Selenium, copper, zinc, iron and manganese content of seven meat cuts from Hereford and Braford steers fed pasture in Uruguay

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1. Introduction

Today, minerals deficiencies in human are common world-wide and there are evidences which suggest that deficiencies may play a negative role in children’s development, pregnancy and elderly health (Black, 2003; Failla, 2003; Grantham-McGregor & Ani, 2001; Hambridge & Krebs, 2007). For example, insufficient intake of iron and zinc causes anemia, fatigue, poor growth, rickets and impaired cognitive performance in humans (Murphy & Allen, 2003). Furthermore, minerals such as Se, Cu, Zn, Fe, and Mn are keys for the enzymatic system that counteract the free radicals in the organism.

Consumption of beef can be a good way to respond qualitatively and quantitatively to the mineral requirements of human nutrition. Published reports show that red meat is a major source of minerals for the human diet, and provides the essential minerals, of high bioavailability, to human nutrition (Kotula & Lusby, 1982; Littledeike, Wittmann, & Jenkins, 1995; Marchello, Milne, & Slanger, 1984; Santell, Martinez, Ros & Periago, 1997; Zarkadas et al., 1987). However, the mineral composition of beef changes with breed and age of animals (Ammerman, Loaiza, Blue, Gamble, & Martin, 1974; Buckett, Wagner, Yates, Dolezal, & May, 1993), muscles type and feeding practices (Purchas & Busboom, 2005), geographical site of rearing (Hintze, Lardy, Marchello, & Finley, 2001, 2002) and processing (Chen, Pearson, Gray, Fooladi, & Ku, 1984; Purchas, Simcock, Knight, & Wilkinson, 2003; Revilla & Vivar-Quintana, 2006).

Uruguay is the world’s 8th largest beef exporter, (around 70% of its production is exported) whereas the beef per capita consumption in 2007 was 56 kg (MLA, 2008). Beef production in Uruguay is largely based on pasture and part of the produced meat is exported as refrigerated and unprocessed meat. In spite of the high economical value of meat production for Uruguay, there is limited scientific information about the beef meat produced on pasture in this country (De la Fuente et al., 2007; del Campo et al., 2008; Oliver et al., 2006; Realini, Duckett, Brito, Dalla Rizza & De Mattos, 2004; Realini et al., 2009). Moreover, only a limited number of articles have been published on the mineral composition of beef meat produced on pasture in South America (Giuffrida-Mendoza, Arenas de Moreno, Uzcátegui-Braicho, Rincón-Villalobos, & Huerta-Leidenz, 2007; Huerta-Leidenz, Arenas de Moreno, Moron-Fuenmayor & Uzcategui-Braicho, 2003). Information on minerals is needed by Uruguayan farmers when they need to promote, in the international meat market, their meat traditionally produced on pasture (Oliver et al., 2006).
So, in the present investigation, we determined the content of selenium, copper, zinc, iron and manganese in seven meat cuts (tenderloin, eye of rump, striploin, eye round, tri-tip, rib-eye roll and 3 rib plate-flank on) obtained from young Hereford and Brahford steers (2–4 teeth) aged of 24–30 months and produced on pasture in Uruguay. Hereford breed is the main breed reared for meat in Uruguay and Brahford crossbred (3/8 Bos indicus-5/8 Bos Taurus) is gaining popularity during the last years in the country due to its rusticity (Pittaluga, 2005).

2. Materials and methods

2.1. Animals and pasture

Hereford (n = 14) and Brahford (n = 15) crossbred (3/8 Bos indicus-5/8 Bos Taurus) young steers (2–4 teeth) were reared under conditions characteristic of Uruguay, based on the exploitation of natural resources with traditional extensive grazing. Animals 26–30 months of age with a live weight average of 460 kg, were grazed on natural pasture and finished (150 days before slaughtering) on an improved pasture (80% natural and 20% cultivated grass) consisting in red clover (Trifolium pratense), white clover (Trifolium repens), lotus (Lotus corniculatus) and dactylic (Dactylis glomerata) with a forage rate of 2000 kg grass dry matter/ha. All animals were grown separated by breed at the Experimental Unit of Glencoe (INIA, Tacuarembó, Uruguay), and slaughtered in an authorized abattoir (Tacuarembó, Uruguay) according to the governmental regulations determined by the INAC-MGAP (Uruguay).

2.2. Meat cuts sampling

The meat cuts (and corresponding main muscles) evaluated in the present investigation were tenderloin (m. Psosas major), eye of rump (m. Gluteus medius), striploin (m. Longissimus dorsi), eye round (m. Semitendinosus), tri-tip (m. Tensor fascia lata), rib-eye roll (m. Longissimus dorsi, m. Multifidus dorsi). Note that m. Illiocostalis was removed and 3 rib plate-flank on (m. Oblique internus abdominis, m. Oblique externus abdominis, m. Transversus abdominis and m. Rectus abdominis). The cuts and muscles names were determined according to the Handbook of Uruguayan Meat (INAC, 2006). Fresh samples (500 g) taken 24 h post-slaughter from the middle region of each cut were kept in sealed bags at –20 °C until analysis.

2.3. Minerals contents determination

Meat samples were trimmed of visible adipose and connective tissue, chopped and dried in oven at 105 °C to obtain a constant weight. After that, the samples were ashed in a covered crucible at 550 °C in a furnace for 16 h to obtain a white residual ash. The ashes were subjected to an acid digestion process in an Erlen-flask, covered with a micro glass-ball to avoid projections, with a 1 M hydrochloric acid and 1 M nitric acid solution heated on a hot plate (AOAC, 1990; Mader, Szakóvá, & Miholová, 1998). Determination of Cu, Zn, Fe and Mn were performed by flame atomic absorption spectrophotometer (Analyst 300, Perkin Elmer, USA) following the analytical methods described by AOAC (1990), Jorhem (2000). Selenium was analyzed by graphite furnace atomic absorption (Bohrer, Becker, Cicero do Nascimento, Dessuy & Machado de Carvalho, 2006; Chen & Marshall, 1999) with Cu and Mg (nitrate salts, Fluka) as chemical modifiers for the determination of selenium in aqueous media. All the determinations were performed in triplicate.

All reagents used were of analytical grade, and Millipore-MilliQ distilled deionized water was used throughout. Glass and polyethylene material were soaked in HNO3 (sp. gr. 1.38) and rinsed with deionized water. Standard solutions of Cu, Zn, Fe, Mn and Se were prepared immediately before use by dilution (with deionized water) of a 1000 mg/l standard solution. Quality control was performed by running bovine liver standard (NIST standard, SRM 1577b, Gaitherburg, USA). Minerals content were expressed in mg/kg of wet tissue.

2.4. Statistical analysis

Data were analyzed by one-way analysis of variance to determine differences between meat cuts for a same breed or differences between breeds for each meat cut. The main effects of breed, meat cut and its interaction were determined using the GLM procedure (NCSS software release 2006, 329 North 1000 East, Kaysville, UT 84037, USA) for a fixed effect model with two breeds and seven meat cuts. When treatment effects were significant (P < 0.05) means were compared with Tukey-Kramer test (NCSS software release 2006, 329 North 1000 East, Kaysville, UT 84037, USA).

3. Results

Selenium content in the two breeds shows a significant main effect (P < 0.00001) for meat cut, but neither a breed nor an interaction effect (Fig. 1). In Hereford, tenderloin (T), tri-tip (TT) and 3 rib plate-flank on (RP) show a significantly higher level in Se in comparison to eye of rump (E), striploin (S), eye round (ER), rib-eye roll (RR). In Brahford, with the exception of T, TT and RP show a significantly higher level in comparison to the other meat cuts, (Fig. 1). ER has a significantly higher level of Se in Hereford in comparison to Brahford (Fig. 1).

Copper content in the two breeds shows a significant main effect (P < 0.00001) for meat cut, but neither a breed nor an interaction effect (Fig. 2). In Hereford, RP had significantly more Cu than ER, TT, and RR. In Brahford, ER and RR show a significant lower Cu level in comparison to the other meat cuts. T shows a significantly higher level of Cu (P < 0.022) in Brahford in comparison to Hereford (Fig. 2).

Zinc content in the two breeds shows a significant main effect (P < 0.00001) for meat cut, but neither a breed nor an interaction effect (Fig. 3). In Hereford, RP had the highest content in comparison to the other meat cuts. T cut had the lowest level compared to TT and RP cuts (Fig. 3). In Brahford, RP had the highest level of Zn in comparison to the other studied meat cuts (Fig. 3).

Iron content in the two breeds shows a significant main effect (P < 0.00001) for meat cut, but neither a breed nor an interaction effect (Fig. 4). In Hereford, RR shows a significant lower content in comparison to the other meat cuts, except for RP and S.

In Brahford, RR had the significantly lowest level of Fe in comparison to the other studied meat cuts, except for RP and T. The T, E, S, ER and TT cuts had similar level of Fe (Fig. 4). The comparison between the two breeds shows that T and RR have a significantly higher level of Fe in Hereford in comparison to Brahford (Fig. 4).

Manganese content in the two breeds (Fig. 5) shows a significant breed effect (P < 0.0019), muscles effect (P < 0.00001) and a significant interaction effect (P < 0.0001). In Hereford no significant differences were detected between the seven meat cuts. In Brahford, ER cut shows significantly more Mn than the other six meat cuts (Fig. 5).

4. Discussion

4.1. Selenium, copper, zinc, iron and manganese content in Hereford and Brahford meat

Previously published reports show a level of Se in Longissimus dorsi and Psosas major muscles of 0.106 mg and 0.095 mg/kg wet
tissue, respectively. The two muscles were obtained from steers weighing approximately 300 kg (Daun, Johansson, Önning, & Åkes-son, 2001). In another study which compares the Se content in raw meat considered in nutritional database of four countries, the results show Se levels of 0.065 mg, 0.070 mg, 0.10 mg and 0.308 mg (per kg wet tissue) in Denmark, United Kingdom, Australia and USA, respectively. However, no mention about the type of animal and muscles used were informed in the article (Williamson, Foster, Stanner, & Buttriss, 2005). The Se concentration in meat is primarily determined by its geographical origin (Hintze et al., 2001, 2002). It has been clearly determined that the meat from America is much more concentrated in Se than meat from Europe (Franke, Gremaud, Hadorn, & Kreuzer, 2005). This fact may explain why in the reports of Williamson et al. (2005), the Se content of meat from USA shows approximately between three and five times more Se in comparison to the other evaluated meat. A similar result was obtained in a recent work which compares meat produced in Switzerland to meat produced in USA. All meat cuts were purchased in supermarket, and no mention on breed and animals type were made in the report. That work shows that the sirloin and rib-eye cuts from USA have three and four times more Se than the same meat cuts from Switzerland (Gerber et al., 2009). All these observations can probably help to explain the relatively high level of Se detected in the meat cut of the two breeds studied in the present investigation (Fig. 1).

![Selenium content in seven meat cuts from Hereford and Braford steers fed on pasture. Bars are means ± SEM (n = 10–15). P when included at the top of the bars shows significant difference and value of P within the same cut, between Hereford and Braford. Within the same breed, different letters show significant difference between cuts at level of P < 0.05. Cuts name are according to the Uruguayan meat book (INAC, 2006). T = Tenderloin. E = Eye of rump. S = Striploin. ER = Eye round. TT = Tri-tip. RR = Rib eye roll. RP = 3 Rib plate-flank on.](image-url)
in the Italian market. However, no mention about the breed and animals type were made in the report. The authors reported Cu levels ranged from 0.4 mg to 0.90 mg/kg wet tissue. In another report by Huerta-Leidenz et al. (2003), the Cu level of Longissimus dorsi muscle was determined in different breeds reared in Venezuela. The investigation shows that the mean Cu level was of 0.84 mg/kg wet tissue with values ranged from 0.10 mg to 2.60 mg/kg wet tissue. The higher levels of Cu detected in that investigation seem to be present principally in meat from Zebu-influenced cattle (Giuffrida-Mendoza et al., 2007; Huerta-Leidenz et al., 2003).

Another report Gerber et al. (2009) compared the Cu content of different meat cuts purchased in supermarket in Switzerland and USA. The authors found that the sirloin from Switzerland and USA shows a Cu level of 0.77 mg and 0.50 mg/kg wet tissue, respectively. In the same investigation, the authors found that the Cu level of rib-eye from Switzerland and USA had a Cu level of 0.56 mg and 0.76 mg/kg wet tissue, respectively. These reported levels are similar to results found in the present investigation.

The present investigation shows that Hereford as well as Braford meat contains a slightly lower Zn level in comparison to other previously published reports. The RP cut in Hereford and Braford breed shows twice or more level of Zn in comparison to all the other cuts (Fig. 3). The authors have no explanation for this interesting result concerning a meat cut, called “Asado” in Uruguay, largely consumed as grilled meat and appreciated in South America and particularly in Uruguay, Argentina and Southern Brazil.

In the report of Lombardi-Boccia et al. (2005), the Zn levels in beef determined in sirloin, fillet, roast beef, topside and thick flank cuts purchased in the Italian market ranged from 39.4 mg to 47.5 mg/kg wet tissue. In a report by Gerber et al. (2009), the
sirloin and the rib-eye cuts, from Switzerland market, show a Zn level of 37 mg and 51 mg/kg wet tissue, respectively. The same meat cuts from USA show a Zn level of 38 mg and 42 mg/kg wet tissue. In the comparison between meat databases of four countries, Williamson et al. (2005) report Zn levels from 40 mg to 47 mg/kg wet tissue detected in raw meat in Denmark, United Kingdom, Australia and USA, respectively. In their investigation, Kotula and Lusby (1982) compared the Zn content in five different meat cuts obtained from Aberdeen Angus steers fed 70% concentrate and 30% roughage. Their results show levels ranged from 29.5 mg to 55.1 mg/kg wet tissue.

The lower Zn level found in the present investigation in Hereford and Braford meat, in comparison to other previously published reports, could be related to the low level of Zn in Uruguayan soil and grass observed by Morón and Baethgen (1998).

For iron, in comparison to other previously published reports, our results show in the present work that Hereford and Braford breeds have a relatively high content (Fig. 4). In the report of Lombardi-Boccia et al. (2005), the five evaluated meat cuts show a Fe level ranged from 18.0 mg to 23.7 mg/kg wet tissue. Another report shows that Fe contents ranged from 20.8 mg to 38.8 mg/kg wet tissue in five different muscles (Kotula and Lusby, 1982). Purchas et al. (2005) compared Fe content in meat of Angus cross heifers pasture-finished in New Zealand, to Angus cross heifers feedlot-finished in USA. The animals pasture-finished from New Zealand show a level of 22.3 mg/kg wet tissue, significantly more

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**Fig. 3.** Zinc content in seven meat cuts from Hereford and Braford steers fed on pasture. Bars are means ± SEM (n = 10–15). Within the same breed, different letters show significant differences between cuts at level of P < 0.05. Cuts name are according to the Uruguayan meat book (INAC, 2006). T = Tenderloin. E = Eye of rump. S = Striploin. ER = Eye round. TT = Tri-tip. RR = Rib eye roll. RP = 3 Rib plate-flank on.
elevated than the animals feedlot-finished from USA, which show a level of 16.5 mg/kg wet tissue. In their comparison between four countries, Williamson et al. (2005) found that Fe content in raw meat from Denmark, United Kingdom, Australia and USA shows levels ranged from 16 mg to 24 mg/kg wet tissue. Finally, the report of Gerber et al. (2009) shows that sirloin, and rib-eye cuts from Switzerland and USA show levels of Fe ranged from 16 mg to 25 mg/wet tissue.

Data about Mn in beef meat are limited in the scientific literature. Nonetheless, the results obtained in the present work were similar those previously reported by others. However, the ER cut in Braford shows an unexplained high level of Mn, between three and five times the Mn level found in the other meat cuts evaluated in the present investigation (Fig. 5). The Mn level detected in Longissimus dorsi of different breeds of cattle produced in Venezuela shows values ranged from 0.08 mg to 0.09 mg/kg wet tissue (Huerta-Leidenz et al., 2003). Gerber et al. (2009) show that sirloin and rib-eye cuts, from United Kingdom and USA market, show Mn levels ranged from 0.056 mg to 0.108 mg/kg wet tissue.

**Fig. 4.** Iron content in seven meat cuts from Hereford and Braford steers fed on pasture. Bars are means ± SEM (n = 10–15). *P* < when included at the top of the bars shows significant difference and value of *P* within the same cut, between Hereford and Braford. Within the same breed, different letters show significant difference between cuts at level of *P* < 0.05. Cuts name are according to the Uruguayan meat book (INAC, 2006). T = Tenderloin. E = Eye of rump. S = Striploin. ER = Eye round. TT = Tri-tip. RR = Rib eye roll. RP = 3 Rib plate-flank on.
4.2. Contribution of Hereford and Braford meat to RDA for Se, Cu, Zn, Fe and AI for Mn in human nutrition

The comparison between the levels of minerals found in the present investigation and their recommended daily allowance (RDA) for Se, Cu, Zn and Fe, and adequate intake (AI) for Mn in human nutrition, shows that the different meat cuts studied in the present investigation supply differently to the nutritional need of adult male, adult female, and children (Fig. 6). The contribution of a fresh 100 g-piece of meat in studied minerals, were compared to the RDA and AI for adult male (19–50 years), adult female (19–50 years) and children (4–8 years) as advised by IMNA (2009).

For Se, the seven meat cuts from Hereford meat cover the RDA in children. For adults, male and female, except RR cut, all the other meat cuts cover the RDA in Se (Fig. 6). For Braford, the seven meat cuts cover the RDA for Se in children and, except S cut, all the other meat cuts cover the RDA for Se in adults, male and female (Fig. 6). Furthermore, as much in Hereford meat cuts as in Braford meat cuts T, TT and RP cuts exceed the RDA for Se for human nutrition.

Taking account the beneficial effect of Se in human health (Berr et al., 2009; Brinkman, Reulen, Kellen, Buntinx, & Zeegers, 2006; González, Huerta, Fernández, Patterson, & Lasheras, 2006;...
Piekutowski, Makarewicz, & Zachara, 2007) the meat cuts studied here can be advised to be consumed if Se are needed in the regime.

The present investigation shows that beef meat is a poor Cu dietetic source (Cámara, Amaro, Barnerá, & Clemente, 2005). However, substantial differences between meat cuts were observed, depending on the RDA considered (Fig. 6). For children, Cu supplied by RP cut in Hereford, and T and RP cuts in Braford, cover approximately 22–24% of the RDA (Fig. 6). Due to the important biological action of Cu in human health (Arvanitidou et al., 2007; Desai & Kaler, 2008; Kelley, Daudu, Taylor, Mackey, & Urnlund, 1995; Uauy, Olivares, & González, 1998; Zuo, Chen, Zhou, Li, & Mei, 2006) the beef meat remains a good way to supply, at least partially, the RDA for Cu in adult and especially for children.

For Zinc, the different meat cuts from the two breeds supply to adult male from 21% to 66% of the RDA, for adult female from 29% to 91%, and for children from 46% to 145% (Fig. 6). In the two breeds, RP cut shows the highest contribution in Zn to the RDA with levels of 66%, 91% and 145% for adult male, adult female and children, respectively. Zinc has important health implications in human and Zn deficiency is a special concern in human nutrition...
(Arvanitidou et al., 2007; Bonham, O’Connor, Hannigan, & Strain, 2002; Hambridge & Krebs, 2007; Zuo et al., 2006). Meat cuts studied here, especially RP, were adequate to counteract a great part of this deficiency (Fig. 6).

For iron, the different meat cuts from the two breeds supply to adult male from 18% to 60% of the RDA, for adult female from 8% to 27%, and for children from 14% to 48% (Fig. 6). The lower contribution to the RDA for adult and children were made by the RR and RP cuts in the two breeds (Fig. 6). The other five cuts contribute together to RDA 50–52% for adult male, 21–23% for adult female and 40–41% for children. So, only a 100 g-piece of meat from those five cuts contributes notably to the RDA in human for Fe. Furthermore, the Fe form which should be consumed is of great importance to achieve its absorption and incorporation in the organism. The haem Fe is the most preferable form to consume this mineral in the diet, and meat is one of the richest source in haem Fe (Anderson, Fraser, & McLaren, 2009; Hallberg, Hoppe, Anderson, & Hulthén, 2003; Umbreit, 2005).

For manganese, the different meat cuts from Hereford and Braford breed supply to adult male 0.17% to 2%, for adult female 0.22% to 2.6% and for children 0.26% to 3.2%, of the adequate intake (AI). As the values of the contribution of the different meat cuts were so low to visualize in comparison to the AI, the results for Mn supply from the meat cuts were not included in Fig. 6. In fact, the higher level of contribution to Mn AI by the different meat cuts in adults and children was due, as stated before, to the unexplained high level of Mn in ER cuts in the two breeds (Fig. 5). When the mean contribution from the different meat cuts to the Mn AI was calculated without the ER value, the highest value of these contributions became <0.61% in adult male, <0.77% in adult female and <0.93% in children.

All presented data concerning the contribution of the different meat cuts to RDA and AI have been calculated on wet tissue basis. However, the meat is consumed generally after a cooking process. So, the calculated RDA and AI could be slightly different. Although the meat cooking caused a weight loss of around 40% (Lombardi-Boccia et al., 2005; Purchas et al., 2003) due essentially to water loss, the minerals content were not necessarily significantly reduced. In the work of Lombardi-Boccia et al., 2005, the content of Fe, Zn and Cu was determined before and after cooking in five beef meat cuts. Their results show a limited loss of minerals in some meat cuts. In the work of Purchas et al. (2003), the recovery of Fe after cooking was around 90% of the initially determined level. Of course, the cooking process is variable among different cultures and countries and consequently, the minerals content of consumed meat should be determined in each specific condition. Much work remains to be done in this aspect.

5. Conclusion

The results of the present investigation show that the content of selenium, copper, zinc, iron and manganese varies with the considered meat cuts. The comparative mineral compositions of all studied meat cuts were presented together in Fig. 7 for Hereford breed. This figure can be useful to help in the choice of the most advised meat cut in relation to a specific mineral, needed in a particular regime, for example, RP cut when Zn is needed, and TT when Fe is required (Fig. 7). Furthermore, comparison presented in Fig. 7 shows that the TT cut has the quantitative best mineral profile if that five studied minerals are needed in a diet. A similar conclusion can be made for the meat cuts from Braford breed. The compared composition of meat cuts presented in Fig. 8 show, as in Hereford breed, that the TT cuts have the same interesting minerals composition when the five studied minerals are required in the diet.

These differences in minerals composition between meat cuts from pasture-fed Hereford and Braford steers found in the present investigation, could be of importance when a particular meat-based food has to be prepared, for example baby food. The results obtained in our work could be important for the preparation of
functional foods proposed as minerals-rich meat-based foods. Future investigation on the meat cuts and minerals composition and solubility should be conducted, especially after cooking, to determine the grade of loss and retention of the different minerals in different meat cuts. So, the results of the present and future investigations will help to advice adequately the best use of each beef meat cut.

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