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CONTENT OF MACRO- AND MICROELEMENTS IN THE MEAT OF YOUNG BULLS OF THREE NATIVE BREEDS (POLISH RED, WHITE-BACKED AND POLISH BLACK-AND-WHITE) IN COMPARISON WITH SIMMENTAL AND POLISH HOLSTEIN-FRIESIAN*

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Abstract

The material for the study consisted of 80 samples taken from the *longissimus lumborum* (LL) and *semitendinosus* (ST) muscles of young bulls of five breeds (8 samples of each muscle per breed), including three native breeds included in the genetic resources conservation programme, i.e. Polish Red, White-Backed and Polish Black-and-White, which together with the Simmental and Polish Holstein-Friesian breeds. The content of the elements (K, Na, Mg, Ca, Zn, Fe, Mn, and Cu) analysed in the meat of the young bulls (fattened in a semi-intensive system on fodder from permanent grassland) was found to depend (in varying degrees) on the breed of cattle. The greatest differences (P<0.01 and P<0.05) were noted between the Polish Holstein-Friesians (PHF) and the remaining breeds, mainly in the content of Mg, Ca, Zn and Mn. The results obtained in the four other breeds for most of the macro- and microelements were more uniform, with the highest content noted in the muscles of the young bulls of the native breeds.

Key words: beef, minerals, young bulls, native breeds

Mineral deficiencies in the human diet continue to be a current problem all over the world. They can be particularly dangerous for children, pregnant women and the elderly. Red meat (primarily beef) is regarded as one of the best means of prevent-

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ing mineral deficiencies, as it supplies essential elements with high bioavailability, particularly Fe and Zn (Cabrera et al., 2010; García-Vaquero et al., 2011; Williams, 2007; Williamson et al., 2005).

The main source of beef in many EU countries (particularly in Central Europe) is dairy breeds of cattle (primarily Holstein-Friesian) and dual-purpose breeds such as Simmental, with beef breeds playing a minor role (Nogalski et al., 2014). The cattle population in Poland is characterized by marked dominance of the dairy breed Holstein-Friesian (Black-and-White and Red-and-White varieties), followed by the Simmental breed, which is a dual-purpose breed (dairy and beef). The dual-purpose type of cattle is also represented by four native breeds included in the genetic resources conservation programme, i.e. Polish Red (protected since 1999), White-Backed (since 2003), Polish Red-and-White (since 2006) and Polish Black-and-White (since 2007).

According to García-Vaquero et al. (2011) and Lombardi-Boccia et al. (2005) microelement content in meat as reported in the literature varies considerably, which can be linked to various factors, including different animal farming techniques and the type of muscle analysed. The global improvement in the quality of life in recent years has raised consumer expectations regarding food, including beef. Consumers are particularly interested in products (or raw materials) of high nutritional value, with functional and bioactive components that play a significant role in maintaining health (Scollan et al., 2006). This type of food should be considered to include products obtained from local breeds of cattle, usually raised on low-input farms with a traditional feeding system, i.e. green forage in the summer and hay in the winter (Litwińczuk et al., 2014). Animals fed on pasture forage supply meat with a more favourable proportion of *n-6/n-3* acids and higher content of beneficial PUFA (especially *n-3*) and of other biologically substances, including vitamin E, carotenoids, iron and zinc (Cabrera and Saadoun, 2014). García-Vaquero et al. (2011) claim that differences in essential metal concentrations between muscles could be related to differences in metabolic activity and/or blood circulation among muscles. Moreover, the most active muscles and those containing less fat have the ability to accumulate greater amounts of essential microelements and smaller amounts of non-essential ones.

In recently published studies (Cabrera et al., 2010; Pilarczyk, 2014; Ramos et al., 2012) analysing mineral content in beef from cattle raised in the same conditions, breed was found to be a significant factor determining the content of elements in muscle tissue.

Several studies have recently been published concerning the carcass value and physicochemical properties of the meat of native cattle breeds (Iwanowska et al., 2010; Litwińczuk et al., 2012; Litwińczuk et al., 2014), but information is lacking on the content of macro- and microelements in the meat of these animals. Therefore, a study was undertaken in order to analyse the content of selected macro- and microelements in 2 muscles of young bulls of three native breeds – Polish Red (PR), White-Backed (WB) and Polish Black-and-White (PBW) – and to compare the results with the meat of young Simmental (SIM) and Polish Holstein-Friesian (PHF) bulls fattened in the same conditions.

Material and methods

The research material consisted of samples of the *longissimus lumborum* (LL, n=40) and *semitendinosus* (ST, n=40) muscles collected from the carcasses of young bulls of 5 breeds (8 from each breed). The calves included in the experiment were purchased in south-eastern Poland from local breeders. During the initial period the calves were fed with milk and milk substitutes, and subsequently grass forage, hay, and concentrate (up to 6 months of age).

After this period the semi-intensive fattening was initiated and continued for 12 months, including both a winter and a summer feeding season. The animals were housed in a tie-stall system. The basic feed during the winter consisted of hay and maize silage, and in the summer mainly grass forage supplemented with maize silage and hay. The feed rations were supplemented with small amounts of grain meal. The bulls were slaughtered at the age of 18–20 months. Muscle samples were collected during dissection of the right half of the carcasses (following 24-hour refrigeration at 2°C, relative humidity 85%), vacuum-packed in PA/PE vacuum bags and stored at 2–4°C until analysis, 48 h after slaughter.

The muscles' samples (1 g) were wet-digested with 9 ml concentrated nitric acid (Suprapur grade, Merck) using a MarsXpress microwave oven (CEM Corporation, Matthews, NC, USA). Digested samples were transferred to polypropylene tubes and diluted to 25 ml with ultrapure water. A blank digest (9 ml HNO_3) was carried out in the same way. The concentration of major elements (potassium, sodium, calcium and magnesium) and minor elements (zinc, iron, manganese and copper) was determined by means of flame atomic absorption spectrometry (FAAS; air-acetylene flame) using a Varian Spectra 240FS spectrometer.

Table 1. The detection limits (LOD), mineral concentrations and recoveries (mean ± standard deviation)

	LOD (mg/kg)	Standard Reference Material 1577c Bovine Liver		Recovery (%)
		certified value (mg/kg)	measured value (mg/kg)	
K	0.04	10.230±640	9.868.6±480.71	96.5
Na	0.01	2.033±64	2.086.1±69.23	102.6
Ca	0.22	131±10	140.4±6.63	107.1
Mg	0.47	620.4±42	627.1±42.06	101.1
Zn	0.01	181.1±1.00	176.1±4.54	97.2
Fe	0.09	197.9±0.65	196.5±2.09	99.8
Mn	0.01	10.5±0.47	10.5±0.71	100.3
Cu	0.01	275.±4.60	287.2±7.02	104.4

In order to determine sodium and potassium levels, a solution of caesium chloride was added as a deionized buffer to all of the samples and standards. A lanthanum chloride solution was used as a correction buffer to determine calcium and potassium. During the analysis deuterium background correction was used and limits of quantification (LOQ) and detection (LOD) were taken into account. Method accuracy was evaluated using minerals determined in the Standard Reference Material 1577c Bovine Liver. The limits of detection, certified and measured value, and recovery are presented in Table 1. The analyses were performed in triplicate. The content of major and minor elements in the samples was expressed in mg/kg wet mass.

The statistical analyses were performed using SAS Enterprise Guide 6.1 software (SAS, 2013). To test the normality and the homogeneity of variance of data, Kolmogorov–Smirnov's test and Levene's F-test, respectively, were used. One-way analysis of variance (ANOVA), followed by Tukey's (HSD) test, was used to compare means of mineral concentration in the individual muscles of different cattle breeds (PR, WB, PBW, SIM and PHF). Differences between means at confidence levels of 95% and 99% ($P<0.05$ and $P<0.01$, respectively) were considered statistically significant.

Results

The data in Tables 2 and 3 show that the content of K, Na, Mg, Ca, Zn, Mn and Cu in the meat of the young bulls (fattened in a semi-intensive system mainly based on fodder from permanent grassland) depended on the breed of cattle. In both muscles analysed (LL and ST), the content of Mg and Ca was significantly lower in the dairy breed (PHF), and in the ST muscle K content was lower as well. The average content of Mg in the meat of the PHF bulls was 227.2 mg/kg in the ST and 246.6 mg/kg in the LL, which was nearly 1/3 lower than in the meat of the native breeds (PR, WB and PBW) and the Simmentals, which represent a dual-purpose type of cattle. It should be emphasized that in all dual-purpose breeds Mg content was very comparable, ranging from 295.2 mg/kg in the LL of the WB bulls to 323.7 mg/kg in the ST of the PR bulls. Similar tendencies were noted for Ca content. In the meat of the PHF bulls it was also very similar in the two muscles, i.e. 19.8 mg/kg (ST) and 21.0 mg/kg (LL), and nearly two times lower than in the other four dual-purpose breeds (32.7–47.4 mg/kg). The highest Ca content was noted in the muscles of the young bulls of the native breeds, particularly WB and PBW, for which the differences were significant not only with respect to PHF but in comparison with SIM as well.

The data in Tables 2 and 3 show that both muscles of the young bulls of the dairy breed PHF contained significantly ($P<0.05$) more Zn, and the ST muscle also contained more Mn ($P<0.05$). Zn content in the two muscles was very similar in the PHF bulls (41.9 mg/kg in the LL and 40.5 mg/kg in the ST), and considerably higher than in the muscles of the SIM bulls (22.6 mg/kg – ST and 28.8 mg/kg – LL). In the muscles of the young bulls of the native breeds the Zn concentration was intermediate, ranging from 34.9 (PR) to 39.2 (WB) mg/kg in the LL muscle and from 26.3 (PR) to 37.3 (PBW) mg/kg in the ST. The lowest Cu content (0.44 mg/kg and 0.60 mg/kg) was noted in the muscles of the young SIM bulls, and in the case of the ST muscle it was statistically significant ($P<0.05$).

Table 2. Content of macro- and microelements (in mg/kg fresh tissue) in the *longissimus lumborum* (LL) muscle of the young bulls (mean ± standard error and minimum – maximum in parentheses)

	Native breed			Native breed average	Reference group	
	PR	WB	PBW		SIM	PHF
K	3.705.7 ab±90.56 (3410.8–4149.4)	3.764.4 b±161.84 (3182.4–4355.5)	3.679.9 ab±118.28 (3111.1–4169.2)	3.716.7±70.45 (3111.1–4355.5)	3.268.9 a±68.96 (2984.3–3524.3)	3.411.4 ab±303.01 (2738.9–3678.3)
Na	548.9 B±57.22 (395.6–795.1)	367.6 A±20.71 (299.5–450.4)	447.8 AB±37.84 (342.2–632.4)	454.7±27.57 (299.5–795.1)	483.2 AB±15.04 (445.0–551.7)	464.0 AB±39.07 (305.2–683.0)
Mg	315.3 B±6.22 (280.5–343.4)	295.2 B±13.25 (245.1–341.7)	320.1 B±10.41 (297.5–381.7)	310.2±56.15 (245.1–381.7)	310.2 B±9.28 (265.0–339.9)	246.6 A±8.19 (203.5–269.1)
Ca	36.5 bc±2.23 (25.7–47.9)	46.4 bc±2.77 (35.1–56.1)	47.4 c±4.30 (37.3–66.6)	43.4±2.05 (25.7–66.6)	34.4 b±1.27 (29.0–39.3)	21.0 a±3.42 11.9–40.4
Zn	34.9 ab±1.82 (28.9–43.3)	39.2 b±3.49 (27.9–56.2)	38.8 b±1.99 (33.0–47.6)	37.6±1.46 (27.9–56.2)	28.8 a±1.82 (20.7–34.5)	41.9 ±2.52 31.5–56.1
Fe	25.3±2.02 (16.2–30.6)	21.6±1.26 (17.2–27.4)	18.5±1.66 (12.0–27.8)	21.8±1.09 (12.0–30.6)	21.9±2.91 (12.6–32.2)	21.6±1.17 17.0–27.2
Mn	0.1 A±0.01 (0.1–0.2)	0.6 B±0.09 (0.1–1.4)	0.1 A±0.01 (0.1–0.2)	0.3±0.07 (0.1–1.4)	0.1 A±0.01 (0.1–0.2)	0.5 AB±0.08 0.2–0.8
Cu	0.6±0.03 (0.5–0.8)	0.7±0.05 (0.6–0.9)	0.6±0.02 (0.–0.6)	0.6±0.02 (0.5–0.9)	0.6±0.01 (0.6–0.7)	0.7±0.08 0.4–1.0

A, b, c – values in rows with different letters differ significantly (P<0.05).
A, B, C – as above for P<0.01.
PR – Polish Red breed; WB – White-Backed breed; PBW – Polish Black-and-White breed; SIM – Simmental breed; PHF – Polish Holstein-Friesian breed.

Table 3. Content of macro- and microelements (in mg/kg fresh tissue) in the *semitendinosus* (ST) muscle of the young bulls (mean ± standard error and minimum – maximum in parentheses)

	Native breed			Native breed average	Reference group	
	PR	WB	PBW		SIM	PHF
K	3.970.4 C±84.00 (3701.5–4346.1)	3.764.1 BC±114.35 (3185.3–4312.9)	3.516.4 B±100.04 (3054.5–3768.6)	3.750.3±67.49 (3054.5–4346.1)	3.646.1 B±98.29 (3326.8–4103.8)	2,998.2 A±80.17 (2519.7–3195.0)
Na	418.2 bc±37.43 (278.6–566.2)	337.7 a±6.83 (320.4–369.7)	382.1 ab±25.45 (303.7–499.2)	379.3±16.11 (278.6–566.2)	536.6 d±23.41 (462.8–644.5)	478.4 cd±35.91 (320.9–574.2)
Mg	323.7 B±7.46 (293.9–361.9)	303.0 B±11.67 (250.8–345.6)	321.7 B±11.09 (301.1–376.9)	316.1±5.98 (250.8–376.9)	314.9 B±12.63 (259.6–364.6)	227.2 A±11.77 (175.0–276.8)
Ca	34.4 bc±2.62 (27.5–49.1)	41.5 c±3.80 (26.3–55.8)	36.0 bc±2.60 (30.3–50.2)	37.3±1.81 (26.3–55.8)	32.7 b±1.47 (26.5–38.9)	19.8 a±2.66 (12.4–35.6)
Zn	26.3 a±1.96 (20.6–38.5)	34.5 b±1.22 (30.0–37.3)	37.3 bc±2.38 (25.2–44.7)	32.7±1.43 (20.6–44.7)	22.6 a±2.20 (13.5–34.0)	40.5 c±1.70 (31.3–47.6)
Fe	17.4 ab±1.43 (12.2–23.5)	17.5 ab±0.50 (14.1–18.8)	19.2 b±1.96 (11.6–26.9)	18.0±0.81 (11.6–26.9)	13.4 a±1.90 (6.6–18.1)	22.0 b±2.33 (11.0–27.9)
Mn	0.1 A±0.01 (0.1–0.2)	0.1 A±0.01 (0.1–0.2)	0.1 A±0.01 (0.1–0.2)	0.1±0.01 (0.1–0.2)	0.2 A±0.01 (0.1–0.2)	0.7 B±0.06 (0.4–0.9)
Cu	0.5 a±0.04 (0.3–0.7)	0.7 c±0.03 (0.6–0.8)	0.6 bc±0.03 (0.5–0.7)	0.6±0.03 (0.3–0.8)	0.4 a±0.05 (0.3–0.7)	0.5 ab±0.07 (0.3–0.8)

a, b, c – values in rows with different letters differ significantly (P<0.05).
A, B, C – as above for P<0.01.
PR – Polish Red breed; WB – White-Backed breed; PBW – Polish Black-and-White breed; SIM – Simmental breed; PHF – Polish Holstein-Friesian breed.

Discussion

Summing up the results obtained we can conclude that the breed of cattle has a significant effect on the content of macro- and microelements in the meat of animals fattened in the same conditions. The greatest (and significant) differences were obtained for the PHF breed, mainly in the content of Mg, Ca, Zn and Mn. In the other four breeds the results obtained for most of the macro- and microelements analysed were less varied.

Ramos et al. (2012) analysed the content of microelements (Se, Cu, Zn, Fe and Mn) in the muscles of Hereford and Braford steers, and found significantly higher content of Cu and lower content of Fe in the former. On the other hand, Cabrera et al. (2010) noted significant differences in steers of these breeds only in the case of Mn. Although meat and meat products are a marginal source of manganese in the human diet in comparison with plant products, according to Ramos et al. (2012) it is worth determining Mn level in meat due to the limited information on its content in animal products. Pilarczyk (2014) analysed the percentages of 15 elements in the LL of young bulls of three breeds (Charolais, Hereford and Simmental) fattened intensively in north-western Poland and found that the breed significantly influenced content of K, Mg, Fe, Zn, Cu and Mn. According to the author, the differences between breeds in the content of minerals have a metabolic basis, and the significantly lower percentage of certain elements in the meat of the Charolais bulls may indicate that this breed has a higher demand for minerals during intensive growth of muscle tissue. This is also pointed out by Ward et al. (1995), who demonstrated higher demand for Cu in Simmental and Charolais cattle than in the Angus breed. These differences were probably determined not only by different degrees of copper absorption from the digestive tract, but also by differences in metabolism and the degree of its utilization after it is absorbed. Similar results to those mentioned above were obtained by Mullis et al. (2003), who noted a lower Cu concentration in the serum and liver and lower serum ceruloplasmin activity in steers of the Simmental breed than in Angus steers. Observed relationships suggest that Simmental cattle have a higher demand for copper. Other studies have also indicated that breed influences Mg and Ca contents and the Zn content in the liver (Greene et al., 1989; Littledike et al., 1995). The influence of breed on the efficiency of Cu metabolism is well documented in the literature, and the differences observed may be caused not only by genetic differences, but also by biliary excretion of copper and by the amount of fodder consumed by the animals (Du et al., 1996; Gooneratne et al., 1994; Pilarczyk, 2014). Gooneratne et al. (1994) revealed that biliary excretion of copper was two times greater in the Simmental breed than in Aberdeen Angus, irrespective of the level of Cu in the feed ration. Miranda et al. (2010) revealed that steers of the beef breed Galician Blond (GB) and its crossbreds with Holstein-Friesian (HF) consumed 18% and 9% less fodder, respectively, than purebred Holstein-Friesians. The authors suggest that animals (especially beef breeds) characterized by a higher dressing percentage and better carcass conformation have a greater demand for Cu, which leads to increased mobilization of Cu from the liver (the main Cu storage site) and in consequence to lower Cu retention in this organ. Similar correlations were observed in the presented study, as the lowest Cu content was in the ST muscle of the Simmental bulls, which have the most pronounced musculature of the five breeds compared, with significant (P<0.05) differences noted with respect to the WB and PBW breeds. It should be noted that in our previous study (Litwińczuk et al., 2014) the young bulls of the SIM breed attained significantly (P<0.05) higher daily weight gain (986 g) than the other four breeds evaluated (854–919 g).

Moreover, Miranda et al. (2010) evaluating Cu content in three muscles (*semitendinosus*, *pectoralis* and *diaphragma*) in steers of GB and HF breed and their crossbreds, found significant differences only in the case of the ST muscle. The lowest Cu level in the ST was noted in the GB beef breed (0.541 mg/kg fresh weight), while the highest level was noted in HF (0.790 mg/kg fresh weight). Also, our results showed that the LL and ST muscles of the SIM bulls contained the least Zn, with significant (P<0.05) differences confirmed with respect to the breeds WB, PBW and PHF.

García-Vaquero et al. (2011) claim that in situations of adequate mineral status in the muscle, trace element concentrations are dependent on their own internal metabolism. To maintain mineral homeostasis in muscles and other tissues, organisms have developed different mechanisms such as metallothioneins, chaperones, and other metal transporters, particularly divalent metal transporter 1 (involved in traffic of divalent metals, including Fe, Zn and Cu, into cells), ubiquitously expressed in all tissues including the kidney, the brain, and cardiac muscle (Gunshin et al., 1997; Mackenzie et al., 2007; Ke et al., 2003). The fact that some of the essential metals do not follow the same intermuscular distribution pattern could be related to metal interactions or antagonisms to maintain a correct mineral balance (García-Vaquero et al., 2011).

Owing to the fact that the content of the most of macro- and microelements analysed was highest in the meat of the young bulls of the native breeds in comparison with the other two breeds (the reference group), the meat of these animals can be a valuable source of important elements for human beings.

References

Cabrera M.C., Saadoun A. (2014). An overview of the nutritional value of beef and lamb meat from South America. Meat Sci., 98: 435–44.

Cabrera M.C., Ramos A., Saadoun A., Brito G. (2010). Selenium, copper, zinc, iron and manganese content of seven meat cuts from Hereford and Braford steers fed pasture in Uruguay. Meat Sci., 84: 518–528.

Du Z., Hemken R.W., Harmon R.J. (1996). Copper metabolism of Holstein and Jersey cows and heifers fed diets high in cupric sulfate or copper proteinate. J. Dairy Sci., 79: 1873–1880.

García-Vaquero M., Miranda M., Benedito J.L., Blanco-Penedo I., López-Alonso M. (2011). Effect of type of muscle and Cu supplementation on trace element concentrations in cattle meat. Food Chem. Toxicol., 49: 1443–1449.

Gooneratne S.R., Symonds H.W., Bailey J.V., Christensen D.A. (1994). Effects of dietary copper, molybdenum, and sulfur on biliary copper and zinc excretion in Simmental and Angus cattle. Can. J. Anim. Sci., 74: 315–325.

Greene L.W., Baker J.F., Hardt P.F. (1989). Use of animal breeds and breeding to overcome the incidence of grass tetany: a review. J. Anim. Sci., 67: 3463–3469.

Gunshin H., Mackenzie B., Berger U.V., Gunshin Y., Romero M.F., Boron W.F., Nussberger S., Gollan J.L., Hediger M.A. (1997). Cloning and characterization of a mammalian proton-coupled metal-ion transporter. Nature, 388: 482–488.
Iwanowska A., Pospiech E., Łyczyński A., Rosochacki S., Grześ B., Mikołajczak B., Iwańska E., Rzosińska E., Czyżak-Runowska G. (2010). Evaluation of variations in principal indices of the culinary meat quality obtained from young bulls of various breeds. Acta Sci. Pol.-Technol. Aliment., 9: 133–149.
Ke Y., Chen Y.Y., Chang Y.Z., Duan X.L., Ho K.P., Jiang D.H., Wang K., Qian Z.M. (2003). Post-transcriptional expression of DMT1 in the heart of rat. J. Cell. Physiol., 196: 124–130.
Littledike E.T., Wittum T.E., Jenkins T.G. (1995). Effect of breed, intake, and carcass composition on the status of several macro and trace minerals of adult beef cattle. J. Anim. Sci., 73: 2113–2119.
Litwińczuk Z., Chabuz W., Domaradzki P., Jankowski P. (2012). The slaughter value of young bulls of Polish Black-White, White-Backed, Polish Holstein-Friesian and Limousin breeds from semi-intensive fattening. Ann. Anim. Sci., 12: 159–168.
Litwińczuk Z., Żółkiewski P., Florek M., Chabuz W., Domaradzki P. (2014). Semi-intensive fattening suitability and slaughter value of young bulls of 3 Polish native breeds in comparison with Polish Holstein-Friesian and Simmental. Ann. Anim. Sci., 14: 453–460.
Lombardi-Boccia G., Lanzi S., Aguzzi A. (2005). Aspects of meat quality: Trace elements and B vitamins in raw and cooked meats. J. Food Compos. Anal., 18: 39–46.
Mackenzie B., Takanaga H., Hubert N., Rolfs A., Hediger M.A. (2007). Functional properties of multiple isoforms of human divalent metal ion transporter 1 (DMT1). Biochem. J., 403: 59–69.
Miranda M., Gutiérrez B., Benedito J.L., Blanco-Penedo I., García-Vaquero M., López-Alonso M. (2010). Influence of breed on blood and tissue copper status in growing and finishing steers fed diets supplemented with copper. Arch. Anim. Nutr., 64: 98–110.
Mullis L.A., Spears J.W., McCraw R.L. (2003). Effects of breed (Angus vs Simmental) and copper and zinc source on mineral status of steers fed high dietary iron. J. Anim. Sci., 81: 318–322.
Nogalski Z., Wielgosz-Groth Z., Purwin C., Nogalska A., Sobczuk-Szul M., Winarski R., Pogorzelska P. (2014). The effect of slaughter weight and fattening intensity on changes in carcass fatness in young Holstein-Friesian bulls. Ital. J. Anim. Sci., 13: 66–72.
Pilarczyk R. (2014). Concentrations of toxic and nutritional essential elements in meat from different beef breeds reared under intensive production systems. Biol. Trace Elem. Res., 158: 36–44.
Ramos A., Cabrera M.C., Saadoun A. (2012). Bioaccessibility of Se, Cu, Zn, Mn and Fe, and heme iron content in unaged and aged meat of Hereford and Braford steers fed pasture. Meat Sci., 91: 116–124.
Scollan N., Hocquette J.F., Nuernberg K., Dannenberger D., Richardson I., Moloney A. (2006). Innovations in beef production systems that enhance the nutritional and health value of beef lipids and their relationship with meat quality. Meat Sci., 74: 17–33.
Ward J.D., Spears J.W., Gengelbach G.P. (1995). Differences in copper status and copper metabolism among Angus, Simmental, and Charolais cattle. J. Anim. Sci., 73: 571–577.
Williams P. (2007). Nutritional composition of red meat. Nutr. Diet., 64: 113–119.
Williamson C.S., Foster R.K., Stanner S.A., Buttriss J.L. (2005). Red meat in the diet. Nutr. Bull., 30: 323–355.

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