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The effect of meat cuts and thermal processing on selected mineral concentration in beef from Holstein–Friesian bulls

Małgorzata Czerwonka [a,*], Arkadiusz Szterk [b]

[a] Department of Bromatology, Faculty of Pharmacy with the Laboratory Medicine Division, Medical University of Warsaw, 1 Banacha, 02-097 Warsaw, Poland
[b] Department of Food Analysis, Prof. Waclaw Dabrowski Institute of Agricultural and Food Biotechnology, 36 Rakowiecka, 02-532 Warsaw, Poland

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ABSTRACT

The impact of meat cuts (nine muscles and liver) and thermal processing on selected mineral (potassium, sodium, phosphorus, magnesium, zinc, iron, including heme form) concentration in beef from Holstein–Friesian bulls was evaluated in the present study. The mineral's content widely varied depending on the tissue type (skeletal muscles/liver, except zinc) and between the different bovine muscles. The greatest diversity between the muscles demonstrated was zinc (3.5–6.9 mg 100 g^{-1} f/w) and iron (1.7–2.3 mg 100 g^{-1} f/w), however, there were no significant differences in heme iron to total iron ratio (average 74%). Thermal processes conducted on longissimus dorsi muscles also significantly affected mineral concentration. Grilled, roasted and fried bovine meat was characterised by a higher content (by 6–26%) of most studied minerals (except sodium) as compared to raw meat. Sodium levels in processed meat were 16–33% lower than in raw samples.

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1. Introduction

Meeting the human body's needs in providing all nutrients for proper development and health maintenance requires consumption of products of both plant and animal origin. Diets excluding animal products increase the risk of deficiencies of many valuable nutrients. Consumption of red meat, especially beef, can be a good way to respond to the macro- and micromineral requirements (Forestell, Spaeth, & Kane, 2012; McNeill & Van Elswyk, 2012; Williams, 2007; Williamson, Foster, Stanner, & Buttriss, 2005).

However, the concept of bovine meat includes a broad group of raw material which is composed of skeletal muscles and other tissues, which are also commonly consumed (e.g. liver, heart, tongue). Differences in histology, the functions performed in the body and work intensity during the animal's life can cause the nutrient concentration to vary depending on meat cuts. Moreover, the mineral composition of beef may change with breed, the age of the animal, feeding practices, geographical site of rearing and many other factors (Cabrera, Ramos, Saadoun, & Brito, 2010; Driskell et al., 2011; García-Vaquero, Miranda, Benedito, Blanco-Penedo, & López-Alonso, 2011; Lawrie & Ledward, 2006; Ramos, Cabrera, & Saadoun, 2012).

In central and eastern European countries, multipurpose cattle production is still dominated. The most popular cattle breed in Poland is Holstein–Friesian, which constitutes for over 85% of the population (Neja, Jankowska, Sawa, & Bogucki, 2013; Węglarz, 2010). However, only a limited number of articles have been recently published on the nutritional quality of meat from this breed of cattle. Information on nutritional value, including mineral concentration, is needed by producers to promote this kind of meat.

Contemporary, conscious consumers expect not only information about the nutritional content of raw meat, but also in products ready to eat. Thermal processing of meat can lead to significant modifications of macro- and micromineral levels, which depend on the type of cooking and process parameters (Gerber, Scheeder, & Wenk, 2009; Lombardi-Boccia, Lanzi, & Aguzzi, 2005). The scientific literature about the culinary treatment of bovine meat that influences the mineral concentration, including the nutrients losses associated with thermal leakage, is poor.

Beef, among other commonly consumed meats, is considered to be the richest source of certain macro- and microminerals in the diet, especially of iron and zinc. However, the literature data indicate wide variation in the content of these nutrients in bovine meat (Cabrera et al., 2010; García-Vaquero et al., 2011; Ramos et al., 2012; Williams, 2007; Williamson et al., 2005). The aim of this study was to evaluate the impact of meat cuts (nine muscles and liver) and of thermal processing on selected mineral (potassium, sodium, phosphorus, magnesium, zinc, iron, including the heme form) concentrations in beef from Holstein–Friesian cattle. The research focused on the content of zinc and iron, including the heme form of iron, because these components largely affect the nutritional quality of beef. The studies also examined the macro- and microminerals in liver. This organ is also

* Corresponding author. Tel.: +48 508 104 764.
E-mail address: malgorzata.czerwonka@wum.edu.pl (M. Czerwonka).

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considered to be bovine meat and is commonly consumed, but the differences in the histology and functions performed in the animal body make the nutrient content in liver much different than that in skeletal muscle.

2. Material and methods

2.1. Research material

The studies were divided into two experiments. In the first experiment, the research material consisted of 9 muscles and livers taken from the carcasses of 28 bulls (aged 18–22 months) of the Polish Holstein–Friesian breed, black-and-white variety. The cattle were fed a grass/corn silage diet (ad libitum) with concentrated feed (~3 kg per day — 70% grains: oat/barley; 25% rapeseed meal). The bulls were slaughtered in commercial slaughterhouses in the Masuria region. The carcass dissections, according to UNECE standards (2004) took place 48 h after slaughter. The extracted muscles (m. psoas major—PM; m. longissimus dorsi—LD; m. infraspinatus—IF; m. triceps brachii—TB; m. gluteus medius—GM; m. rectus femoris—RF; m. biceps femoris—BF; m. gracilis—GR, m. semimembranosus—SM) were vacuum-packed and stored at 2 °C. On the tenth day after the slaughter muscle samples (~150 g; taken from the middle region of each muscle) were vacuum packed, frozen and stored at −80 °C until determination. Beef livers were collected immediately after slaughter, stored one day at 2 °C, then cut into ~10 g pieces, vacuum packed, frozen and stored at −80 °C.

In the second experiment the longissimus dorsi (LD) muscles were taken from 14 bulls of the Polish Holstein–Friesian breed, black-and-white variety. Animal rearing conditions, ante-mortem and post-mortem treatments were analogous to the first experiment. Each muscle was divided into six steaks (each steak was 2 cm thick; with 3 steaks for frying and 3 steaks for grilling), a 0.5 kg portion for roasting and a 0.2 kg portion which was raw vacuum-packed and stored at −80 °C.

Grilling (G-LD) was performed using an iron electric contact grill (Silex, T-10.20, Hamburg, Germany), preheated to a temperature of 240 °C. The meat was grilled for the same amount of time on each side. Roasting (R-LD) was carried out in hot air at 180 °C in a combi steamer oven (Kuppersbusch, CPE 110, Gelsenkirchen, Germany). Frying (F-LD) was performed using an electric pan (Kuppersbusch, KCO 0050, Gelsenkirchen, Germany) preheated to a temperature of 180 °C. The steaks were fried on each side, immersed in rapeseed oil up to ¼ of their thickness and rotated after 1 min. All heat treatments were carried out until a temperature of 70 °C was reached inside the piece of meat/steak (measurement: Bartscher 361 with thermal probe BTA291040, Bartscher GmbH, Poland). After the cooking processes, samples were cooled (20 min at room temperature), vacuum-packed, frozen and stored at −80 °C. Immediately prior to analysis, meat samples were defrosted and homogenised (Büchi, B-400 with ceramic knives, Flawil, Switzerland).

The efficiency of the cooking process (CPE) was calculated based on the sample's mass before and after each heat treatment.

2.2. Analytical methods

2.2.1. Reagents

Nitric acid (70%, ultrapure) and hydrochloric acid (36%, pure) were purchased in POCH Gliwice, Poland. Analytical standards of hemin and acetonitrile (HPLC grade) were bought in Sigma-Aldrich Corp., Poznan, Poland. Single element standards for ICP-OES (Na, K, P, Mg, Zn, Fe) were provided by GBC, MS Spektrum, Warsaw, Poland. Ultrapure water was obtained from HLP 5UV demineraliser, Hydrolab, Wiślina/Gdansk, Poland.

2.2.2. Determination of mineral content

Mineral content in bovine meat was determined using the ICP-OES method. The sample preparation procedure involved microwave digestion in HNO_3 (mineraliser: MAGNUM II, Ertec, Wroclaw, Poland). Approximately 0.7–0.8 g of the meat samples (0.5–0.6 g of liver sample) was digested in 3 ml of concentrated nitric acid. The following parameters of sample mineralisation were used: pressure—32 bar, temperature—295 °C, and time—20 min. After mineralisation, the solution was transferred quantitatively from a Teflon dish to a volumetric flask (50 ml) using ultrapure water.

Determination of the iron and zinc content in beef was performed using the inductively coupled plasma optical emission spectrometer INTEGRA, GBC, Braeside, Australia. The ICP parameters were set to the following: observation height in the plasma—10 mm, plasma gas flow—10 l/min, nebuliser gas flow—0.5 l/min, RF power—1200 W, PMI voltage—500 V, sample transport rate—10 rpm. The analytical wavelengths: Na—589.592 nm, K—766.490 nm, P—214.914 nm, Mg—285.213 nm, Fe—213.856 nm and Zn—259.940 nm. The method was fully validated, separately for each mineral. In Supplement 1 the most important validation parameters have been provided.

2.2.3. Heme iron determination

The heme iron (Fe^H) content in beef was determined using the colorimetric method as described by Hornsey (1956), with some modifications proposed by Lombardi-Boccia, Martínez-Domínguez, Aguzzi, and Rincón-León (2002). About 3 g of a ground meat sample was homogenised with a 15 ml extraction mixture consisting of ACN, 36% HCl and H_2O (*v*/*v*—80:3:17) and then kept in the dark for 1 h (at room temperature). The suspension was centrifuged, and then the supernatant was transferred quantitatively to a 25 ml volumetric flask. The flask was filled up with the extraction mixture and the solution was filtered. Absorbance of the sample was measured by a spectrophotometer (Helios Gamma, Thermo Scientific, Anchem Comp., Warsaw, Poland) at λ—640 nm. The heme iron concentration was calculated against the calibration curve plotted for a certified standard of hemin.

2.2.4. Dry matter content

Dry matter (d/w) in raw and processed beef samples was determined gravimetrically. Calculations were based on loss of weight during sublimation drying (lyophiliser: ChristAlpha 1-4/2-4 LSC, pressure: 1.03 mbar, temperature: 35 °C, time: 34 h). The procedure was carried out according to AOAC International (2002), Anklam, Burke, and Isengard (2001), and Greenfield and Southgate (2003), in which the authors recommended sublimation drying to determine the dry matter content.

2.3. Statistical analysis

All analyses were performed in triplicate. The results are presented as mean values ($\bar{x}$) and standard deviation (SD). Data was analysed by a one-way analysis of variance to determine the differences ($P < 0.01$) in mineral concentrations between meat cuts and thermal treatments. The Tukey test was used to evaluate the statistical significance ($P < 0.05$) of the differences between the mean values; letters indicated homogeneous groups. The data was evaluated using STATISTICA 10 software (StatSoft, Krakow, Poland).

3. Result and discussion

3.1. Mineral content in beef muscles and liver

Nutrient distribution in an animal's body is uneven and depends on the demands of each organ. The differences in the macro- and micromineral concentration in beef carcass anatomical elements result from the functions of those elements in the body, and from the intensity of work that is performed during the animal's life (Chikuni et al., 2010; García-Vaquero et al., 2011; Kerry & Ledward, 2009). The results show that the mineral's content varies depending on the tissue type (skeletal muscle/liver; $P < 0.01$, except zinc) and between the different muscles

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