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Determination of the Iron Content of the Muscle and Organ Meats from a Cow Carcass

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ABSTRACT
Iron is an essential micronutrient for all animal species, and its deficiency causes fatigue, poor growth, impaired cognition, and anaemia. The World Health Organization (WHO) estimates that anaemia affects approximately 30% of the global population, with iron deficiency as the primary cause. This work sought to provide data on the protein, iron and moisture content of the muscle and organ meats of a cow carcass, using atomic absorption spectrometry (AAS) to determine non-haem iron and spectrophotometry to determine haem iron. Results showed that the lungs exhibited the highest moisture content (83.91 ± 1.37 %) while the spleen had the lowest (73.79 ± 2.24 %), with a statistically significant difference ($p<0.05$). Muscle meat exhibited the highest crude protein (18.63 ± 1.06 %), followed by spleen (18.51 ± 0.91 %) and liver (17.26 ± 0.73 %); kidney demonstrated the lowest (13.99 ± 1.09 %), with lungs and heart showing similarly low levels ($p>0.05$). The spleen had the highest haem iron (247.53 ± 5.91 µg haematin/g meat) and non-haem iron (586.07 ± 22.31 mg/kg), with significant differences ($p<0.05$). The heart demonstrated the lowest haem iron (128.95 ± 8.10 µg haematin/g meat), closely followed by lungs (132.61 ± 4.16 µg haematin/g meat), with no significant difference ($p>0.05$), while the kidney had the lowest non-haem iron (117.87 ± 6.96 mg/kg), ($p<0.05$). Conclusively, both muscle and organ meats (liver, spleen) are rich in protein, while iron contents were higher in the organs (spleen, liver), with the spleen being significantly ($p<0.05$) higher. Therefore, these meat parts should be chosen for consumption especially when optimum iron and protein nutrition is targeted.

Keywords: Iron content, Cow carcass, Haem iron, Non-haem iron, Muscle meat, Organ meat, Moisture content, Crude protein

INTRODUCTION

Meat is the edible tissue of animals and encompasses various parts including muscle tissue (skeletal and smooth), organs (liver, lungs, kidney, heart, spleen), fat, bones, connective tissue, and intestines (Pereira, 2013). It is a nutritionally dense food, providing protein, vitamins, and essential minerals, and is mainly consumed cooked or processed (Pereira, 2013). Beef, the culinary term for meat from cattle (*Bos taurus*), is particularly valued for its protein, iron, and vitamin B12 content (McAfee et al., 2010). Meat is mainly composed of water, protein, and fat, and its quality is influenced by the genetics, age, and nutritional status of the animal (Listrat et al., 2016).

Iron deficiency remains one of the most prevalent nutritional problems globally. The World Health Organization (WHO, 2001) estimates that iron deficiency is the primary cause of anaemia, which affects over 1.6 billion people worldwide, with particularly high prevalence among women, infants, and populations in developing countries. Animal-derived foods, especially red meat, are recognized as among the best dietary sources of bioavailable iron, primarily in the haem form, which is more readily absorbed by the body than non-haem iron from plant-based sources (Geissler and Singh, 2011).

Several studies have investigated the iron content of bovine tissues. Valenzuela et al. (2009) reported that total iron in bovine viscera varied markedly across organs, with the spleen recording the highest total iron content, and haem iron comprising over 60% of total iron in muscle cuts. Ponnampalam et al. (2017) similarly documented significant variation in iron concentrations across bovine muscle and offal tissues. Lombardi-Boccia et al. (2002) reported on the proximate composition and mineral content of meat, confirming that organ meats generally contain higher mineral concentrations than skeletal muscle. Despite these contributions, comprehensive data on both haem and non-haem iron across multiple tissues of a single cow carcass — particularly under conditions relevant to sub-Saharan African food systems — remain limited (FAO, 2018). This regional gap is significant because indigenous cattle breeds common to sub-Saharan Africa, together with differences in forage composition, grazing systems, and traditional rearing practices, may produce biochemical and nutrient profiles that differ meaningfully from cattle raised under the intensively managed systems typical of the temperate-zone studies cited above.

Understanding the iron distribution across different tissues of a cow carcass is important for developing evidence-based nutritional guidelines and informing dietary recommendations, especially in iron-deficient populations. This study therefore addresses that gap. The aim of this study was to determine the iron content of the muscle and organ meats from a cow carcass. The specific objectives were to: (i) determine the moisture content of the meat samples; (ii) determine the crude protein content; and (iii) determine the haem and non-haem iron content.

MATERIALS AND METHODS

Collection of Meat Samples

Meat samples (liver, kidney, lungs, heart, spleen, and muscle meat) were obtained from Zango Abattoir, Samaru, and

transported to the Department of Biochemistry, Ahmadu Bello University (ABU), Zaria, Kaduna State, for further processing. Acetone was obtained from the Biochemistry Department, ABU, and used for haem iron analysis. All samples were obtained from single female cattle carcass of the White Fulani (Bunaji) breed, aged 3 years, presented as apparently healthy at the time of slaughter. The triplicate determinations reported throughout this study represent analytical (technical) repeatability from this single animal and do not capture biological variation among cattle; the absence of biological replicates (i.e., multiple animals) is a significant limitation that constrains the generalisability of these findings to the wider cattle population, and results should be interpreted accordingly.

Sample Preparation

The collected samples were carefully rinsed with deionized water, arranged, labeled, and packaged in accordance with standard laboratory protocols to ensure identification, organization, and integrity.

Moisture Content Determination (AOAC 2016)

Aluminum dishes were thoroughly washed, dried to constant weight in an oven at 100°C, removed, and cooled in a desiccator. The dishes were weighed (W1) before adding 2 g of the cut meat sample; the sample-containing dishes were then oven-dried for 3 hours, cooled, and re-weighed (W3). Moisture content was calculated using the formula:

Moisture (%) = (W2 – W3) × 100 / (W2 – W1)

Determination of Crude Protein (AOAC, 2016)

Kjeldahl digestion was employed to determine crude protein content. The samples, each (0.5 g) was weighed into a Kjeldahl flask, followed by addition of copper catalyst and 15 ml of concentrated sulfuric acid (H_2SO4). The mixture was heated in a fume cupboard until it turned green. After cooling, the digest was transferred to a 100 ml volumetric flask with distilled water. The Markham distillation apparatus was steamed for 15 minutes before use. A 100 ml conical flask containing 10 ml of boric acid indicator was placed under the condenser. Ten millilitres of digest was pipetted into the apparatus, followed by distilled water and 10 ml of 40% NaOH solution. Steam distillation was performed for 5–7 minutes to collect ammonium sulphate. The collected distillate was titrated with 0.01N hydrochloric acid. Protein content was determined using the formula:

Protein (%) = (Final reading – Initial reading – Blank) × 1.4 × 6.25 / Initial weight

Determination of Non-Haem Iron in Meat Samples

Exactly 0.5 g of each sample was weighed into a clean glass beaker. A 30 ml mixture of nitric-perchloric acid (3:1 ratio) was added to facilitate digestion using a digestion block. Following digestion, samples were cooled and transferred quantitatively into 50 ml volumetric flasks. Solutions were diluted and shaken vigorously, then allowed to settle for 15 minutes. Atomic absorption spectrometry (AAS) was employed to quantify non-haem iron concentrations. Instrument parameters were optimized according to manufacturer guidelines. Calibration standards (0–10 ppm) were prepared using certified reference materials. Triplicate aspirations of standards and samples were performed, with absorbance readings recorded and averaged. Sample iron concentrations were interpolated from the calibration curve. The packaged samples were transported to the Institute of Agricultural Research (IAR) for digestion, and further analysis was conducted at the Multipurpose Laboratory, Chemistry Department, ABU, Zaria.

Determination of Haem Iron in Meat Samples (Pretorius et al., 2016)

Exactly 0.3 g of each sample was weighed into 50 ml conical flasks. A 6 ml acid-acetone mixture was added, followed by vortex mixing for 15 seconds. An additional 6 ml of the acid-acetone mixture was added and the samples vortex-mixed again for 15 seconds. To facilitate haematin extraction, samples were allowed to stand in the dark for 60 minutes, with occasional manual swirling. Following incubation, the samples were filtered through Whatman No. 1 filters to obtain clear filtrates. Spectrophotometric analysis was performed by measuring the absorbance of the filtrate at 640 nm against a reagent blank. The absorbance value was converted to micrograms of haematin per gram of meat by multiplying by 6800 and dividing by the sample weight.

Statistical Analysis

Results are expressed as mean ± standard deviation (SD) of three determinations. Statistical significance was determined at $p<0.05$ level.

RESULTS AND DISCUSSION

The moisture, crude protein, haem, and non-haem iron contents of the muscle and organ meats from a cow carcass are presented in Tables 1–3.

Moisture Content

The moisture content analysis revealed significant variations among the different tissues studied (Table 1). The lungs exhibited the highest moisture content (83.91 ± 1.37)% while the spleen had the lowest moisture content (73.79 ± 2.24)% with a statistically significant difference ($p<0.05$). The spleen, muscle, and liver showed close moisture levels ($p>0.05$). These variations are consistent with the physiological function of each organ. The high moisture content in lungs is attributable to its spongy, air-filled structure and high vascular supply. These variations are consistent with the physiological function of each organ. The high moisture content in lungs is attributable to its spongy, air-filled structure and high vascular supply. Similar tissue-dependent variability in moisture content has been reported in other ruminant offal studies, where moisture content differed significantly across organs, ranging from around 66–67% in muscle to as high as 80% in brain (Biel et al., 2019). Comparable lung and spleen moisture values, in the mid-to-high 70s%, have also been reported in cooked ovine offal, supporting the general pattern of high moisture retention in these highly vascularized organs (Hoffman et al., 2013).

Table 1: Moisture Content of the Muscle, Kidney, Heart, Liver, Lungs and Spleen from a Cow Carcass

Meat Samples	Moisture (%)
Muscle	74.57 ± 5.79^{ab}
Kidney	79.97 ± 7.31^{c}
Heart	68.59 ± 4.01^{a}
Liver	78.84 ± 5.22^{ab}
Lungs	83.91 ± 1.37^{c}
Spleen	73.79 ± 2.24^{ab}

Values are mean ± SD of three determinations. Means with different superscripts in the same column are statistically significant ($p<0.05$).

Crude Protein Content

The crude protein content (%) analysis showed significant differences ($p<0.05$) among the meat samples (Table 2). Muscle meat exhibited the highest crude protein content (18.63 ± 1.06 %) closely followed by spleen (18.51 ± 0.91 %) and liver (17.26 ± 0.73 %). Kidney demonstrated the lowest crude protein content (13.99 ± 1.09 %) with lungs and heart showing similarly low levels, indicating no significant difference ($p>0.05$). This finding is consistent with Listrat et al. (2016) who reported that muscle tissue is composed predominantly of contractile structural proteins required for repeated contraction and relaxation. The higher crude protein in muscle meat is attributable to the abundance of structural proteins such as myosin and actin that are critical for muscle function (Moustarah et al., 2024).

Table 2: Crude Protein Content of the Muscle, Kidney, Heart, Liver, Lungs and Spleen from a Cow Carcass

Meat Samples	Crude Protein (%)
Muscle	18.63 ± 1.06^{b}
Kidney	13.99 ± 1.09^{a}
Heart	14.44 ± 0.47^{a}
Liver	17.26 ± 0.73^{b}
Lungs	14.39 ± 0.90^{a}
Spleen	18.51 ± 0.91^{b}

Values are mean ± SD of three determinations. Means with different superscripts in the same column are statistically significant ($p<0.05$).

Haeme and Non-Haeme Iron Content

The haem and non-haem iron analysis revealed distinct patterns across the different tissues (Table 3). The spleen exhibited the highest concentration of haem iron (247.53 ± 5.91 µg haematin/g meat) and non-haem iron (586.07 ± 22.31 mg/kg), indicating significant differences ($p<0.05$). This finding is similar to the work of Valenzuela et al. (2009). Valenzuela et al. (2009) reported total iron concentrations of 31.2 ± 0.4 mg/100 g in bovine spleen, compared with 6.0 ± 0.1 mg/100 g in liver and 3.0 ± 0.05 mg/100 g in kidney, with haem iron accounting for 72.8% of total iron in spleen versus only 13.6% in liver — a pattern of splenic iron dominance consistent with the present findings. Similarly, Lombardi-Boccia et al. (2002) reported haem iron content of raw beef loin at approximately 23.5 mg/kg fresh weight (range 8.01–24.23 mg/kg), with haem iron comprising 72–87% of total iron in red meats generally. Direct numerical comparison with the present haem iron values (expressed as µg haematin/g meat via the acid-haematin method) is limited by differences in analytical method and units; nonetheless, the consistent direction of these findings — spleen and liver exceeding muscle in iron content — across studies using different techniques strengthens confidence in the present results. The heart demonstrated the lowest haem iron content (128.95 ± 8.10 µg haematin/g meat), closely followed by the lungs (132.61 ± 4.16 µg haematin/g meat), indicating no significant difference ($p>0.05$). The kidney displayed the lowest non-haem iron content (117.87 ± 6.96 mg/kg), indicating significant difference ($p<0.05$). The low non-haem iron content of the kidney is consistent with its physiological role in iron conservation rather than storage. Under normal conditions, transferrin-bound iron filtered by the glomerulus is almost completely reabsorbed by renal tubular epithelial cells via transferrin receptor 1 and the megalin-cubilin receptor complex, preventing urinary iron wasting (Van Raaij et al., 2019). This efficient reabsorption mechanism means that the kidney retains only minimal quantities of storage iron under homeostatic conditions, which is reflected in the low non-haem iron values recorded in the present study.

The high iron content of the spleen is attributable to its primary physiological role in filtering blood and recycling haemoglobin from aged red blood cells, consequently accumulating high levels of both haem and storage iron. The biochemical basis for this accumulation is well established. Splenic red pulp macrophages (RPMs) perform erythrophagocytosis — the engulfment of senescent red blood cells — after which haemoglobin is degraded within the phagolysosome, releasing iron that is either recycled for erythropoiesis or stored as ferritin. Approximately 90% of the body's daily iron needs are met through this internal recycling mechanism, making the spleen the primary site of iron turnover in the body (Klei et al., 2021). This physiological role directly explains the exceptionally high haem and non-haem iron concentrations measured in the spleen in the present study.

The variation in the levels of iron, protein, and moisture could be a result of physiological factors (oxygen demand, cellular metabolism, blood flow, and circulation) and biochemical factors (enzymatic activity, protein synthesis and degradation, antioxidant mechanisms). These findings reinforce the nutritional value of organ meats, particularly spleen, as superior sources of bioavailable iron compared to muscle meat (Geissler and Singh, 2011; McAfee et al., 2010).

Table 3: Haem and Non-Haem Iron Content of the Muscle, Kidney, Heart, Liver, Lungs and Spleen from a Cow Carcass

Meat Samples	Haem Iron (µg haematin/g meat)	Non-Haem Iron (mg/kg)
Muscle	115.23 ± 8.08^{a}	209.57 ± 10.07^{ab}
Kidney	145.94 ± 15.99^{b}	117.87 ± 6.96^{a}
Heart	128.95 ± 8.10^{ab}	205.13 ± 23.14^{ab}
Liver	188.59 ± 14.31^{c}	266.77 ± 18.48^{bc}
Lungs	132.61 ± 4.16^{ab}	228.83 ± 8.59^{c}
Spleen	247.53 ± 5.91^{d}	586.07 ± 22.31^{d}

Values are mean ± SD of three determinations. Means with different superscripts in the same column are statistically significant ($p<0.05$).

These findings carry direct relevance for public health nutrition in sub-Saharan Africa, where iron deficiency anaemia remains a leading cause of morbidity. Mwangi et al. (2021) reported that the epidemiology of iron deficiency anaemia in sub-Saharan Africa is shaped by reliance on monotonous plant-based diets rich in iron absorption inhibitors, making haem iron from animal sources particularly valuable. The high bioavailable iron content identified in bovine spleen and liver in the present study supports their potential role as affordable, locally available dietary interventions. Organ meats from cattle which are frequently regarded as low-value by-products in commercial processing, are an underutilised nutritional resource that could meaningfully contribute to reducing iron deficiency in vulnerable populations, including women of reproductive age and young children.

CONCLUSION

In this study, the spleen was identified as the richest source of both haem and non-haem iron, making it particularly valuable for addressing iron deficiency. Muscle meat and spleen had the highest crude protein levels. As these findings are derived from a single cow carcass, they should be regarded as preliminary and indicative rather than definitive; broader validation across a larger sample of cattle, spanning different breeds, ages, and rearing conditions, is required before these results can confidently inform public health policy or nutritional recommendations. Therefore, these findings have relevance in nutritional labeling, dietary guidance, and public health advocacy and policy, subject to such further validation.

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