Meat Science 82 (2009) 469–471

Contents lists available at ScienceDirect

Meat Science

journal homepage: www.elsevier.com/locate/meatsci

Physical and chemical characteristics of donkey meat from Martina Franca breed

P. Polidori [a,*], C. Cavallucci [a], D. Beghelli [a], S. Vincenzetti [b]

[a] Dipartimento di Scienze Ambientali, Università di Camerino, Via Circonvallazione 93, 62024 Matelica (MC), Italy
[b] Dipartimento di Scienze Morfologiche e Biochimiche Comparate, Via Gentile III da Varano, 62032 Camerino (MC), Italy

ARTICLE INFO

Article history:
Received 4 December 2008
Received in revised form 11 March 2009
Accepted 12 March 2009

Keywords:
Donkey
Meat colour
Fatty acids
Amino acids

ABSTRACT

The rheological and chemical characteristics of meat obtained from 12 Martina Franca donkey males, slaughtered at 14 months of age and a mean final body weight of 169 kg were determined. Meat samples were taken four days *post mortem* from muscles *Longissimus thoracis et lumborum* and *Biceps femoris*, colorimetric parameters were measured to determine L^* (lightness), a^* (redness), b^* (yellowness) and chroma. The *Longissimus* was significantly lighter ($P < 0.05$) compared to the *Biceps femoris*, with L^* indexes of 35.86 and 31.34, respectively. Fatty acid composition of the intramuscular fat showed a high content of polyunsaturated fatty acids (PUFAs) in both muscles, respectively 25.16 g/100 g total fatty acids in the *Longissimus* and 24.97 g/100 g total fatty acids in the *Biceps femoris*; oleic acid and palmitic acid were the two most abundant fatty acids in both muscles. The percentages of essential amino acids were higher in both muscles compared with the total amino acid content, respectively 52.88% in the *Longissimus*, and 51.26% in the *Biceps femoris*. The high level of unsaturation of the intramuscular fat resulted in a high ratio of unsaturated to saturated fat, and the total amount of essential amino acids, exceeding 50% of the total amino acids showed that donkey meat from a health point of view is a good alternative to traditional red meats.

© 2009 Elsevier Ltd. All rights reserved.

1. Introduction

Donkey (*Equus asinus, Perissodactyla*) is a domestic animal belonging to the equine family, which includes horses, zebras and mules (Wilson, 1990). Donkey has been domesticated for thousands of years (Aganga, Aganga, Thema, & Obocheleng, 2003), and has contributed to the development of various civilizations. Even today, in some countries such as Egypt, Nigeria, Mali, Niger and Sudan donkeys are more common than horses (Payne & Wilson, 1999). In these countries, and in other parts of the world, like the Middle East and/or Asia, donkeys are still an important means of transport (Aganga, Tsopito, & Seabo, 1994; Smith & Pearson, 2005).

In the second half of the last century, the donkey population dramatically decreased in Europe, which can mainly be attributed to the substitution of work animals by machinery (Cardellino, 2006). However at the beginning of the 21st century, the number of donkeys in the south of Europe is increasing (Giosuè, Alabiso, Russo, Alicata, & Torrisi, 2008), because of the great interest in donkey's milk, whose composition resembles that of human milk more than bovine and/or goats milk (Piccione, Fazio, Caola, & Refinetti, 2008; Vincenzetti, Polidori, & Vita, 2008). Not all male donkeys reared on farms can be used for breeding, but meat from young males is an easy way to obtain a cheap meat with good nutritional characteristics, as demonstrated by Polidori, Vincenzetti, Cavallucci, and Beghelli (2008). Donkey meat obtained from old animals is considered unacceptably tough, and is mostly destined to be transformed into salami or other salted horse meat-based products (Paleari, Moretti, Beretta, Mentasti, & Bersani, 2003).

In the south of Italy, donkeys of the Martina Franca breed are very popular. This breed is well known as a tall animal, strong, frugal and patient, with the females able to produce milk during a 6–8 months lactating period (Balasini, 2000). In the Apulia region, from where the Martina Franca breed originates, the consumption of both horse and donkey meats is traditional, but most of the quality parameters of donkey meat have not been investigated.

The objectives of the present study were to determine the physical (colour) and chemical (fatty acids composition and amino acids content) characteristics of two different muscles, *Longissimus thoracis et lumborum* and *Biceps femoris*, taken from 12 young male donkeys belonging to the Martina Franca breed.

2. Materials and methods

2.1. Sample collection

The study was performed using 12 entire donkey males of the Martina Franca breed, slaughtered at 14 months of age with a mean fasted final body weight of 169 ± 13 kg. Animals were reared on the same farm and were fed the same diet, then were slaughtered on different days according to their birth date. The animals

* Corresponding author. Tel.: +39 0737 403426; fax: +39 0737 403402.
E-mail address: paolo.polidori@unicam.it (P. Polidori).

0309-1740/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.meatsci.2009.03.001

were fasted (only water was available) for about 18 h before slaughter; transport of the donkeys to the slaughter house took about 60 min. All the carcasses were skinned and eviscerated, then stored in a cold room at about 1 °C, suspended by their hind legs; the size of the cold room was about 15 m^2, the air velocity was 1 m/s, the distance between each carcass was about 70 cm. Carcasses were chilled for four days, then from the left side of the carcasses approximately 400 g of muscle sample was taken from *Longissimus thoracis et lumborum* (LTL), between the 12th and the 13th rib, and from the *Biceps femoris* (BF). Each sample was placed in labeled bags and put on ice in a cooler for transport to the laboratory, where each sample was divided into two parts, one was used immediately for colorimetric determination, and the other half was repackaged in labeled vacuum-packaged bags and stored at −20 °C until further analysis.

2.2. Chemical and physical analysis

Fatty acid composition was determined for all the samples. Total lipids were extracted from the meat as described by Bligh and Dyer (1959); for the preparation of fatty acid methyl esters the lipid sample (20 mg) was dissolved in 0.1 ml of tetrahydrofuran in a test tube and 10% methanolic hydrogen chloride (2 ml) was added (Sukhija & Palmquist, 1988). The sample was sealed and heated at 100 °C for 1 h. To each sample 2 ml of 1 M potassium carbonate solution was added. The fatty acids methyl esters were extracted with 2 × 2 ml of hexane and 1 μl was injected into a gas-chromatograph. Fatty acid analysis was performed on a Chrompack (model CP 9003) gas-chromatograph with a flame ionization detector and a fused-silica capillary column, film thickness 0.2 μm, packed with CP Sil 88 (50 m × 0.25 mm i.d.). Helium was used as the carrier gas and the column temperature was held at 80 °C for 4 min, and then increased at 10 °C/min from 80 °C to 140 °C, then at 5 °C/min from 140 °C to a final temperature of 210 °C (held for 14 min). Fatty acid identification was made by comparing gas chromatographic retention times with the anti-oxidant standard butylated hydroxytoluene (BHT).

The colorimetric parameters were measured using a Minolta CR-10 colorimeter (Minolta Camera Co., Osaka, Japan), with the Hunter-Lab method, repeating the measurements three times, turning the samples three times by 90°, and repeating the procedure in three different places, to determine L^* (lightness), a^* (redness) and b^* (yellowness). The instrument was calibrated to a standard tile provided before analysis. The colorimetric parameters were measured four days after slaughter, on a fresh surface of both muscles, LTL and BF. The arithmetic mean of the 27 values obtained from each sample was used for statistical analysis. The coordinates a^* and b^* were used for the determination of the chroma = $(a^2 + b^2)^{1/2}$, as described by Mancini and Hunt (2005).

For the amino acid determination after acid hydrolysis, 10 g of each sample were homogenised (Ultra Turrax T25, Ika, Germany) with sulfosalicylic acid 5% (w/v); after centrifugation the liquid phase was brought to a known volume, as described by Paleari et al. (2003). For amino acid determinations 100 μl were injected into an Amino Acid Analyser (model 3A30, Carlo Erba, Milano, Italy). The analytical conditions were: the column was a cation exchange resin (150 mm × 4.6 mm i.d.) with a four step lithium buffer gradient pH 2.80–5.40, flow rate was 30 ml/min with a temperature gradient of 43–73 °C; derivatisation was post-column with ninhydrin; detection was by a colorimeter at 570 and 440 nm; data were acquired by an integrator (model C-R6A, Shimadzu, Kyoto, Japan).

2.3. Statistical analysis

Data were analysed by the method of least squares using the general linear model procedures of SAS (2001) and results were expressed as least square means. Significant differences between means were indicated when $P < 0.05$.

3. Results and discussion

Fatty acid composition of the intramuscular fat did not show significant differences between the two muscles examined, with the exception of myristic acid (C14:0), that was significantly greater ($P < 0.05$) in the BF (Table 1). An interesting content of polyunsaturated fatty acids (PUFAs) was found in both muscles, respectively 25.16 g/100 g total fatty acids in the LTL and 24.97 g/100 g total fatty acids in the BF. The two most abundant fatty acids in both muscles were oleic acid ($18:1_{cis9}$), respectively 29.54 and 29.65 g/100 g total fatty acids in the BF and LTL, and palmitic acid (C16:0), with contents of 29.44 and 29.77 g/100 g total fatty acids, respectively in the BF and LTL (Table 1). Saturated fatty acid (SFA) content was very similar in both muscles in the LTL and BF, respectively being 41.08 and 40.78 g/100 g total fatty acids; data on the same muscles taken from Italian Heavy Draft horses had higher amounts of SFA, 43.69 and 44.24 g/100 g total fatty acids (Tateo, De Palo, Ceci, & Centoducati, 2008). Monounsaturated fatty acid (MUFA) content in the LTL was 33.76 g/100 g total fatty acids and 34.25 g/100 g total fatty acids in the BF; these values were very similar to those obtained by Lanza, Landi, Scerra, Galofaro, and Pennini (2009) on meat samples taken from Sanfratellano and Haflinger foals.

The SFA/MUFA ratio was, respectively, 1.19 in the BF and 1.22 in the LTL, while the ratio between SFA/PUFA was 1.63 in both muscles (Table 1). The SFA/MUFA ratio in meat from Italian Heavy Draft horses was 1.33 in the BF and 1.34 in the LTL (Tateo et al., 2008), while in meat obtained from Sanfratellano and Haflinger foals the SFA/PUFA ratio in the LTL was, respectively, 1.23 and 1.18 (Lanza et al., 2009).

The colorimetric characteristics showed a significantly ($P < 0.05$) higher lightness (L^*) and redness (a^*) in the LTL compared to the BF, respectively 35.86 versus 31.34 and 10.43 versus 9.23 (Table 2), indicating a darker colour of the LTL compared with the hind leg muscle BF. Colour is considered the most important sensory attribute affecting consumer purchasing decisions of red meat, because red colour is associated with freshness (Morrissey, Buckley, Sheehy, & Monahan, 1994). The L^* values obtained indicated that donkey meat colour can be considered very similar to other red meats, such as beef (Boakye & Mittal, 1996), horse meat (Tateo et al., 2008) and lamb (Luciano et al., 2009). Redness (a^*) and yellowness (b^*) indexes can be important in evaluating meat qual-

Table 1
Fatty acid composition (% total fatty acids) determined in donkey LTL and BF muscles (means ± s.e.).

Fatty acid	LTL ($n = 12$)	BF ($n = 12$)
C14:0	3.88 ± 0.53[a]	4.51 ± 0.74[b]
C16:0	29.77 ± 2.98	29.44 ± 2.01
C16:1	3.16 ± 0.64	3.78 ± 0.58
C18:0	7.43 ± 0.87	6.83 ± 1.01
C18:1	29.65 ± 3.23	29.54 ± 2.88
C18:2	18.75 ± 2.86	19.43 ± 3.01
C18:3	4.32 ± 0.89	3.89 ± 0.76
C20:1	0.95 ± 0.11	0.93 ± 0.09
C20:4	2.09 ± 0.37	1.65 ± 0.29
SFA	41.08 ± 2.02	40.78 ± 1.91
MUFA	33.76 ± 1.68	34.25 ± 1.55
PUFA	25.16 ± 1.21	24.97 ± 1.01
SFA/MUFA	1.22	1.19
SFA/PUFA	1.63	1.63
SFA/UFA	0.7	0.69

SFA: saturated fatty acid; MUFA: monounsaturated fatty acid; PUFA: polyunsaturated fatty acid; UFA: total unsaturated fatty acid.
Different letters in the same row indicate a significant difference (b: $P < 0.05$).

Table 2
Colour parameters for the LTL and BF donkey muscles (means ± s.e.).

Parameter	LTL	BF
L^*	35.86 ± 1.49[a]	31.34 ± 1.63[b]
a^*	10.43 ± 0.38[a]	9.23 ± 0.43[b]
b^*	−0.78 ± 0.11	−0.67 ± 0.21
Chroma	10.46 ± 0.66[a]	9.26 ± 0.58[b]

Different letters in the same row indicate a significant difference (b: $P < 0.05$).

Table 3
Amino acid composition (g/100 g muscle) of LTL and BF muscles (means ± s.e.) of donkey ($n = 12$).

	LTL	BF
Essential		
Arginine	1.44 ± 0.18	1.38 ± 0.21
Histidine	0.86 ± 0.08	0.93 ± 0.09
Isoleucine	1.05 ± 0.11	0.99 ± 0.14
Leucine	1.51 ± 0.65	1.60 ± 0.51
Lysine	1.77 ± 0.34	1.63 ± 0.48
Methionine	0.74 ± 0.13	0.65 ± 0.18
Phenylalanine	0.83 ± 0.17	0.76 ± 0.13
Threonine	0.88 ± 0.14	0.91 ± 0.13
Tryptophan	0.24 ± 0.08	0.19 ± 0.12
Valine	1.01 ± 0.34	1.09 ± 0.45
Non-essential		
Alanine	1.22 ± 0.23	1.09 ± 0.11
Aspartic acid	1.79 ± 0.45	1.92 ± 0.59
Cystine	0.22 ± 0.05	0.18 ± 0.05
Glutamine	3.09 ± 1.25	3.26 ± 1.58
Glycine	0.97 ± 0.36	0.84 ± 0.65
Proline	0.95 ± 0.58	1.00 ± 0.42
Serine	0.75 ± 0.23	0.64 ± 0.20
Tyrosine	0.59 ± 0.17	0.70 ± 0.29
Total	19.91 ± 2.32	19.76 ± 3.21
Essential AA (%)	10.33 ± 1.11 (52.88 %)	10.13 ± 2.01 (51.26 %)

ity when it is possible to determine changes over time, because their changes describe meat colour deterioration from red to brown, reflecting myoglobin concentration and its redox state in muscle (Mancini & Hunt, 2005). In this study a^* and b^* values were determined only four days after slaughter; in the future it will be important to follow changes during storage. Chroma (Table 2) was significantly ($P < 0.05$) different between the LTL and BF, with values of respectively, 10.46 and 9.26. Chroma describes the intensity of a fundamental colour with respect to the amount of white light in the background (Boakye & Mittal, 1996); the differences between the two muscles demonstrated, for all indexes evaluated, a darker colour in the LTL compared with the BF.

The amino acid content is shown in Table 3; both the LTL and BF had higher essential amino acid percentages, respectively 52.88% in LTL and 51.26% in BF, compared with the total amino acid contents. Arginine was included between the essential amino acids, as done by Hoffman, Kritzinger, and Ferreira (2005), because arginine is considered a conditionally essential amino acid (Arienti, 2003). The essential amino acids at the highest concentration in donkey meat were lysine (1.77 g/100 g in LTL, 1.63 g/100 g in BF) and leucine (1.51 g/100 g in LTL, 1.60 g/100 g in BF), as shown in Table 3. No statistically significant differences in amino acid contents were found between the muscles. Values were very similar to those given by Badiani and Manfredini (1994) in a review on horse meat quality characteristics.

4. Conclusions

Donkey meat can be considered a product of high nutritional value, characterised by a high content of unsaturated fatty acids, and specifically a high amount of PUFA, some of which can play important roles as, for example, precursors of antithrombotic factors (Kinsella, 1988). The good nutritional qualities of donkey meat are confirmed by the high content of essential amino acids, a factor that is very important in determining food quality (Harper, 1999). Meat colour is influenced by the myoglobin content, and the myoglobin content varies between species and with age (Lawrie, 1985). The results obtained in the present work, based on animals slaughtered at 11 months can be extended using older and/or younger animals to determine the effect of animal age on meat quality. The effects of storage can also be evaluated.

References

Aganga, A. A., Aganga, A. O., Thema, T., & Obocheleng, K. O. (2003). Carcass analysis and meat chemical composition of the donkey. *Pakistan Journal of Nutrition, 2*, 138–147.

Aganga, A. A., Tsopito, C. M., & Seabo, D. (1994). Donkey power in rural transportation. Botswana case study. *Appropriate Technology Journal, 21*, 32–33.

Arienti, G. (2003). *Le basi molecolari della nutrizione* (2nd ed.). Padova: Piccin Nuova Libraria S.p.A.

Badiani, A., & Manfredini, M. (1994). La produzione della carne di cavallo. *Zootecnica e Produzione Animale, 20*(Suppl. 1), 5–43.

Balasini, D. (2000). *Zootecnica Applicata. Equini*. Bologna: Calderini-Edagricole.

Bligh, E. G., & Dyer, W. J. (1959). A rapid method of total lipid extraction and purification. *Canadian Journal of Biochemical Physiology, 37*, 911–917.

Boakye, K., & Mittal, G. S. (1996). Changes in colour of beef m. *longissimus dorsi* muscle during ageing. *Meat Science, 42*, 347–354.

Cardellino, R. A. (2006). L'asino nel mondo. In *Proceedings 2nd Convegno Nazionale sull'Asino* (pp. 17–19), 21–24 September 2006, Palermo, Italy.

Giosuè, C., Alabiso, M., Russo, G., Alicata, M. L., & Torrisi, C. (2008). Jennet milk production during the lactation in a Sicilian farming system. *Animal, 2*, 1491–1495.

Harper, A. E. (1999). Defining the essentiality of nutrients. In M. E. Shills, J. A. Olson, M. Shike, & A. C. Ross (Eds.), *Modern nutrition in health and disease* (9th ed.). Baltimore: Williams and Wilkins Ed.

Hoffman, L. C., Kritzinger, B., & Ferreira, A. V. (2005). The effects of region and gender on the fatty acid, amino acid, mineral, myoglobin and collagen contents of impala (*Aepyceros melampus*) meat. *Meat Science, 69*, 551–558.

Kinsella, J. E. (1988). Food lipids and fatty acids: Importance in food quality, nutrition and health. *Food Technology, 42*, 124–145.

Lanza, M., Landi, C., Scerra, M., Galofaro, V., & Pennini, P. (2009). Meat quality and intramuscular fatty acid composition of Sanfratellano and Haflinger foals. *Meat Science, 81*, 142–147.

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

Luciano, G., Monahan, F. J., Vasta, V., Biondi, L., Lanza, M., & Priolo, A. (2009). Dietray tannins improve lamb meat colour stability. *Meat Science, 81*, 120–125.

Mancini, R. A., & Hunt, M. C. (2005). Current research in meat color. *Meat Science, 71*, 100–121.

Morrissey, P. A., Buckley, D. J., Sheehy, P. J. A., & Monahan, F. J. (1994). Vitamin E and meat quality. *Proceedings of the Nutrition Society, 53*, 289–295.

Paleari, M. A., Moretti, V. M., Beretta, G., Mentasti, T., & Bersani, C. (2003). Cured products from different animal species. *Meat Science, 63*, 485–489.

Payne, J. A., & Wilson, T. R. (1999). *An introduction to animal husbandry in the tropics* (5th ed.). Oxford: Blackwell Science Ltd..

Piccione, G., Fazio, F., Caola, G., & Refinetti, R. (2008). Daily rhythmicity in nutrient content of asinine milk. *Livestock Science, 116*, 323–327.

Polidori, P., Vincenzetti, S., Cavallucci, C., & Beghelli, D. (2008). Quality of donkey meat and carcass characteristics. *Meat Science, 80*, 1222–1224.

SAS (2001). *Statistical analysis system. SAS/STAT guide for personal computers* (version 8 edition). Cary, NC.

Smith, D. G., & Pearson, R. A. (2005). A review of the factors affecting the survival of donkeys in semi-arid regions of sub-Saharan Africa. *Tropical Animal Health and Production, 37*(Suppl. 1), 1–19.

Sukhija, P. S., & Palmquist, D. L. (1988). Rapid method for determination of total fatty acid content and composition of feedstuffs and faeces. *Journal of Agricultural and Food Chemistry, 36*, 1202–1206.

Tateo, A., De Palo, P., Ceci, E., & Centoducati, P. (2008). Physicochemical properties of meat of Italian Heavy Draft horses slaughtered at the age of 11 months. *Journal of Animal Science, 86*, 1205–1214.

Vincenzetti, S., Polidori, P., & Vita, A. (2008). Nutritional characteristics of donkey's milk protein fraction. In A. B. Boscoe & C. R. Listow (Eds.), *Protein research progress* (pp. 169–187). New York: Nova Science Publishers Inc..

Wilson, T. R. (1990). The donkey. In W. J. A. Payne (Ed.), *An introduction to animal husbandry in the tropics* (pp. 581–603). Oxford: Blackwell Science Ltd..