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Importance of breed aptitude (beef or dairy) in determining trace element concentrations in bovine muscles

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ABSTRACT

The aim of this study was to determine the concentrations of various trace elements in muscles with different oxidative/glycolytic profiles (cardiac [CA]; diaphragm [DI], as oxidative; trapezius [TR], as intermediate oxidative/glycolytic; and semimembranosus [SM], as glycolytic muscle) of ten dairy-aptitude (Holstein-Friesian, HF), ten beef-aptitude (Galician Blonde, GB) and ten cross-breed (GBxHF) calves. The type of muscle was a highly significant factor in relation to the concentrations of all elements, whereas breed was only significant for Fe, Mn and Zn in the SM muscle. The concentrations of the main trace elements (Cu, Fe, Se and Zn) were significantly lower in GB and GBxHF than in HF, that were mainly associated with differences in the oxidative/glycolytic profile, probably due to the muscular hypertrophy characteristic of heavily muscled breeds. The pattern of distribution was similar in all breeds, with significantly higher concentrations in the CA muscle, followed by the DI; trace element concentrations in the SM and TR muscles were very similar.

1. Introduction

Lean red meat plays an important role in healthy balanced diets because of the nutrients that it contains. In addition to being rich in proteins and low in carbohydrates, red meat contains essential trace elements in higher and more readily available concentrations than other foods. Red meat contains useful concentrations of the following important elements: iron (which helps prevent anaemia), zinc (important for immune system functioning and fertility) and selenium (which has antioxidant properties that help reduce the risk of heart disease and certain cancers) (Biesalski, 2005; Cabrera, Ramos, Saadoun, & Brito, 2010; Mateescu et al., 2013).

Trace element concentrations are not uniformly distributed across the carcass. Although red muscle is known to contain higher amounts of iron than other muscles (Bacou & Vigneron, 1988; Macdougall, Bremner, & Dalgarno, 1973), recent studies have indicated that most trace element concentrations vary significantly across the carcass and that veal cuts including muscles with a high proportion of oxidative slow-twitch fibres (red muscles) contain higher levels of essential trace elements than veal cuts including glycolytic fast-twitch fibres (white muscles) (Czerwonka & Szterk, 2015; López-Alonso, Miranda, Benedito, Pereira, & García-Vaquero, 2016; McGilchrist, Greenwood, Pethick, & Gardner, 2016).

In addition, breed-related differences in trace element concentrations in meat are well documented in the literature (Cabrera et al., 2010; Domaradzki, Florek, Staszowska, & Litwińczuk, 2016; Duan et al., 2015; Pilarczyk, 2014). Recent studies have indicated that trace mineral concentrations in muscle are at least partly genetically determined and heritable (Mateescu et al., 2013; Morris et al., 2013), that the genes involved may act via receptor, transporter and chaperone proteins (Morris et al., 2013) and, moreover, that trace element concentrations are associated with the main organoleptic properties (Duan et al., 2015).

In a recent study in intensively reared beef cattle, we found significantly higher trace element concentrations in the muscles of a dairy-aptitude breed (Holstein Friesian) than in the muscles of a beef-aptitude breed (Galician Blonde), with the cross-breed showing an intermediate position (Pereira, Carbajales, López-Alonso, & Miranda, 2018). Considering measurements of trace element concentrations in blood and other organs, the most plausible explanation seems to be differences in the capacity to deliver trace element to the muscles. This ability may be related to significant differences in muscular mass (higher in beef-aptitude breeds) and metabolic activity (higher in dairy-aptitude breeds). However, it is also possible that breed-related differences in trace element concentrations in meat may be at least partly related to differences in the muscle composition. Selection for enhanced muscling in

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animal production has been shown to increase the proportion of the fast-twitch glycolytic type IIX myofibres in cattle (Wegner, Albrecht, & Fiedler, 2000), sheep (Greenwood, Gardner, & Hegarty, 2006) and pigs (Ruusunen & Puolanne, 2005).

As far we are aware, very few studies have evaluated trace element concentrations in different types of muscles (depending on their oxidative or glycolytic capacity) in different breeds reared under the same type of production system, in order to establish the degree to which breed-related differences in muscle composition and/or trace element metabolism determine trace element concentrations in meat cuts across the carcass. In a preliminary approach addressing this question, we determined trace element concentrations in several muscles with different oxidative/glycolytic profiles (diaphragm [DI], an oxidative-type muscle; trapezius [TR], an intermediate oxidative/glycolytic type muscle; and semimembranosus [SM], a glycolytic-type muscle) in a dairy-aptitude breed (Holstein-Friesian, HF), a beef-aptitude breed (Galician Blonde, GB) and their crosses (GB x HF). We also included cardiac (CA) muscle in the study because it contains high levels of trace elements and because of its particular structure (α-cardiac slow fibres).

2. Material and methods

2.1. Animals

We selected 30 calves for the study: ten dairy-aptitude HF; ten beef-aptitude GB (the main beef-aptitude breed in the region of the study with high presence in the national market) and ten GB x HF cross-breed calves, aged between 9 and 10 months old. The calves were selected at random from a larger group (n = 214) reared in a commercial feedlot with the typical feed conditions used in Spain. All animals were from different farms, have different progenitors and were introduced in the feedlot after weaning (approximately at 8 weeks of age). The animals were fed a standard diet (including trace element supplementation) based on concentrate feed. The calves were allowed free access to feed, water and barley straw. Trace element concentrations in the concentrate feed, barley straw and water were analysed (Co: 0.40 mg/kg DM (concentrate feed), 0.089 mg/kg DM (barley straw), 0.200 μg/L (water); Cr: 3.11, 0.411, 0.152; Cu: 23.6, 2.13, 163; Fe: 136, 63.2, 48.1; Mn: 168, 171, 3.86; Mo: 1.44; 0.293; 0.089; Ni: 2.01, 0.514, 1.59; Se: 0.339, 0.009, 0.275; Zn: 151; 13.1; 88.3, respectively). Details of the ingredients and nutritional composition of the diet are shown in Table 1.

Table 1
Chemical composition and ingredients of the concentrate fed in this study.

Chemical composition (% DM)	
Crude protein (CP)	15.5
Crude fibre (CF)	5.6
Neutral detergent fibre (NDF)	21.6
Acid detergent fibre (ADF)	7.2
Ether extract (EE)	4.7
Ash	5.1
Ingredient (% DM)	
Corn	29
Barley	19.5
Soybean meal (44% CP)	13.9
Corn gluten feed	12.4
Wheat bran	8.4
Soybean hulls	7.5
Molasses	3.5
Palm oil	2
Vitamin/mineral premix[a]	3.2
Sodium bicarbonate	0.6

[a] Contains per kg of concentrate: 10.000 IU vitamin A, 2000 IU vitamin D, 10 mg vitamin E, 0.3 mg Co, 16 mg Cu, 10 mg Fe, 1.8 mg I, 110 mg Mn, 0.3 mg Se and 120 mg of Zn.

2.2. Sample collection

Four muscles were selected for study: cardiac (CA, left ventricle) and diaphragm (DI) muscle, because these muscles have a high oxidative capacity (based on their oxidative:glycolytic activity), trapezius (TR) muscle, as example of muscle with a predominance of fast-twitch fibres, and semimembranosus (SM) muscle, representative of muscle with a high predominance of slow-twitch fibres (Talmant, Monin, Briand, Dadet, & Briand, 1986).

Samples of muscles were collected from animals immediately after slaughter in a commercial abattoir. All samples were refrigerated immediately and transported to the laboratory. The muscle tissue was cleaned of connective tissue and fat. Triplicate subsamples (ca. 10 g) were stored at −20 °C until analysis.

2.3. Zootechnical data

The carcass and liver weights were recorded, and carcass performance was calculated. The carcass weights (kg) were 204 ± 23, 244 ± 21 and 231 ± 28 for HF, GB and GBxHF, respectively. The liver weights were 6.12 ± 0.92, 4.68 ± 0.61 and 5.14 ± 0.54 for HF, GB and GBxHF, respectively. Carcass performance (%) values were 52.2 ± 1.21, 62.4 ± 3.11 and 59.7 ± 2.33 for HF, GB and GBxHF, respectively.

2.4. Trace element analysis

Subsamples of approximately 1 g were digested in 5 mL of 69% nitric acid and 2 mL 33% w/v hydrogen peroxide in a microwave digestion system (Ethos Plus; Milestone, Sorisole, Italy). The digested samples were transferred to polypropylene sample tubes and diluted to 15 mL with ultrapure water. The concentrations of cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), selenium (Se) and zinc (Zn) were determined by inductively coupled plasma mass spectrometry (ICP-MS, Agilent 7700× ICP-MS system, Agilent Technologies, Tokyo, Japan).

An analytical quality control was applied throughout the study by analysis of blank samples at the same time as test samples. The values obtained for the blank samples were subtracted from the values obtained for the test samples before calculation of the final results. The limits of detection (LoD) were calculated as three times the standard deviation of the reagent blanks (Table 2). The limits of quantification were calculated on the basis of the mean sample weight. Analytical recoveries were determined from certified reference material (1577c Bovine Liver, National Institute of Standards & Technology, USA), which was analysed at the same time as the test samples. There was a good agreement between the measured and the certified values (Table 2).

Table 2
Analytical quality program expressed as mean ± standard deviation used in the determination of trace elements.

	Detection limit (μg/L)	SRM 1577c[a]	
		Analysed levels	Certified levels
Co	0.1	307 ± 14 (μg/Kg)	300 ± 18 (μg/Kg)
Cr	0.2	50 ± 16 (μg/Kg)	53 ± 14 (μg/Kg)
Cu	4.3	274.1 ± 13.7 (mg/Kg)	275.2 ± 4.6 (mg/Kg)
Fe	11	198.01 ± 1.94 (mg/Kg)	197.94 ± 0.65 (mg/Kg)
Mn	2.1	10.11 ± 0.18 (mg/Kg)	10.46 ± 0.47 (mg/Kg)
Mo	1.3	3.27 ± 0.11 (mg/Kg)	3.30 ± 0.13 (mg/Kg)
Ni	0.3	47.7 ± 11.1 (μg/Kg)	44.5 ± 9.2 (μg/Kg)
Se	1.6	2.051 ± 0.029 (mg/Kg)	2.031 ± 0.045 (mg/Kg)
Zn	11	180.1 ± 0.7 (mg/Kg)	181.1 ± 1.0 (mg/Kg)

[a] SRM 1577c: Standard Reference Material (SRM) 1577c is a certified reference material of bovine liver.