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Effect of muscle and intensity of finishing diet on meat quality of foals slaughtered at 15 months

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ABSTRACT

The effect of muscle and intensity of finishing diet on meat quality of foals slaughtered at 15 months was study. For this work, a total of twenty one foals and six muscles: *longissimus dorsi* (LD), *semimembranosus* (SM), *semitendinosus* (ST), *biceps femoris* (BF), *triceps brachii* (TB) and *Psoas major & minor* (PM) from two different intensities of finishing diet (1.5 vs. 3 kg/day) were analysed.

Meat quality (chemical composition, colour characteristics, and textural traits), fatty and amino acid profile and mineral composition were studied. In general the factor muscle had more effect on all traits measured in this study than finishing effect, especially in the fatty acids and mineral composition. SM muscle showed the highest percentage of protein in both finishing groups (22.34 and 21.74% for 3 and 1.5 kg of commercial feeding, respectively). The intramuscular fat content in the analysed muscles ranged between 0.15% (LD in 1.5 group) and 1.83% (PM in 3.0 group). The highest values of iron heme that were obtained in TB muscle (2.46 mg/100 g meat) are a considerable source of bioavailable iron content.

The three most abundant fatty acids in both groups and for all muscles studied were oleic acid, palmitoleic acid and linoleic acid. From a healthy point of view, muscles from foals finishing with a minor amount of commercial fodder were the best. The best nutritional value was reached for PM and ST with 14.73% of total omega 3 and the highest polyunsaturated/saturated ratio (1.10), respectively. Concerning amino acid profile, values of essential/non-essential ratio were significantly higher ($P < 0.001$) in muscles of 1.5 diet group foals (0.856) than the other group (0.833). Finally, potassium (243 mg/100 g) and phosphorous (202 mg/100 g) were the two main minerals, followed by sodium (54 mg/100 g) and magnesium (26 mg/100 g).

1. Introduction

Horses are usually raised in Spain for sports and recreation and in the past as working horses. The use of horses as a meat source has been questioned in terms of food quality in spite of its nutritional value, low cost and low fat content compared to other meat as pork or beef (Badiani, Nanni, Gatta, Tolomelli, & Manfredini, 1997). Although horsemeat is considered a delicacy in many cultures (Gill, 2005) in Spain most of the horsemeat produced are exported to Italy and France.

Compared to beef, horsemeat has a low percentage of fat, which makes it a lean meat. The nutritional characteristics of horsemeat currently draw some attention despite the little information on its nutritional value, particularly on fatty acid profile, rich in omega-3 (Lorenzo, Fuciños, Purriños, & Franco, 2010) and cholesterol concentrations (Badiani et al., 1997).

To increase the horsemeat production a more detailed study about meat quality is necessary. In addition inside a whole carcass there are different muscles depending on whether it is support muscle or a locomotive muscle therefore their culinary use will be different, so it is necessary try to value the whole carcass. Previous works revealed these differences in beef (Belew, Brooks, McKenna, & Savell, 2003) lamb (Tschirhart-Hoelscher, Baird, King, McKenna, & Savell, 2006) or horse (Tateo, DePalo, Ceci, & Centoducati, 2008). With the exception of the last work, practically there are no studies that evaluate the influence of commercial cut on horsemeat quality, so this study will provide practical and useful information on the nutritional quality of muscles. Several of these commercial cuts are highly appreciated in other species by the consumers in restaurants, such as sirloin or loin.

On the other hand it has been established that meat quality can be influenced by finishing feeding, mainly due to final variations in the intramuscular level. These variations have a clear effect on colour traits, tenderness and fatty acid profile. Examples for different species were reported in horses (Sarriés & Beriain, 2006), poultry (Franco, Rois, Vázquez, & Lorenzo, 2012), pig (Nuernberg et al., 2005) or cull dairy cows (Vestergaard et al., 2007). Finally these parameters are related to sensory characteristic of meat and thus with consumer acceptability (Belew et al., 2003; Mennecke, Townsend, Hayes, & Lonergan, 2007).

Thus, the aim of this study was to assess the effect of finishing diet and muscle type in foals slaughtered at 15 months on commercial and

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nutritional quality of foal meat, so that these results can be relevant for the meat industry or by nutritionists to describe tables of the food composition.

2. Material and methods

2.1. Experimental design and animal management

For this study, twenty one foals: twelve from Galician Mountain genotype and nine from crossing Galician Mountain and Hispano Bretón were used. Animals were obtained from the experimental herd of Agricultural Research Centre of Mabegondo (Marco da Curra, A Coruña, Spain). The majority of the foals were born in April and May 2010. Animals were reared with their mothers on pasture and were allowed to suck freely. Foals were weaned when they were 6–8 months old. The finishing period was 4 months (April to August). Then, foals were fed with concentrate and pasture in the best conditions of amount and quality. Foals were fed with two different amounts of concentrate (10 foals with 1.5 kg of fodder/foal-day and 11 foals with 3 kg of fodder/foal-day).

There was a period of adaptation to the concentrate feeding, in order to avoid colics that usually appear with a sudden change in the diet. The amount of commercial feed was gradually increased, starting with small quantities to reach the final amount. The period of adaptation was 20 and 30 days for each group (1.5 and 3 kg, respectively). Composition (%) of commercial feed was: crude protein (15.1), crude fibre (6.7), ashes (5.5), fat (4.5) and sodium (0.2). Commercial feed was composed of barley, corn, soybean flour, wheat bran, alfalfa, sugar cane molasses, beet, animal fat, calcium carbonate, sodium chloride and powder lactose. This ration was supplemented with the next mineral/vitamin mix: vitamin A (6000 UI/kg), vitamin D3 (600 UI/kg), mineral expressed in mg/kg zinc (150), manganese (70), iron (90), cooper (10), cobalt (0.30) and iodine (2) and butyl-hydroxyanisol (0.03 mg/kg), etoxiquine (0.03 mg/kg). Animals were slaughtered with a mean live weight of 256.67 kg (average carcass weight of 128.52 kg) and transported to the abattoir the day before slaughter, without mixing foals with different groups at any time, and trying to minimize the animal stress. The animals were stunned with a captive bolt and slaughtered and dressed in an accredited slaughter house. Carcasses were chilled at 4 °C in a cold chamber immediately after slaughtering for 24 h. At this point, the muscles [*longissimus dorsi* (LD), *semimembranosus* (SM), *semitendinosus* (ST), *biceps femoris* (BF), *triceps brachii* (TB) and *psoas major & minor* (PM)] were excised from the left side of each carcass. Visual fat and connective tissue were eliminated and muscle samples were cut into seven 2.5 cm thick steaks. The first three steaks were used to determine pH, colour, proximate composition and fatty acid and amino acid profile. The fourth and fifth steaks were packed under vacuum conditions of 99% in a vacuum packaging machine (FRIMAQ, V-900, Lorca, Spain) for 7 days at 4 °C. Water holding capacity (WHC) and texture parameter were measured after this period.

2.2. Analytical methods

2.2.1. pH, colour parameters, heme-iron content and chemical composition

The pH of the samples was measured using a digital pH-metre (Thermo Orion 710 A+, Cambridgeshire, UK) equipped with a penetration probe. A portable colorimeter (Konica Minolta CR-600d Osaka, Japan) with the next settings machine (pulsed xenon arc lamp, angle of 0° viewing angle geometry and aperture size of 8 mm) was used to measure the meat colour in the CIELAB space (CIE, 1976) (lightness, L*; redness, a*; yellowness, b*).

Samples were allowed to bloom for 1 h before measuring directly in contact with air (Insausti et al., 1999). Heme-iron was measured in duplicate, according to the methodology of Hornsey (1956) with the following formula (Merck index, 1989):

$$\text{Hematin}\ (\mu\text{ghematin/gmuscle}) = \text{absorbance} \times 342.44$$

$$\text{Heme iron}\ (\text{mg}/100\text{gmeat}) = (\text{hematin} \times 8.82)/100.$$

Moisture, fat, protein (Kjeldahl N × 6.25) and ash were quantified according to the ISO recommended standards 1442:1997 (ISO, 1997), 1443:1973 (ISO, 1973), 937:1978 (ISO, 1978), and 936:1998 (ISO, 1998), respectively. Briefly, moisture percentage was calculated by weight loss experimented by the sample (5 g) maintained in the oven (Memmert UFP 600, Schwabach, Germany) at 105 °C, until constant weight. Ash percentage was calculated by weight loss experimented by the sample (5 g) maintained in a muffle furnace (Carbolite RWF 1200, Hope Valley, England) into a porcelain capsule at 600 °C until constant weight. For the determination of fat content samples (3 g) were subjected to a liquid–solid extraction using hexane in an extractor apparatus (FOSS Soxtec Avanti 2050, Höganäs, Sweden) extractor during 3 h. Previously samples were hydrolyzed with HCl in a FOSS Soxtec System (2047 SoxCap, Höganäs, Sweden). Fat content was calculated by gravimetric difference. Protein content was determined according to Kjeldahl Total Nitrogen method, multiplying the total nitrogen content by 6.25. Sample (1 g) was subjected to reaction with sulphuric acid (cuprum sulphate was employed as a catalyst) in a digester (Gerhardt Kjeldatherm KB, Bonn, Germany). Organic nitrogen was transformed to ammonium sulphate, which was distilled in alkali conditions in a distillation apparatus (Gerhardt Vapodest 50 Carrousel, Bonn, Germany).

2.2.2. WHC and texture analysis: Warner–Bratzler (WB) test and texture profile analysis (TPA)

WHC was measured in two ways: cooking loss (CL) and drips loss (DL) as described in Franco et al. (2011). Foal steaks were cooked placing vacuum package bags in a water bath with automatic temperature control (JP Selecta, Precisdg, Barcelona, Spain) until they reached an internal temperature of 70 °C, controlled by thermocouples type K (Comark, PK23M, UK), connected to a data logger (Comark Diligence EVG, N3014, UK). After cooking, samples were cooled in a circulatory water bath set at 18 °C during a period of 30 min and the percentage cooking loss was recorded. All samples were cut or compressed perpendicular to the muscle fibre direction at a crosshead speed of 3.33 and 1 mm s^{-1} for WB and TPA tests respectively. A texture analyser (TA-XT2, Stable Micro Systems, Godalming, UK) was used in both tests. Seven pieces of meat of 1 × 1 × 2.5 cm (height × width × length) were removed parallel to the muscle fibre direction. Samples were completely cut using a WB shear blade with a triangular slot cutting edge (1 mm thickness). Maximum shear force, shear firmness and total necessary work performed to cut the sample were obtained. A minimum of five pieces of meat of 1 × 1 × 1 cm (height × width × length) parallel to the muscle fibre direction were removed for TPA test according to methodology proposed by Bourne (1978). Textural parameters were measured by compressing to 80% with probe of 19.85 cm^2 of surface contact. Between the first and second compression, the probe waited for 2 s. Hardness, cohesiveness, springiness, and chewiness were obtained.

2.2.3. Fatty acid profile

Before analysis, intramuscular fat was extracted from 5 g of ground meat sample, according to Folch, Lees, and Stanley (1957). Lipid extracts were evaporated to dryness under vacuum at 35 °C and stored at −80 °C until analysis by preparation of fatty acid methyl esters (FAMEs). Lipids were transesterified with a solution of boron trifluoride (14%) in methanol, as described by Carreau and Dubacq (1978). Fifty milligrammes of the extracted lipids was esterified and FAMEs were stored at −80 °C until chromatographic analysis. Separation and quantification of the fatty acid methyl esters were carried out using a gas chromatograph (GC, Agilent 6890 N, Agilent Technologies Spain, S.L., Madrid, Spain) equipped with a flame ionization detector and an automatic sample injector HP 7683, and using a Supelco SPTM-2560 fused silica capillary column (100 m, 0.25 mm i.d., 0.2 μm film thickness, Supelco Inc., Bellefonte, PA, USA). The chromatographic conditions