DIETARY INTAKE OF IRON FROM DIFFERENT MEATS AND LIVERS IN SERBIAN ADULTS

Ivana Branković Lazić*, Sasa Janković, Jasna Đinović-Stojanović

Institute of Meat Hygiene and Technology, Kacanskog 13, 11000 Belgrade, Serbia

*Corresponding author:
E-mail address: ivana.brankovic@inmes.rs

ABSTRACT

Meat and meat products are an important part of the human diet in Serbia. They are a convenient source of high-value proteins, essential vitamins, and important minerals needed for good health throughout life. Iron (Fe) is found especially in red meat, and it is indicated that vegetarians may be at risk of iron deficiencies. The aim of this study was to analyse beef, lamb, pork, equine, chicken, and turkey meats, as well as livers from the same animal species, except turkey liver, regarding the iron content. Samples were gathered from different meat processing facilities in Serbia during 2023. The level of iron was determined by inductively coupled plasma mass spectrometry (ICP-MS). The estimated daily dietary intake (EDI) of Fe was calculated using data of Fe levels obtained in this study as well as data of dietary intake of estimated meats and livers from the European Food Safety Authority (EFSA) database. The following mean levels of Fe were found (µg g^{-1}) in meat: beef 20.2, lamb 17.8, pork 7.90, equine 38.8, chicken 4.43, and turkey 6.74. The highest Fe mean level was obtained in equine liver (330.00 µg g^{-1}) while the lowest level was obtained in beef liver (57.7 µg g^{-1}). The results for EDI are expressed as percent of the Recommended Dietary Allowance (RDA) for adults (male: 8 µg g^{-1}; female: 18 µg g^{-1}). The analysed meats and livers provide in total 16.2% and 7.20% for male and female respectively of the RDA for Fe. The obtained results showed that the estimated meats and livers can be considered as important dietary sources of Fe, but other food types are clearly necessary to provide adequate dietary levels of Fe for the Serbian adult population.
Keywords*: iron, meats, livers, Serbian adults, intake*

INTRODUCTION

Meat and meat products are significant components of the human diet, offering essential nutrients such as omega-3 fatty acids, B-vitamins (especially niacin and riboflavin), and bioavailable forms of iron and zinc. Moreover, it contains notable amounts of macronutrients (proteins and fat). Meat contains significant amounts of macronutrients, such as proteins and fat and essential nutrients, such as omega-3 fatty acids, B-vitamins (especially niacin and riboflavin), bioavailable forms of iron and zinc, and other different elements and that depends of its composition (Mann, 2013; Lopez-Alonso at al., 2016). Essential elements such as iron (Fe), copper (Cu), zinc (Zn), selenium (Se) and manganese (Mn) are required in appropriate amounts to maintain a range of physiological functions in humans (Noël et al., 2012 (Dawczynski et al., 2022).
From ancient times, man has recognized the special role of iron in human health and its deficiency can cause some disease (Beard et al., 1997). Iron is component of a number of proteins including hemoglobin, myoglobin, cytochromes and enzymes involved in redox potential, and is biologically essential component of every living organism (Aisen et al., 2001). Almost two-thirds of the iron in body is found in hemoglobin in circulating erythrocytes, which is important for transport of oxygen to tissues throughout the body.
Wholegrain cereals, meats, fish and poultry are the major contributors to iron intake, while the iron from plant sources is less bioavailable. The form in which iron is consumed will affect dietary intake requirements as not all dietary iron is equally available to the body. The factors that determine the proportion of iron absorbed from food are complex. They include the iron status of an individual, as well as the iron content and composition of a meal. Normal absorption may vary from 50% in breast milk to 10% or less in infant cereals. Dietary Iron occurs in two general forms – as heme or non-heme iron (Hurrell and Egli, 2010). The primary source of heme iron are hemoglobin and myoglobin from consumption of meat,

poultry and fish, while nonheme iron is obtained from cereals, legumes, fruits and vegetables (FAO/WHO, 2001). Heme iron is highly bioavailable (15%-35%) and dietary factors have little effect on its absorption, whereas nonheme iron absorption is much lower (2%-20%) and strongly influenced by the presence of other food components (Hurrell and Egli, 2010).
According to the data of Nutrient Reference Values for Australia and New Zealand to achieve iron balance, adult men need to absorb about 1 mg/day and adult menstruating women about 1.5 mg/day, although this is highly variable. Requirements are higher during periods of rapid growth in early childhood and adolescence. Inadequate iron intake can lead to varying degrees of deficiency, from low iron stores (as indicated by low serum ferritin and a decrease in iron-binding capacity); to early iron deficiency (decreased serum transferrin saturation; increased erythrocyte protoporphyrin concentration and increased serum transferrin receptor) to iron-deficiency anemia (low hemoglobin and hematocrit as well as reduced mean corpuscular hemoglobin and volume). These biochemical measures are used as the key indicators in setting the iron requirements. Iron and the other essential elements in meat and meat products have been intensively analysed in past decade, because these elements improve quality of meat and meat products and affect at consumer health (Djinovic-Stojanovic et al., 2017).
Meat and meat products are significant portion of daily consumption in Serbian adult population. The average annual consumption of meat in Serbia in 2013 was 60.8 kg/per capita (the EU average is 78 kg/per capita) of which pork was the most commonly consumed meat (27.3 kg), followed by poultry (17.2 kg) and beef (14.4 kg) (USDA Foreign Agricultural Service, 2013). There is very little scientific data available on the content of Fe in meat and meat products from Serbia. These data are necessary for future studies on the total dietary intake of Fe by the Serbian adult population. Therefore, the aim of the present study was to determine the Fe levels in meats and livers from different species of animals from Serbia as well as assess Fe intake through consumption of meat and livers. The established Fe levels in commonly consumed meats were also compared in order to suggest to consumers which of analysed meats are better sources of Fe.

MATERIAL AND METHODS

In total 219 meat and liver samples were collected: 148 red meat samples (11 turkey, 19 chicken, 12 lamb, 60 pork, 35 beef, 11 equine meats) and 71 liver samples (17 chicken, 12 lamb, 17 pork, 14 beef, 11 equine liver). Meat and liver samples were collected from different meat facilities in Serbia during 2023. After collection samples were homogenized, labeled and stored in polyethylene bags and frozen at -18 °C prior to analysis.

Sample preparation and ICP-MS analysis

Frozen samples were thawed at +4 ºC for a day before analysis and then homogenized. An amount, approximately 0.5 g, of each thawed, homogenized tissue, was transferred into a teflon vessel with 5 mL nitric acid (67% Trace Metal Grade, Fisher Scientific, Bishop, UK), for microwave digestion. The microwave (Mars 6, CEM Corporation, Matthews, NC, USA) program consisted of three steps: 5 min from room temperature to 180°C, 10 min hold at 180°C, 20 min vent. After cooling, the digested sample solutions were quantitatively transferred into disposable flasks and diluted to 100 mL with deionized water produced by a water purification system (Purelab DV35, ELGA, Buckinghamshire, UK).
Analysis of the iron (Fe) was performed by inductively coupled plasma mass spectrometry (ICP-MS), (iCap Q mass spectrometer, Thermo Scientific, Bremen, Germany). The most abundant isotope ^{57}Fe was used for quantification.
Torch position, ion optics and detector settings were re-adjusted daily using tuning solution (Tune B, Thermo Scientific), in order to optimize mechanical and electrical parameters and minimize possible interference. Basic operating conditions of the instrument were: RF power (1550 W); cooling gas flow (14 L/min); nebulizer flow (1 L/min); collision gas flow (1 mL/min); operating mode (Kinetic Energy Discrimination-KED); dwell time (100 ms).

Standard stock solution containing 1000 mg/L of Fe was purchased from CPAchem (Bogomilovo, Bulgaria). This solution was used to prepare standards for five-point calibration curves (including zero). Multielement internal standard (^{6}Li, ^{45}Sc, ^{71}Ga, ^{89}Y, ^{209}Bi) was introduced online by an additional line through the peristaltic pump. All solutions (standards, internal standards and samples) were prepared in 2% nitric acid.

Quality assurance

The quality of the analytical process was verified by analysis of the certified reference material NIST 1577c (bovine liver, Gaithersburg, MD, USA). Reference material was prepared as samples using microwave digestion. Measured Fe concentrations were corrected for response factors of internal standards using the interpolation method and were within the range of the certified value (Table 1).

Table 1. Range of the certified value of Fe

Element	Certified value*	Analysed value**	Recovery
Fe	µg kg^{-1}	µg kg^{-1}	%
	197.94 ± 0.65	197.43 ± 5.21	99.7

* Certified value as given by the manufacturer.
** The data are presented as means ± standard deviation.

Statistical analysis

Statistical analysis of experimental data was performed using software Statistica 10.0 (StatSoft Inc., Tulsa, OK, USA). One-way analysis of variance - ANOVA and Tukey's HSD test for comparison of means were used to analyse variations of the Fe levels in meats and livers different species of animals.

RESULTS AND DISCUSSION

The measured contents of the Fe in the meats and livers of different animal species are shown in Tables 2 and 3.

Table 2. Fe contents in analysed meat samples

Type of sample	**Number of samples**	**Fe content*** ***µg g^{-1}***
Chicken meat	19	4.43 ± 2.07 ^{a}
Turkey meat	11	6.74 ± 3.04 ^{a}
Pork meat	60	7.90 ± 4.71 ^{a}
Lamb meat	12	17.83 ± 6.68 ^{b}
Beef meat	35	20.25 ± 8.54 ^{b}
Equine meat	11	38.8 ± 11.07 ^{c}

* results presented as mean ± standard deviation
$^{a–c}$ Different superscripts within the column indicate significantly different means according to Tukey's HSD test; ($p < 0.05$)

The concentrations of Fe in pork, turkey and chicken meat were not significantly different ($p > 0.05$), while the Fe content in equine meat was significantly higher compared with other meats. The mean Fe levels in beef and lamb meat were significantly higher than levels in pork, turkey and chicken meat. Fe level in beef meat from present study was in line with data available in Danish Food database (22.00 µg g^{-1}) (FRIDA, 2024). Also, according to the same database equine and lamb meat had content of Fe (35.0 µg g^{-1} and 15.0 µg g^{-1}, respectively) similar to our results. Bilandžić et al (2021) analyzed Fe content in meats and livers from the Croatian market in chicken (4.2 µg g^{-1}), pork (11 µg g^{-1}) and beef meat (20 µg g^{-1}) and they were in line with results from this study. However, the Fe concentrations in this study were higher than Fe concentrations presented in meat and poultry obtained from the Lebanese TDS study (Nasreddine et al, 2010).

Table 3. Fe contents in analysed liver samples

Type of sample	Number of samples	Fe content* $\mu g\ g^{-1}$
Beef liver	14	57.68 ± 24.81 [a]
Lamb liver	12	76.48 ± 31.48 [a]
Chicken liver	17	125.27 ± 36.34 [b]
Pork liver	17	220.95 ± 50.42 [c]
Equine liver	11	330.00 ± 12.34 [d]

* results presented as mean ± standard deviation

[a–d] Different superscripts within the column indicate significantly different means according to Tukey's HSD test; ($p < 0.05$)

The average Fe contents in beef and lamb liver were not significantly different ($p > 0.05$) and were lower than Fe in liver of other species. Equine livers had the highest mean Fe content and it was significantly different than Fe levels in all other analyzed livers. The Fe contents for chicken (91.5 µg g^{-1}) and pork livers (134 µg g^{-1}) reported by FRIDA database (FRIDA, 2024) were lower than levels in present study. The Fe content in beef liver in the current study was lower than the Fe content in beef liver (73±69 µg g^{-1}) from Croatian market (Bilandžić et al, 2021), but in line with respective FRIDA database (FRIDA, 2024).

Intake assessment

The dietary intake of Fe was expresed as the daily intake (DI) and calculated using the equation: DI = C x DC where C is the Fe content (µg g^{-1}) and DC is daily consumption of meats and livers (g per day). DC data for meats and livers for Serbian adult population were used from the food consumption data which was published as part of the EFSA Comprehensive European Food Consumption Database (EFSA, 2022). Mean values of meats and livers consumption, expressed as grams per day (g day^{-1}) are shown in Table 4.

Table 4. Daily meats and livers intake

Type of product	Intake (g/day)
Pork liver	0.63
Pork meat	41.05
Chicken liver	0.69
Chicken meat	50.98
Beef meat	23.84
Lamb meat	2.51

Data for intake of equine meat and beef, lamb and equine livers are not available in EFSA database for Serbia probably because it's insignificant.

Calculated daily intake of Fe from different meats and livers as well as their contribution in total intake are shown in Table 5.

Table 5. Daily intake of Fe

Type of product	Fe intake (µg/day)	Contribution (%)
Lamb meat	44.82	3.44
Chicken liver	85.90	6.59
Pork liver	139.22	10.69
Chicken meat	225.82	17.33
Pork meat	324.29	24.89
Beef meat	482.47	37.03
Total	**1302.78**	**100**

Our results shown that highest Fe daily intake was by beef meat (37.03%), followed by pork meat (24.89%), while the lowest intake was through lamb meat consumption (3.4%).

Intake recommendations for Fe provided in the Dietary Reference Intakes (DRIs) developed by the Food and Nutrition Board (FNB) at the Institute of Medicine (IOM) of the National Academies (formerly National Academy of Sciences) (Institute of Medicine, 2001). According of this source recommended daily intake of Fe in adult is 8 mg for male and 18 mg for female. Total Fe intake by examination food items (1302.78 µg/day) represents 16.25% and 7.2% of recommended daily intake for male and female, respectively.
The obtained results regarding the iron content in liver indicate a possible path of increasing Fe intake through increased consumption of this iron-rich foodstuff. Having in mind relatively low current consumption of just 0.63 g/day (pork liver), increase in consumption to e.g 2 g/day would result in 23.3% of increase in total iron intake through meat consumption, i.e. one large pork liver meal (250 g) would cover recommended weekly intake for males and three day intake for females.

CONCLUSIONS

This study presents the Fe content in meats and livers from different animal species originating from meat processing facilities in Serbia during 2023. The highest mean contents of Fe were measured in equine and beef meat, equine and pork livers, while the lowest Fe content were established in chicken and turkey meats. Total Fe intake by meat and liver consumption of different animal species represents 16.25% and 7.2% of recommended daily intake for male and female, respectively. The obtained results showed that the estimated meats and livers can be considered as important dietary sources of Fe, hence other food types are clearly necessary to provide adequate dietary intake of Fe for the Serbian adult population.

ACKNOWLEDGEMENTS

This study was supported by the Ministry of Science, Technological Development and Innovation, Republic of Serbia, Grant No. 451-03-66/2024-03/200050 from 05.02.2024.

REFERENCES

Aisen, P., Enns, C., Wessling-Resnick, M. (2001). Chemistry and biology of eukarotyc iron metabolism. *Int j Biochem Cell Biol.* 33, 940-55.

Beard, J.L., Dawson, H.D., Iron, In: O'Dell, B.L., Sunde, R.A. (1997). *Handbook of Nutritionally Essential Mineral Elements* (p. 275-334). New York. CRC Press.

Bilandžić, N., Sedak, M., Čalopek, B., Dokić, M., Varenina, I., Solomun Kolanović, B., Božić Luburić, Đ., Varga, I., Hruškar, M. (2021). Dietary exposure of the adult Croatian population to meat, liver and meat products from the Croatian market: Health risk assessment. *Journal of Food Composition and Analysis*, 95, 103672.

Dawczynski, C., Weidauer, T., Richert, C., Schlattmann, P., Dawczynski, K., Kiehntoph, M. (2022). Nutrient intake and nutrition status in vegetarians and vegans in comparasion to omnivores- the nutritional evaluation (NuEva) Sudy. *Front. Nutr*.

Djinovic-Stojanovic, J.M., Nikolic, D.M., Vranic, D.V., Babic, J.A., Milijasevic M.P., Pezo L.L., Jankovic S.D. (2017). Zinc and magnesium in different types of meat and meat produsts from Serbian market. *J. Food Compos*. *Anal*. 59, 50-54.

EFSA (2022) Compressive European Food Consumption Database, Chronic Food Consumption Survey on adults in Serbia

FAO/WHO (2001). *Food based approachesto meeting vitamin mineral needs. In:human vitamin and mineral requerements* . Rome. P7-25

FRIDA (2024). Food data (frida.fooddata.dk), version 5.2. National Food Institute, Technical University of Denmark.

Hurrell, R., Egli, I. (2010). Iron bioavailability and dietary reference values. *Am J Clin Nutr.* 91: 1461-7S.

Institute of Medicine (2001). Food and Nutrition Board . Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc : a Report of the Panel on Micronutrientsexternal link disclaimer. Washington, DC: National Academy Press.

Lopez-Alonso, M., Miranda, M., Bonedito, J.I., Pereira, V., Garcia-Vaquero, M. (2016). Essential and toxic trace element concentracion in different commercial veal cuts in Spai. *Meat Science*, 121, 47-52.

Mann, N (2013). Human evolution and diet: a modern conundrum of health versus meat consumption, or is it? *Anim. Prod. Sci.*, 53 (11), 1135-1142.

Mann, N. (2007). Meat in human diet: An anthropological perspective. *J. Nutr. Diet,* 64 (4), s102-s107.

Nasreddine, L., Nachalian, O., Naja, F., Itani, L., Parent-Massian, D., Nabhani-Zeidan, M., Hwalla, N. (2010). Dietary exposure to essential and toxic trace elements from a Total diet study in an adult Lebanese urban population. *Food Chemistry and Toxicology*, 48, 1262-1269.

National Food Institute, Technical University of Denmark (2024) https://frida.fooddata.dk/links?lang=en

Noel, L., Chekri, R., Millour, S., Vastel, C., Kadar, A., Sirot, V., Leblanc, J.C., Guerin, T. (2012). Li, Cr, Mn, Co, Ni, Cu, Zn, Se and Mo levels in foodstufs from the 2th french TDS. *Food Chem.* 132, 1502-1513.

Shone, F., Ibel, A., Larkowski, S., Ihling, M., Ramminger, S., Kirmse, R., Sporl, K., Kieβling, G., Glei, M. (2023). Composition of pork and german meat products with a focus on iron, selenium and iodine. *Journal of food Composition and analysis*, 19, 105246.

USDA Foreign Agricultural Service. (2013).