eds.), *Progress in South American camelids research* (pp. 101–109). Wageningen: EAAP Publication No. 105.

Dransfield, E. (1994). Optimisation of tenderisation, ageing and tenderness. *Meat Science*, *36*, 105–121.

Den Hertog-Meischke, M. J. A., Van Laack, R. L. J. M., & Smulders, F. J. M. (1997). The water-holding capacity of fresh meat—a literature review. In M. J. A. Den Hertog-Meischke (Ed.), *The water-holding capacity of fresh meat* (pp. 13–35). The Netherlands: ADDIX, Wijk bij Duurstede.

Den Hertog-Meischke, M. J. A., Klont, R. E., Smulders, F. J. M., & Van Logtestijn, J. G. (1997). Variation in rate of glycolysis does not result in variation in water-holding capacity of moderately chilled, non stimulated veal Longissimus muscle. In M. J. A. Den Hertog-Meischke (Ed.), *The water-holding capacity of fresh meat* (pp. 39–47). The Netherlands: ADDIX, Wijk bij Duurstede.

Flores Ochoa, J. A. (1982). Causas que originaron la actual distribuciòn espacial de las Alpacas y Lamas. In L. Miliones, & H. Tomoedea (Eds.), *El hombre y su ambiente en los Andes centrales Vol. 10* (pp. 63–92). Ethological Studies: Osaka.

Frank, E. N. (1995). Genetic improvement of fibre production in South American domestic camelids. An approach for the Argentina population. In *Proceedings 2nd European Symposium on South American Camelids*, 30 August–2 Septmber, (pp. 15–37). Camerino, Italy.

Greaser, M. L. (1986). Conversion of muscle to meat. In P. J. Bechtel (Ed.), *Muscle as food* (pp. 37–102). New York: Academic Press.

Kauffman, R.G., Joo, S.T., & Schultz, C. (1994). Measuring water-holding capacity in post-rigor muscle. In *Proceedings 47th reciprocal meat conference* (pp. 70–72). Chicago, IL.

Kiesling, C. (1995). Weight estimates for llamas based on body dimension. In *Proceedings 2nd European symposium on South American camelids*, 30 August–2 Septmber 1995 (pp. 71-76) Camerino, Italy.

Lauvergne, J. J. (1993). Characterization of genetic resources of American camelids. In *Proceedings 1st European symposium on South American camelids*, 30 September–1 October 1993, (pp. 59–65) Bonn, Germany.

Lawrie, R. A. (1985). *Meat science* (4th ed). Oxford, New York, Toronto, Sydney, Paris, Frankfurt: Pergamon Press.

Marsh, B. B. (1977). The basis of tenderness in muscle foods. *Journal of Food Science*, *42*, 295–297.

Offer, G., & Knight, P. (1988). The structural basis of water-holding in meat. In R. A. Lawrie (Ed.), *Developments in meat science Vol. 4* (pp. 173–243). London: Elsevier Applied Science.

Pérez, P., Maino, M., Guzmàn, R., Vaquero, A., Körich, C., & Pokniak, J. (2000). Carcass characteristics of llamas (*Lama glama*) reared in Central Chile. *Small Ruminant Research*, *37*, 93–97.

Polidori, P., Lee, S., Kauffman, R. G., & Marsh, B. B. (1999). Low voltage electrical stimulation of lamb carcasses: effects on meat quality. *Meat Science*, *53*, 179–182.

Purchas, R. W. (1990). An assessment of the role of pH differences in determining the relative tenderness of meat from bulls and steers. *Meat Science*, *27*, 129–140.

Renieri, C. (1993). The genetic basis of pigmentation in South American camelids. In Proceedings 1st European symposium on South American camelids, 30 September–1 October (pp. 31–41). Bonn, Germany.

SAS. (2001). *SAS/STAT guide for personal computers, version* (8.1 ed.). Cary, NC: SAS Institute Inc.

Stevenson, J. M., Seman, D. L., & Littlejohn, R. P. (1992). Seasonal variation in venison quality of mature, farmed red deer stags in New Zealand. *Journal of Animal Science*, *70*, 1389–1396.

Thompson, J. (2002). Managing meat tenderness. *Meat Science*, *62*, 295–308.

Trabalza Marinucci, M., Reali, C., Haouet, N., & Olivieri, O. (1995). South American camelids breeding in Italy: a review. In *Proceedings 2nd European symposium on South American camelids*, 30 August–2 September, (pp. 215-224). Camerino, Italy.

Vinella, S. (1993). The european market for South American camelids wood. In *Proceedings 1st European symposium on South American camelids*, 30 Septmber–1 October (pp. 155–166). Bonn, Germany.

Warner, R. D., Kauffman, R. G., & Greaser, M. L. (1997). Muscle protein changes post mortem in relation to pork quality traits. *Meat Science*, *45*, 339–352.

Watanabe, A., Daly, C. C., & Devine, C. E. (1996). The effects of ultimate pH of meat on tenderness changes during ageing. *Meat Science*, *42*, 67–78.

Wheeler, J. (1991). Origèn, evoluciòn y status actual. In S. Fernandez-Baca (Ed.), *Avances y perspectivas del conocimiento de los camélidos sudamericanos* (pp. 11–48). Santiago: F.A.O.

Wheeler, J. (1993). South american camelids: past, present and future. In *Proceedings 1st European symposium on South American camelids*, 30 September–1 October (pp. 13–28). Bonn, Germany.