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ORIGINAL PAPER

FULFILMENT OF THE REQUIREMENTS OF ADULTS AND CHILDREN FOR MINERALS BY BEEF, TAKING INTO ACCOUNT THE BREED OF CATTLE AND MUSCLE*

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Abstract

As well as having the information about the nutritional value of raw meat, today's consumers expect to be informed to what extent cooked meat meals satisfy recommended nutrition standards. The aim of the study was to estimate the degree to which the demand for selected macrominerals (K, Na, Mg, Ca) and microminerals (Zn, Fe, Mn, Cu) by adults and children is met by a portion of 100 g of cooked beef. For calculations, the average cooking loss at 40% and retention factors between 0.85 and 1.0 were taken into consideration. The degree of satisfying Polish nutrition standards (Recommended Dietary Allowance – RDA and Adequate Intake – AI) was analysed depending on a muscle (*longissimus lumborum* – LL *vs. semitendinosus* – ST) and breed of young bulls (Polish Red – PR, Whitebacked – WB, Polish Black-and-White – PBW, Simmental – SIM and Polish Holstein-Fresian – PHF). Among the evaluated cattle breeds, the meat of PHF bulls met to the greatest degree the recommended dietary allowance (RDA) for Zn, Fe and Mn, and to the smallest degree the daily requirement for K and Mg. The LL and ST muscles satisfied the nutritional standards for major minerals to a similar degree, and were primarily (especially the LL muscle) a good source of Zn and Fe (for adults and children), as well as a source of K, Mg and Cu for children. Consumption of 100 g of cooked meat (depending on the breed) satisfied from 52% to 85% of the RDA for Zn for women, 38-62% for men and as much as 83-136% for children. For Fe, the percentages were 14-20% for women and 26-36% both for men and children. Cooked beef was an important source of Mg, particularly for chil-

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dren, as a portion of 100 g met from 27% to 35% of their RDA. However, the same portion met only 3-5% of the daily standard for Na for adults and 4-6% for children.

Keywords: beef, minerals, Recommended Dietary Allowance, Polish Holstein-Friesian breed, Polish native cattle breeds.

INTRODUCTION

Beef should be treated as functional food which supplies high-quality protein, fatty acids (including essential unsaturated fatty acids and CLA), vitamins and minerals, particularly Fe and Zn (Williams 2007, McAfee et al. 2010, Wyness et al. 2011, Litwińczuk et al. 2015, Buzała et al. 2016). Diets excluding animal products (especially red meat) can be particularly dangerous for children, pregnant women and the elderly (Williams 2007, Cabrera et al. 2010, Wyness et al. 2011)

Mineral content in beef as reported in literature varies considerably, which can be linked to the breed, the age of animals, feeding practice, geographical site of rearing, type of muscle as well as meat processing (Lombardi-Boccia et al. 2005, Cabrera et al. 2010, García-Vaquero et al. 2011, Czerwonka, Szterk 2015). Czerwonka and Szterk (2015) revealed that the content of minerals (except Na) in longissimus dorsi (LD) of Polish Holstein-Fresian (PHF) bulls after different cooking methods significantly increased. Nevertheless, the percentage increase for macrominerals (K, P, Mg) was between 6 and 14%, and for microminerals (Zn and Fe) it ranged from 11 to 26%. The observed increase was not dependent ($P > 0.05$) on cooking methods (grilling, roasting, frying).

In Poland, like in most of Central European countries, the share of beef breeds in the whole cattle population does not exceed 1%. Therefore, the majority of beef is obtained from dairy cattle, mainly Polish Holstein-Friesian breed or dual-purpose cattle. Polish Holstein-Friesian breed represents over 85% in the structure of beef production in Poland (Węglarz 2010, Nogalski et al. 2014). The dual-purpose cattle include the following breeds: Polish Red, Whitebacked, Polish Black-and-White, Polish Red-and-White (covered by the programme of genetic resources protection) and Simmental (Litwińczuk et al. 2014).

In the recent years, the meat nutritional value of PHF breed, including the content of minerals, has been the subject of just a few studies (Czerwonka, Szterk 2015). This is also true about meat from native cattle breeds included in the programme of the genetic resources conservation. One of the main actions that assure the sustainability of native breeds is by promoting food products derived from these animals. However, a key prerequisite is to establish their actual nutritional value.

Informed consumers currently expect not only to obtain nutritional information about raw meat, but also to know to what degree cooked meat meals fulfil recommended nutritional standards. However, literature contains no reports on the degree to which the requirements for macro- and microminerals in the Polish population are satisfied by beef consumption. On the basis of results pertaining to the content of macro- and microminerals in two muscles of young bulls of 5 breeds (Polish Red – PR, White-Backed – WB, Polish Black-and-White – PBW, Simmental – SIM and Polish Holstein-Friesian – PHF), the extent to which the requirement for these minerals in adults and children is met by an edible portion of 100 g of meat was determined.

MATERIAL AND METHODS

Samples

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 of rearing, the calves were fed with milk and milk substitutes, and subsequently received grass forage, hay and concentrate (up to 6 months of age).

After this period, 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 it was mainly composed of grass forage supplemented with maize silage and hay. The feed rations were supplemented with small amounts of grain meal. The bulls were slaughtered at an average age of 18 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.

Sample preparation and analysis

Samples of muscles (1 g) were wet-digested with 9 ml concentrated nitric acid 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 prepared in the same way. The concentration of macrominerals (potassium, sodium, calcium and magnesium) and microminerals (zinc, iron, manganese and copper) was determined by flame atomic absorption spectrometry (FAAS; air-acetylene flame) using a Varian Spectra 240FS spectrometer.

In order to determine sodium and potassium levels, solution of caesium chloride was added as deionised buffer to all of the samples and standards. Lanthanum chloride solution was used as correction buffer to determine calcium and potassium. During the analysis, deuterium background correction was used and limits of quantification (LOQ) were taken into account. The following detection limits (LOD) were considered: 0.01 mg kg^{-1} for Na, Zn, Mn and Cu, 0.04 mg kg^{-1} for K, 0.09 mg/kg for Fe, 0.22 mg kg^{-1} for Ca and 0.47 mg kg^{-1} for Mg. The method's accuracy was evaluated using minerals determined in the Standard Reference Material 1577c Bovine Liver. The analyses were performed in triplicate. The content of macro- and microminerals in the samples was expressed in mg kg^{-1} of wet mass.

Assessment of minerals content in relation to nutrient requirements

Percentages of the recommended daily allowance (RDA) of Mg, Ca, Fe, Zn and Cu and the Adequate Intake (AI) of K, Na and Mn were determined for 100 g of meat after heat treatment, assuming a 40% loss of raw meat due to cooking processes (Purchas et al. 2003, Lombardi-Boccia et al. 2005). The retention factors used for the minerals were as follows: Zn and Cu – 1.0; Ca and Fe – 0.95; and K, Na and Mg – 0.85 (USDA 2007). Due to the lack of available literature data, losses during cooking were not taken into account for Mn and a retention factor of 1.0 was adapted.

The percentage of the RDA and AI for minerals contained in 100 g of cooked beef was determined for adults, i.e. for women aged 19-50 and men aged 19-50, and for children aged 4-9, according to nutritional standards for the Polish population proposed by the National Food and Nutrition Institute in Warsaw (Jarosz 2012). For most of the minerals, these standards are in agreement with recommendations by the Institute of Medicine of the National Academies (Iom 2010), and only slightly higher in the case of Fe for men and Cu for children. Moreover, Polish nutritional standards do not specify a requirement for Mn, so the Adequate Intake (AI) level suggested by the Institute of Medicine of the National Academies (Iom 2010) for these groups was used in the calculations.

Statistical analysis

The statistical analyses were performed using SAS Enterprise Guide 6.1 software (SAS Institute Inc.). The Mann-Whitney-Wilcoxon test was used to compare the mineral concentration in the muscles (LL vs. ST), and the Kruskal-Wallis test by ranks was applied for comparison of medians in the meat of different cattle breeds (PR, WB, PBW, SIM and PHF). Differences between median values at confidence levels of 95% and 99% ($P < 0.05$ and $P < 0.01$, respectively) were considered statistically significant. In the tables, a median, an interquartile range and the range between the 25^{th} percentile and the 75^{th} percentile are given.

RESULTS AND DISCUSSION

The significantly ($P < 0.01$) lowest contents of Mg and Ca were detected in meat from young bulls of PHF breed, which concomitantly contained significantly ($P < 0.01$) less K compared to PR and WB breeds (Table 1). Moreover, meat from PHF bulls was characterized by the significantly ($P < 0.01$) highest Mn content and a higher Zn ($P < 0.01$) content than that from SIM and PR bulls (Table 2). The average concentration of Fe in the examined meat samples was comparable, regardless of a breed. Meat from bulls of native WB breed had the significantly ($P < 0.01$) highest Cu content in comparison with PR and SIM meat. The significantly higher concentrations of Ca ($P < 0.05$), Zn ($P < 0.05$), Fe ($P < 0.01$) and Cu ($P < 0.01$) had LL muscle than ST (Tables 1 and 2).

Many authors suggest that beef, among other commonly consumed meats, is a valuable source of macro- and microminerals in the human diet (Williams 2007, Cabrera et al. 2010, Ramos et al. 2012).

The results presented in Table 1 show that the degree to which the nutritional standards (RDA and AI) for the minerals analysed (particularly the microminerals and magnesium) are met by the meat varies depending on the breed of the bulls. Irrespective of the differences between the breeds, beef was primarily a very good source of Zn and Fe for the population groups analysed. Consumption of 100 g of cooked meat satisfied from 52% to 85% of the RDA for Zn for women, 38-62% for men and as much as 83-136% for children. For Fe, the percentages were 14-20% for women and 26-36% for men and children. The daily requirements for Zn and Fe were satisfied to the greatest degree by the meat of the PHF bulls, followed by the native breeds, while the lowest result was obtained for the young SIM bulls. According to many authors, beef is one of the richest sources of iron and zinc (Lombardi-Boccia et al. 2005, Williams 2007, Wyness et al. 2011). This is particularly significant in view of the fact that Fe and Zn deficiencies are a common problem occurring even in developed countries (Schönfeldt et al. 2010, Wyness et al. 2011).

Williams (2007) reports that 100 g of lean beef satisfies on average 30% of the daily requirement for Zn and 24% of the requirement for Fe in an adult Australian males. A study by Cabrera et al. (2010) showed that 100 g of uncooked meat cuts obtained from Hereford and Braford steers met 29-91% of the RDA for Zn for women, 21-66% for men and 46-145% for children, while the corresponding percentages for Fe were 8-27% for women, 18-60% for men and 14-48% for children.

The present study also shows that cooked beef is an important source of Mg, particularly for children, as an edible portion of 100 g met (depending on the breed) satisfies from 27% to 35% of their daily requirement for this element. The meat of young bulls of native breeds and the SIM breed reached a higher percentage of the standards for Mg (14% of the RDA for women, 11%

Table 1

Content of macrominerals (in mg kg^{-1} fresh tissue, median ± interquartile range and in parentheses the range between the 25th percentile and the 75th percentile of the distribution) and percentage of standard for these elements met by 100 g of cooked meat[a] in different population groups

Specification	Group	mg/day[b]	Breed					Muscle	
			PR	WB	PBW	SIM	PHF	LL	ST
					K				
			$3824.43^{B} \pm 340.65$	$3756.36^{B} \pm 667.28$	$3642.05^{AB} \pm 350.17$	$3422.95^{AB} \pm 282.10$	$3185.68^{A} \pm 407.69$	3502.68 ± 491.72	3691.97 ± 652.64
			(3660.43 - 4001.08)	(3424.92 - 4092.20)	(3438.23 - 3788.40)	(3291.51 - 3573.61)	(3043.06 - 3450.76)	(3319.16 - 3810.87)	(3190.16 - 3842.80)
% of standard	female	4700	12	11	11	10	9	11	11
	male	4700	12	11	11	10	9	11	11
	children	3400	16	16	15	14	13	15	15
					Na				
			$468.16^{B} \pm 142.21$	$335.39^{A} \pm 54.56$	$386.90^{AB} \pm 110.49$	$486.27^{B} \pm 85.26$	$479.28^{B} \pm 143.61$	444.96 ± 106.94	431.86± 176.49
			(395.56 - 537.77)	(321.24 - 375.80)	(345.94 - 456.43)	(462.89 - 548.15)	(400.58 - 544.19)	(386.74 - 493.68)	(327.65 - 504.14)
% of standard	female	1500	4	3	4	5	5	4	4
	male	1500	4	3	4	5	5	4	4
	children	1100	6	4	5	6	6	6	6
					Mg				
			$317.90^{B} \pm 19.73$	$304.54^{B} \pm 68.70$	$304.74^{B} \pm 33.49$	$319.31^{B} \pm 42.08$	$245.91^{A} \pm 46.48$	306.17 ± 55.07	304.79 ± 62.83
			(309.09 - 328.82)	(262.72 - 331.42)	(301.87 - 335.36)	(290.47 - 332.55)	(211.28 - 257.77)	(264.79 - 319.86)	(267.71 - 360.54)
% of standard	female	315	14	14	14	14	11	14	14
	male	410	11	11	11	11	8	11	11
	children	130	35	33	33	35	27	33	33
					Ca				
			$34.49^{B} \pm 9.20$	$42.24^{B} \pm 14.13$	$38.09^{B} \pm 15.00$	$34.45^{B} \pm 5.33$	$17.70^{A} \pm 10.03$	$38.46^{y} \pm 9.65$	$32.54^{x} \pm 11.33$
			(29.40 - 38.60)	(38.60 - 52.72)	(32.16 - 47.16)	(30.63 - 35.95)	(14.55 - 24.58)	(31.47 - 41.12)	(27.25 - 38.58)
% of standard	female	1000	0.6	0.7	0.6	0.5	0.3	0.6	0.5
	male	1000	0.6	0.7	0.6	0.5	0.3	0.6	0.5
	children	1000	0.6	0.7	0.6	0.5	0.3	0.6	0.5

[a] The % of the standard met by 100 g of cooked meat was calculated on the basis of the mineral content in raw meat, assuming 40% cooking loss from the raw meat (Purchas et al. 2003, Lombardi-Boccia et al. 2005) and the following retention factors: Ca – 0.95; K, Na, Mg – 0.85 (USDA 2007);

[b] AI: adequate intake – K, Na; RDA: recommended dietary allowance – Mg, Ca. Source for nutrient requirements Jarosz (2012);

Means for breeds denoted by different letters in rows differ statistically significantly: *A*, *B*, *C* $P < 0.01$. Means for muscles denoted by different letters in rows differ statistically significantly: *x*, *y* $P < 0.05$.

Table 2

Content of microminerals (in mg kg^{-1} fresh tissue, median ± interquartile range and in parentheses the range between the 25th percentile and the 75th percentile of the distribution) and percentage of standard for these elements met by 100 g of cooked meat[a] in different population groups

Specification	Group	mg/day[b]	Breed					Muscle	
			PR	WB	PBW	SIM	PHF	LL	ST
			Zn						
			30.27^{AB} ± 8.36	36.47^{BC} ± 8.33	36.69^{BC} ± 6.98	24.80^{A} ± 10.24	40.80^{C} ± 4.95	36.34^{y} ± 9.60	32.66^{x} ±13.19
			(25.55 – 33.91)	(30.39 – 38.72)	(35.34 – 42.31)	(21.97 – 32.21)	(38.06 – 43.00)	(31.79 – 41.39)	(25.08 – 38.28)
% of standard	female	8	63	76	76	52	85	76	68
	men	11	46	55	56	38	62	55	50
	children	5	101	122	122	83	136	121	109
			Fe						
			20.68 ± 11.16	18.16 ± 3.01	18.81 ± 5.66	16.35 ± 8.35	22.58 ± 7.87	20.69^{Y} ± 10.21	17.86^{X} ± 5.85
			(16.33 – 27.49)	(17.70 – 20.78)	(15.46 – 21.12)	(13.29 – 21.65)	(18.30 – 26.17)	(17.10 – 27.32)	(14.40 – 20.26)
% of standard	female	18	18	16	17	14	20	18	16
	male	10	33	29	30	26	36	33	28
	children	10	33	29	30	26	36	33	28
			Mn						
			0.13^{A} ± 0.04	0.13^{A} ± 0.31	0.12^{A} ± 0.02	0.15^{A} ± 0.03	0.59^{B} ± 0.39	0.14 ± 0.18	0.14 ± 0.07
			(0.11 – 0.15)	(0.11 – 0.42)	(0.12 – 0.14)	(0.14 – 0.17)	(0.41 – 0.80)	(0.12 – 0.30)	(0.12 – 0.18)
% of standard	female	1.8	1	1	1	1	5	1	1
	male	2.3	0.9	0.9	0.9	1	4	1	1
	children	1.5	1	1	1	2	7	2	2
			Cu						
			0.52^{A} ± 0.17	0.68^{B} ±0.12	0.58^{AB} ± 0.10	0.57^{A} ± 0.25	0.54^{AB} ± 0.35	0.59^{y} ± 0.10	0.54^{x} ± 0.27
			(0.44 – 0.61)	(0.63 – 0.75)	(0.52 – 0.63)	(0.39 – 0.64)	(0.41 – 0.76)	(0.56 – 0.66)	(0.41 – 0.68)
% of standard	female	0.9	10	13	11	11	10	11	10
	male	0.9	10	13	11	11	10	11	10
	children	0.55	16	21	18	17	16	18	16

[a] The % of the standard met by 100 g of cooked meat was calculated on the basis of the mineral content in raw meat, assuming 40 % cooking loss from the raw meat (Purchas et al. 2003, Lombardi-Boccia et al. 2005) and the following retention factors: Zn – 1.0; Fe – 0.95 (USDA 2007) and Mn – 1;
[b] AI: adequate intake – Mn; RDA: recommended dietary allowance – Zn, Fe, Cu. Source for nutrient requirements Jarosz (2012) and for Mn – IOM (2010);
Means for breeds denoted by different letters in rows differ statistically significantly: *A*, *B*, *C* $P < 0.01$. Means for muscles denoted by different letters in rows differ statistically significantly: *X*, *Y* $P < 0.01$; *x*, *y* $P<0.05$.

for men and 33-35% for children) than the PHF breed (11%, 8% and 27%, respectively).

The daily requirement for Cu was satisfied to the greatest degree by a 100 g edible portion of meat of young bulls of the WB breed (13% of the RDA for women and men and 21% of the RDA for children), and least by the meat of the PR and PHF cattle (10% of the RDA for women and men and 16% of the RDA for children). Taking into account the important biological functions of copper in the human body, according Cabrera et al. (2010), beef can at least partially meet the nutritional recommendations for adults, and in particular for children. A 100 g portion of tenderloin and three rib plate-flank were shown to meet even 22-24% of the RDA for Cu in children (Cabrera et al. 2010).

In the case of K, consumption of 100 g of cooked meat supplied on average 11% of the daily standard for adults (women and men) and about 15% for children (Table 1). The recommendations were satisfied to the greatest degree by the meat of the PR bulls (12-16% AI), somewhat less by WB, PCB and SIM (10-16% AI), and the least by PHF (9-13% AI). The same portion of beef met only 3-5% of the daily standard for Na for adults and 4-6% of the AI for children. This is particularly important as the supply of sodium in populations of many countries markedly exceeds the recommended intake. Williams (2007) revealed that lean beef supplies a small amount of sodium, and the potassium-sodium ratio is >5.

Many studies have shown that meat in the human diet is a marginal source of Ca (Zanovec et al. 2010) and Mn (Cabrera et al. 2010). Similar tendencies were shown in the present study, in which 100 g of meat supplied only 0.3-0.7% of the RDA for Ca for the groups analysed. In the case of Mn, the differences observed between the breeds were more noticeable, as the meat of the PR, PBW and WB breeds (for men, women and children) supplied 0.9-1% of adequate intake, SIM meat from 1% to 2% of the AI, and PHF meat 4% to 7% of the AI. Cabrera et al. (2010) depending on the breed of steer and the cut of meat, demonstrated that 100 g of meat satisfied the adequate intake for Mn at a level of 0.22- 2.6% in women, 0.17-2% in men and 0.26-3.2% in children.

The LL and ST muscles of the young bulls satisfied the nutritional standards for macrominerals to a similar degree. In the case of microminerals, the recommendations for women, men and children were clearly better satisfied by the LL muscle than the ST. The portion of 100 g of the LL muscle after cooking supplied on average more of the recommended daily requirement (for these population groups) for Zn by 8%, Fe by 4% and Cu by 1.7% in comparison with ST. According to the British Nutrition Foundation (2002), a 'rich source' of a nutrient is a food portion supplying 50% of the RDA, while European Union regulations describe a product as a 'source' if a portion supplies at least 15% of the recommended daily intake (European Parliament 2006, European Commission 2008). Using this nomenclature, we can state that the LL and ST muscles for all the evaluated population groups were primarily a rich source of Zn and a source of Fe, as well as a source of K, Mg and Cu for children.

CONCLUSIONS

For the analysed population groups, the daily requirement for Zn and Fe was satisfied to the greatest degree by the meat of the PHF bulls (62-136% and 20-36%, respectively), followed by the native breeds (46-122% and 16-33%, respectively), and to the smallest degree by the SIM bulls (38-83% and 14-26%, respectively). The meat of the PHF bulls was also the best at meeting the dietary standards for Mn (5-7%), and the meat of the WB breed was distinguished in the case of Cu (13-21%). With regard to the macrominerals (K, Na, Mg, Ca), the evaluated beef was a moderate source only of K and Mg for the population groups analysed, i.e. from 8% to 14% of the RDA for adults, and from 13% to 35% RDA for children. Among the 5 cattle breeds, the meat of the PHF bulls (contrary to microminerals) was the least satisfactory in terms of the daily requirement for K and Mg (especially for children).

The LL muscle had a better nutritional profile than the ST, as it satisfied to a higher degree the standards for microminerals, i.e. Zn, Fe and Cu.

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