Journal of Elementology ISSN 1644-2296

Momot M., Nogalski Z., Sobczuk-Szul M., Pogorzelska-Przybyłek P. 2016. *Effect of fattening intensity on the fatty acid profile and mineral content of meat from Holstein-Friesian bulls*. J. Elem., 21(4): 1081-1091. DOI: 10.5601/jelem.2015.20.4.1085

ORIGINAL PAPERS

EFFECT OF FATTENING INTENSITY ON THE FATTY ACID PROFILE AND MINERAL CONTENT OF MEAT FROM HOLSTEIN-FRIESIAN BULLS

Martyna Momot, Zenon Nogalski, Monika Sobczuk-Szul, Paulina Pogorzelska-Przybyłek

Department of Cattle Breeding and Milk Quality Evaluation
University of Warmia and Mazury in Olsztyn

Abstract

Diets high in saturated fatty acids (SFAs) and n-6 polyunsaturated fatty acids (PUFAs) at the expense of n-3 PUFAs have been shown to increase the risk of cardiovascular disease, obesity and cancer. Animal fat is considered to be the major source of unhealthy saturated fats. However, beef fat has a high nutritional value owing to the presence of minerals, PUFAs, vitamins and selected protein fractions. The aim of this study was to determine the effect of fattening intensity on the fatty acid profile and mineral content of meat from Holstein-Friesian bulls. Holstein-Friesian bulls aged 11 to 19 months were fattened under semi-intensive (SI, 10 animals) and intensive (I, 10 animals) systems. The bulls were fed maize silage, rapeseed meal and premix *ad libitum*. The diets for group I animals were supplemented with 2.5 kg ground triticale provided in an automatic feeding station. Meat samples were collected from *m. longissimus dorsi* (MLD). The samples were mineralized and assayed for mineral content. Fat was extracted from each sample, and the fatty acid profile of beef was determined by gas chromatography. Dietary supplementation with ground triticale increased the average daily gains of bulls and carcass dressing percentage, and contributed to higher carcass conformation and fat cover scores. Beef was found to be a rich source of valuable mineral compounds. The meat of group I animals was characterized by higher potassium levels and lower sodium levels, which points to its higher nutritional value. Semi-intensive (SI) fattening increased PUFA concentrations and decreased the *n*-6/*n*-3 PUFA ratio in beef.

Keywords: beef, bulls, minerals, fatty acids, CLA.

mgr inż. Martyna Momot, Department of Cattle Breeding and Milk Quality Evaluation, University of Warmia and Mazury in Olsztyn, Oczapowskiego 5, 10-719 Olsztyn, Poland, e-mail: martyna.momot@uwm.edu.pl

INTRODUCTION

Beef has a high nutritional value owing to the presence of minerals, polyunsaturated fatty acids (PUFAs), vitamins and selected protein fractions (Harris 2001). Oleic acid (OA) and linoleic acid (LA) lower LDL cholesterol, docosahexaenoic acid (DHA) prevents cardiac arrhythmias (von Schacky et al. 1999) and conjugated linoleic acid (CLA) has antioxidant and anticarcinogenic effects, and it enhances the immune system (Du et al. 2000, Whetsell et al. 2003). Beef is a rich source of minerals, in particular phosphorus, potassium, magnesium and zinc (Kowalski et al. 2010). Of the commonly consumed protein foods, red meat is one of the best sources of readily absorbed iron and zinc (Mateescu et al. 2013). Calcium, magnesium, phosphorus and iron are important to a wide variety of bodily functions, such as bone mineralization, serving as cofactors to many enzyme systems, sustaining muscle and nerve excitation, and – in the case of iron – maintaining the oxygen carrying capacity of blood (Clarkson, Haymes 1995). Magnesium has a strong relation with the immune system, in both non-specific and specific immune responses, also known as innate and acquired immune responses (Tam et al. 2003).

Carcass quality is determined by the animal's genotype, sex, age and final body weight as well as feeding intensity (Toro et al. 2009, Morales et al. 2012, Nogalski et al. 2014). The concentrations of minerals in muscles are largely affected by the nutritional regime, followed by other factors such as the animal's origin (place of birth), age, sex, breed and muscle type (Littledike et al. 1995, Lopez-Alonso 2000, Giuffrida-Mendoza et al. 2007, Hollo et al. 2007, Tizioto et al. 2015). A more extensive knowledge of the mineral composition of beef and the factors that have an influence on it would be appropriate not only from a scientific point of view, but also for the consumer, who could choose the product that suits him better (Barge et al. 2005).

The objective of this study was to determine the effect of fattening intensity on the fatty acid profile and mineral content of meat from Holstein-Friesian bulls.

MATERIAL AND METHODS

The experimental materials comprised 20 samples of *m. longissimus dorsi* (MLD) collected from half-carcasses of Polish Holstein-Friesian bulls. The animals were raised at the Agricultural Experiment Station in Bałcyny (Poland), under the conventional production system (milk replacer, hay and concentrate). Beginning at 6 months of age, the animals were fattened semi -intensively and were fed *ad libitum* a total mixed ration (TMR) composed of grass silage and concentrate. At 11 months of age and body weight of approximately 370 kg, the bulls were placed in a building for controlled fattening, and they were divided into two groups of 10 animals each by the analog method (SI – semi-intensive fattening and I – intensive fattening). From 1 to 60 days of fattening, group SI was fed TMR I (maize silage, rapeseed meal, premix) *ad libitum,* at the 87:12:1 ratio on dry matter basis (Table 1).

Table 1

Chemical composition and nutritional value of experimental diets

Specification	Maize silage	Rapeseed meal	Triticale	TMR I	TMR II
Maize silage				87	89
Rapeseed meal				12	10
Premix				1	1
Dry matter	326.8	890.3	906.0	391.2	379.9
On DM basis (g kg^{-1})					
organic matter	880.3	927.4	944.0	349.5	338.1
crude protein	88.7	400.7	159.1	125.3	119.3
crude fat	29.7	25.7	31.0	37.6	36.3
crude fiber	233.2	149.3	46.1	223.1	224.8
Feed units for meat production (UFV)	0.80	0.96	1.22	0.82	0.82

The diets for group I animals were supplemented with 2.0 kg ground triticale. After 60 days of fattening, the proportions of TMR II components were changed to 89:10:1, and the amount of concentrate in group I was increased to 2.5 kg (Table 2). TMR was dosed from a self-propelled feed cart and delivered twice daily, whereas ground triticale was available in an automatic feeding station. Supplemental minerals and vitamins were provided in the form of a commercial premix for finishing cattle (Cargill Poland Ltd.). Salt licks (Lisal M, LNB Poland Ltd.) were also offered to supplement minerals. Samples of all feed components and TMR were subjected to chemical analyses before the experiment and three times during the fattening trial. The mineral composition of maize silage, ground triticale and premix is presented in Table 3. Fattening was carried out for 8 months until 570 days of age. Next the bulls were transported to a meat processing plant where they were

Table 2

Fattening scheme

Feeding period (days)	Semi-intensive (SI)	Intensive (I)
1-60	TMR I	TMR I + 2.0 kg triticale
>60	TMR II	TMR II + 2.5 kg triticale

Table 3

Mineral composition of feed components (mg kg^{-1})

Components	Elements								
	Na	K	Mg	P	Ca	Fe	Cu	Zn	Mn
Maize silage	5.681	5252.74	948.29	1101.24	209.76	44.312	1.967	13.066	13.197
Premix	79000	-	28000	48000	235000	500000	375	3750	2000
Triticale	2870.0	8160.0	4030.0	6690.0	8570.0	291.0	38.3	170.8	112.5

kept in individual boxes with access to water for 15 to 20 hours. The animals were weighed before slaughter and all slaughter and post-slaughter procedures were carried out in accordance with the relevant industrial standards. Slaughter was performed twice, and 10 animals were slaughtered each time. Half-carcasses were weighed within an accuracy of 0.5 kg, and carcass conformation and fatness were evaluated by a trained grader based on the EUROP system criteria. Intramuscular fat samples were collected from the loin (*m. longissimus dorsi*, between the 11th and 13th thoracic vertebrae).

Samples of MLD were homogenized, approximately 0.5 g of the material was weighed into Teflon vessels, and 7 ml of 65% nitric acid (Merck) was added. Each sample was tested in duplicate. The vessels were sealed and the samples were mineralized in a MARS Xpress 5 microwave oven (Candela, USA). Each mineralization session involved 2 blank samples and 2 samples of certified reference material. The mineralized material was cooled and quantitatively transferred to 25 ml volumetric flasks. Minerals were analyzed with the use of an atomic absorption spectrometer (Candela, USA) equipped with light sources for each element to be determined (potassium, sodium, magnesium, zinc, iron). The elements analyzed by atomic absorption spectrometry and the operating conditions of the spectrometer are shown in Table 4.

In order to determine the fatty acid profile of beef, fat was extracted from ground meat samples by the Soxhlet method (Büchi B-811 extraction system) with hexane as the solvent. The concentrations of 33 fatty acids were determined by gas chromatography in a Varian CP 3800 chromato-

Table 4

Operating conditions of the atomic absorption spectrometer used for the analysis of minerals

Elements	Fuel	Support	Wavelength (nm)	Spectral bandpass (nm)
Potassium	acetylene	air	766.5	0.2
Sodium	acetylene	air	589.0	0.2
Magnesium	acetylene	air	202.6	1.0
Zinc	acetylene	air	213.9	1.0
Iron	acetylene	air	248.3	0.2

graph equipped with a split/splitless injector and a flame-ionization detector (FID). 1 µl samples of fatty acid methyl esters were placed on a capillary column of a length of 100 m and an internal diameter of 0.25 mm, with the CP-sil88 stationary phase. Helium was used as the carrier gas, injector temperature was 260ºC, and the total time of a single analysis was 68 min. The percentage of fatty acids was calculated using Galaxie software.

The effect of fattening intensity on the mineral content and fatty acid profile of beef was determined by one-way ANOVA for orthogonal designs at a significance level of $p = 0.05$ and $p = 0.01$. The results were analyzed statistically in Statistica 10.0 program (StatSoft 2014).

RESULTS AND DISCUSSION

Bulls fed TMR supplemented with ground triticale for 240 days (group I) were characterized by significantly ($P < 0.01$) higher average daily gains and higher final body weights in comparison with semi-intensively fattened bulls (Table 5), which was caused by the richer diet of the former, in particular

Table 5

Body weight (BW) at the beginning and at the end of fattening and selected parameters of bull carcasses (least squares means ± SD)

Elements	Fattening intensity				*p* - value
	semi-intensive (SI)		intensive (I)		
	LSM	SD	LSM	SD	
BW at the beginning of fattening (kg)	370.3	9.40	375.5	9.39	0.8232
BW at the end of fattening (kg)	574.5	18.14	643.3**	9.74	0.0022
Average daily gain (kg)	0.845	0.08	1.115**	0.05	0.0032
Body weight before slaughter (kg)	537.6	47.08	597.3**	29.51	0.0023
Dressing percentage (%)	55.35	0.55	56.86*	0.57	0.0221
[1]Conformation score (pts)	6.00	1.25	6.70	1.25	0.3231
[2]Fatness score (pts)	5.90	0.31	7.10	0.64	0.0629
Intramuscular fat (%)	2.91	1.51	3.25	1.53	0.2156

[1]EUROP conformation: 1 to 15, with 1 = very lean, and 15 = muscled outstanding.
[2]EUROP degree of fat cover: 1 to 15, with 1 = very lean, and 15 = very fat.
Mean values in rows are significantly different: * $P < 0.05$; ** $P < 0.01$.

higher dietary energy concentrations. Carcass dressing percentage was also higher in group I bulls than in group SI animals. The significant difference of 1.51% noted between the groups resulted from differences in carcass conformation and fat cover. The carcasses of group I bulls had a higher fat content and received higher conformation scores, owing to the more intensive feeding and higher final body weights. Our results corroborate the findings of Nogalski et al. (2014), who demonstrated that carcasses of Holstein-Friesian bulls fattened semi-intensively (grass silage) had a lower dressing percentage, a lower fat content and lower conformation scores than the carcasses of bulls fattened intensively. Fattening intensity had no significant effect on the intramuscular fat content of MLD.

The mineral (K, Na, Mg, Zn, Fe) content of meat from Holstein-Friesian bulls was not significantly affected by fattening intensity (Table 6). Similarly

Table 6

Mineral content of meat (mg kg^{-1} of fresh meat) from Holstein-Friesian bulls

Elements	Fattening intensity				p - value
	semi-intensive (SI)		intensive (I)		
	LSM	SD	LSM	SD	
K	4746.5	394.6	4773.8	425.6	0.8832
Na	635.1	65.4	613.0	49.4	0.4061
Mg	217.3	11.5	218.8	18.6	0.8249
Zn	44.0	4.7	48.3	7.1	0.1256
Fe	18.7	2.9	19.4	2.6	0.6079

to Lawrie (1990), Barge et al. (2005) and Hollo et al. (2007), we found that beef is quantitatively the richest source of potassium regardless of the fattening system. In our study, the potassium content of the analyzed meat samples ranged from 4746.5 to 4773.8 mg kg^{-1} of fresh meat. Iron is an important dietary mineral involved in various bodily functions, including oxygen transport in the blood (Mateescu et al. 2013). Potassium and iron concentrations were higher in meat samples collected from groups I bulls in comparison with those collected from group SI animals. Such a trend was also noted in zinc and manganese content. According to Mateescu et al. (2013), 100 g of beef contains an average of 3.89 mg Zn, or 26% of the recommended daily intake. Beef samples analyzed in our study had a higher zinc content. It should be noted than the zinc content of beef is two-fold higher than in pork and veal, and 5- to 7-fold higher than in poultry (Barowicz, Brejta 2000). In the present experiment, the Na content of meat was higher in group SI than in group I (635.1 mg kg^{-1} of fresh meat vs. 613.0 mg kg^{-1} of fresh meat). High potassium levels and low sodium levels in meat from bulls fattened intensively point to its higher nutritional value as compared with meat from bulls fattened semi-intensively. Hollo et al. (2007) also observed higher concentrations of K and Zn in meat samples collected from Holstein-Friesian bulls fattened intensively than in samples collected from extensively fed animals (K – 3384 mg kg^{-1} vs. 3179 mg kg^{-1}, Zn – 36.4 mg kg^{-1} vs. 33.7 mg kg^{-1}). However, the cited authors noted higher concentrations of Mg and Fe and lower

Na levels in meat from bulls fattened extensively, which was not observed in our study. The concentrations of K, Na, Zn and Fe in MLD determined in group I were higher, and Mg content was lower in comparison with the respective values reported by PILARCZYK (2014) who analyzed samples of *m. longissimus lumborum* collected from Limousin, Red Angus and Salers bulls. IBEGBULEM, ABANOBI (2014) also noted lower K and Na levels and higher Mg concentrations in beef, compared with the values observed in our study. CZERWONKA, SZTERK (2015), who analyzed the concentrations of mineral elements in samples of *m. longissimus dorsi* collected from Polish Holstein-Friesian bulls, found lower levels of Fe, K and Na and higher Mg levels in comparison with our study (18.3, 4280.0, 494.0, 272.0 mg kg^{-1} of fresh meat, respectively). In the present experiment, the Mg content of MLD ranged from 217.3 to 218.8 mg kg^{-1} of fresh meat.

Fattening intensity had no significant effect on the concentrations of the majority of fatty acid groups or their mutual proportions (Table 7). A trend

Table 7

The effect of fattening intensity of the total fatty acid pool in beef

Specification	Fattening intensity				*p*-value
	semi-intensive (SI)		intensive (I)		
	LSM	SD	LSM	SD	
SFA (%)	47.377	2.767	45.462	2.496	0.1215
UFA (%)	55.178	3.201	56.824	2. 456	0.2135
MUFA (%)	48.024	2.239	50.435	2.759	0.0458
PUFA (%)	4.562	0.975	4.086	0.756	0.2385
UFA/SFA	1.172	0.141	1.256	0.121	0.1695
PUFA/SFA	0.097	0.025	0.090	0.017	0.4532
MUFA/SFA	1.019	0.110	1.115	0.118	0.0767
n-3 (%)	0.513	0.095	0.441	0.063	0.0483
n-6 (%)	3.207	0.869	2.859	0.686	0.3331
n-6/n-3	6.254	1.239	6.525	1.470	0.6615
DFA (%)	69.285	2.733	70.386	1.824	0.3032
OFA (%)	33.270	2.281	31.900	1.842	0.1565

towards higher levels of SFAs, OFAs, *n*-3 and *n*-6 PUFAs was noted in meat samples collected from group SI bulls, compared with those collected from group I animals. Acid *n*-3 had a significant ($P < 0.05$) share of the total fatty acid pool. Meat from group I bulls was characterized by higher concentrations of UFAs, MUFAs and DFAs than meat from group SI bulls. The difference in MUFA concentrations between groups was statistically significant ($P < 0.05$). In a study by DE SMET et al. (2000), feeding maize silage and concentrate to bulls contributed to an increased fat content of bovine meat, which was paralleled by increased proportions of SFAs and MUFAs and a decreased proportion of PUFAs. In our experiment, similarly to the findings of NOGALSKI et al. (2014), a higher intramuscular fat content of meat from group I bulls was not accompanied by an increase in SFA levels. Meat from group SI bulls contained higher amounts of essential PUFAs (4.562%) that have a beneficial influence on human health, which indicates that beef from cattle fed less intensively delivers more health benefits.

The PUFA/SFA and *n*-6/*n*-3 PUFA ratios are good indicators of the nutritional value of dietary fat (ALFAIA et al. 2007*a*,*b*). XIE et al. (2012) reported that an increase in PUFA concentrations and a lower *n*-6/*n*-3 PUFA ratio are desirable for human health. In our study, the *n*-6/*n*-3 PUFA ratio was relatively high (6.254 in group SI and 6.525 in group I). According to the nutritional recommendations, the PUFA/SFA ratio in the human diet should be above 0.45, and the *n*-6/*n*-3 PUFA ratio should not exceed 4.0 (British Department of Health 1994). In our experiment, the PUFA/SFA ratio was similar to that reported by ENSER et al. (1998) and SOBCZUK-SZUL et al. (2014) – 0.11 and 0.063, respectively, and lower than that noted by ALDAI et al. (2007) – 0.45. According to BARTNIKOWSKA, KULASEK (1994), the optimal *n*-6/*n*-3 PUFA ratio in the human diet is 2-5:1, whereas according to WIJENDRAN, HAYES (2004) it should oscillate around 6:1. The values noted in our study exceed the recommended levels, but according to VARELA et al. (2004) and SCOLLAN et al. (2006), the intramuscular fat of steers fed maize silage and concentrate has a less favorable *n*-6/*n*-3 PUFA ratio in comparison with pasture-finished steers.

Fattening intensity had a significant ($p < 0.05$) effect on the concentrations of oleic acid (C 18:1 *n*-9), which was a predominant functional MUFA

Table 8

The effect of fattening intensity on the concentrations of functional fatty acids (%) in beef

Fatty acids	Fattening intensity				*p* – value
	semi-intensive (SI)		intensive (I)		
	LSM	SD	LSM	SD	
C 18:1 T10+11 vaccenic acid	2.048	0.678	2.127	0.679	0.7973
C 18:1 n-9 oleic acid	37.414	1.936	39.985	2.585	0.0215
C 18:2 linoleic acid	2.593	0.605	2.303	0.437	0.2346
C 18:3 linolenic acid	0.467	0.084	0.410	0.052	0.0825
C 18:2 C9 T11 conjugated linoleic acid (CLA)	0.381	0.078	0.353	0.074	0.4180
C 20:4 arachidonic acid	0.614	0.308	0.556	0.268	0.6573
C 20:5 eicosapentaenoic acid (EPA)	0.046	0.053	0.031	0.035	0.4740
C 22:5 docosapentaenoic acid (DPA)	0.098	0.056	0.097	0.055	0.9836
C 22:6 docosahexaenoic acid (DHA)	0.038	0.033	0.016	0.011	0.0707

in the analyzed meat samples and had a significantly higher share of the total fatty acid pool in group I than in group SI (39.98% vs. 37.41%) – Table 8. Bilik et al. (2009) showed that the fatty acid composition of meat from bulls was more favorable when the animals were fattened semi-intensively with a greater proportion of bulky feeds in the diet, compared with intensive fattening. Meat samples collected from group SI bulls contained higher concentrations of linoleic acid, linolenic acid, CLA, arachidonic acid, eicosapentaenoic acid (EPA) and docosapentaenoic acid (DHA), which are known to have disease-preventing and health-promoting properties. Our results are partially consistent with the findings of Nogalski et al. (2013).

CONCLUSIONS

Intensive fattening of young Holstein-Friesian bulls, compared with semi-intensive fattening, contributed to an increase in the growth rate of animals, carcass dressing percentage, carcass conformation scores and intramuscular fat content of *m. longissimus dorsi*. Our study confirmed that beef is a good source of minerals. The meat of bulls fattened intensively was characterized by higher potassium levels and lower sodium levels, which points to its higher nutritional value. Less intensive fattening increased the PUFA content of beef and decreased the *n*-6/*n*-3 PUFA ratio.

REFERENCES

Aldai N., Najera A.I., Dugan M.E.R., Celaya R., Osoro K. 2007. *Characterisation of intramuscular, intermuscular and subcutaneous adipose tissues in yearling bulls of different genetic groups*. Meat Sci., 76: 682-691.

Alfaia C.P.M., Castro M.L.F., Martins S.I.V., Portugal A.P.V., Alves S.P.A., Fontes C.M.G.A., Bessa R.J.B., Prates J.A.M. 2007*a*. *Effect of slaughter season on fatty acid composition, conjugated linoleic acid isomers and nutritional value of intramuscular fat in Barrosa-PDO veal*. Meat Sci., 75: 44-52.

Alfaia C.P.M., Castro M.L.F., Martins S.I.V., Portugal A.P.V., Alves S.P.A., Fontes C.M.G.A., Bessa R.J.B., Prates J.A.M. 2007*b*. *Influence of slaughter season and muscle type on fatty acid composition, conjugated linoleic acid isomeric distribution and nutritional quality of intramuscular fat in Aroquesa-PDO veal*. Meat Sci., 76: 787-795.

Barge M.T., Piccone G., Barge P., Cignetti A. 2005. *Preliminary results on mineral content of some beef muscles*. Ital. J. Anim. Sci., 4 (Suppl. 2): 272-274.

Barowicz T., Brejta W. 2000. *Modifying dietary values of beef by nutritional factor*. Rocz. Nauk. Zoot., 6: 15-19. (in Polish)

Bartnikowska E., Kulasek G. 1994. *Role of unsaturated fatty acids in humand and animal nutrition*. Part II. *Deficits and nutritional treatment of deficits*. Mag. Wet., 5: 34-38. (in Polish)

Bilik K., Węglarzy K., Choroszy Z. 2009. *Effect of feeding intensity of Limousin bulls on production parameters and dietetic properties of meat*. Rocz. Nauk. Zoot., 36: 63-73.

British Department of Health 1994. *Nutritional aspects of cardiovascular disease: Report of Health and Social Subjects*. No 46. London, HMSO.

Clarkson P. M., Haymes E. M. 1995. *Exercise and mineral status of athletes: Calcium, magnesium, phosphorus, and iron*. Med. Sci. Sports Exerc., 27: 831-843.

Czerwonka M., Szterk A. 2015. *The effect of meat cuts and thermal processing on selected mineral concentration in beef from Holstein–Friesian bulls*. Meat Sci., 105: 75-80.

De Smet S., Webb E.C., Claeys E., Uytterhaegen L., Demeyer D.I. 2000. *Effect of dietary energy and protein levels on fatty acid composition of intramuscular fat in double-muscled Belgian Blue bulls*. Meat Sci., 56: 73-79.

Du M., Ahn D.U., Sell J.L. 2000. *Effects of dietary conjugated linoleic acid and linoleic:linolenic acid ratio on polyunsaturated fatty acid status in laying hens*. Poultry Sci., 79: 1749-1756.

Enser M., Hallet B., Hewitt G., Fursey J., Wood D., Harrington G. 1998. *Fatty acid content and composition of UK beef and lamb muscle in relation to production system and implications for human nutrition*. Meat Sci., 49: 329-341.

Giuffrida-Mendoza M., Arenas De Moreno L., Uzcátegui-Bracho S., Rincón-Villalobos G., Huerta-Leidenz N. 2007. *Mineral content of longissimus dorsi thoracis from water buffalo and Zebu-influenced cattle at four comparative ages*. Meat Sci., 75: 487-493.

Harris W.S. 2001. *Omega 3 fatty acids and human chylomicron metabolism*. World Rev. Nutrit. Diet., 88: 163-167.

Holló G., Nuernberg K., Holló I., Csapó J., Seregi J., Repa I., Ender K. 2007. *Effect of feeding on the composition of longissmus muscle of Hungarian Grey and Holstein - Friesian bulls.* III. *Amino acid composition and mineral content*. Arch. Tierz., 50(6): 575-586.

Ibegbulem C. O., Abanobi S. E. 2014. *Possible correlation between mineral profile and protein content of foods*. Turk. J. Biochem., 39(1): 45-50.

Kowalski I.M., Protasiewicz-Fałdowska H., Jóźwiak-Grabysa D., Kiebzak W., Zarzycki D., Lewandowski R., Szarek J. 2010. *Environmental factors predisposing to pain syndromes among adolescent girls with diagnosed idiopathic scoliosis*. J. Elem., 15(3): 517-530.

Lawrie R.A. 1990. *Meat science*. 5th edn. Pergamon Press, Oxford.

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.

López-Alonso M., Benedito J.L., Miranda M., Castillo C., Hernández J., Shore R.F. 2000. *Arsenic, cadmium, lead, copper and zinc in cattle from Galicia, NW Spain*. Sci. Total Environ., 246: 237-248.

Mateescu R.G., Garmyn A.J., Tait J.R.R.G., Duan Q., Liu Q., Mayes M.S., Garrick D.J., van Eenennaam A.L., van Overbeke D.L., Hilton G.G., Beitz D.C., Reecy J.M. 2013. *Genetic parameters for concentrations of minerals in longissimus muscle and their associations with palatability traits in Angus cattle*. J. Anim. Sci., 91(3): 1067-75.

Morales M., Folch C., Iraira S., Teuber N., Realini C.E. 2012. *Nutritional quality of beef produced in Chile from different production systems*. Chil. J. Agr. Res., 72: 80-86.

Nogalski Z., Wroński M., Wielgosz-Groth Z., Purwin C., Sobczuk-Szul M., Mochol M., Pogorzelska P. 2013. *The effect of carcass conformation class (EUROP system) on the slaughter quality of young crossbred beef bulls and Holstein-Friesians*. Ann. Anim. Sci., 13(1): 121-131.

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. *Elemental composition of muscle tissue of various beef breeds reared under intensive production systems*. Int. J. Environ. Res., 8(4): 931-940.

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.

Sobczuk-Szul M., Nogalski Z., Wielgosz-Groth Z., Mochol M., Rzemieniewski A., Pogorzelaka-Przybyłek P., Purwin C. 2014. *Fatty acid profile in 4 types of fat depots in Polish Holstein-Friesian and Limousine × Polish Holstein-Friesian bulls*. Turk. J. Vet. Anim. Sci., 38: 189-194.

StatSoft Inc. Statistica (data analysis software system), Version 10.0. 2014.

Tam M., Gomez S., Gonzalez-Gross M., Marcos A. 2003. *Possible roles of magnesium on the immune system*. Eur. J. Clin. Nutr., 57: 1193-1197.

Tizioto P.C., Taylor J.F., Decker J.E., Gromboni C. F., Mudadu M. A., Schnabel R.D., Coutinho L.L., Mourão G.B., Oliveira P.S.N., Souza M.M., Reecy J.M., Nassu R.T., Bressani F.A., Tholon P., Sonstegard T.S., Alencar M.M., Tullio R.R., Nogueira A.R.A., Regitano L.C.A. 2015. *Detection of quantitative trait loci for mineral content of Nelore longissimus dorsi muscle*. Genet. Sel. Evol., 47: 15.

Toro P., Catrileo A., Aguilar C., Vera R. 2009. *Modeling supplementation strategies for beef steer rearing and fattening system in Southern Chile*. Chil. J. Agr. Res., 69: 207-213.

Varela A., Oliete B., Moreno T., Portela C., Monserrat L., Carballo J., Sanchez L. 2004. *Effect of pasture finishing on the meat characteristics and intramuscular fatty acid profile of steers of the Rubia Gallega breed*. Meat Sci., 67: 512-522.

von Schacky C., Angerer P., Kothny W., Theisen K., Mudra H. 1999. *The effect of dietary omega-3 fatty acids on coronary atherosclerosis. A randomized, double-blind, placebo-controlled trial*. Ann. Int. Med., 130: 554-62.

Whetsell M., Raybun E., Dossier J.D. 2003. *Human health effects of fatty acids in beef. Pasture-Based Beef Systems for Appalachia Project, Extension Service*. West Virginia University, Morgantown, Virginia, USA.

Wijendran V., Hayes K.C. 2004. *Dietary n-6 and n-3 fatty acid balance and cardiovascular health*. Annu. Rev. Nutr., 24: 597-615.

Xie X., Meng Q., Cui Z., Ren L. 2012. *Effect of cattle breed on meat quality, muscle fiber characteristics, lipid oxidation and fatty acids in China*. Asian-Aust. J. Anim. Sci., 25: 824-831.