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RESEARCH ON THE MINERAL AND VITAMIN CONTENT OF BROWN TROUT MEAT DIFFERENTIATED FEED

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Abstract

Trout meat is rich in essential minerals and vitamins that contribute to human health. These nutrients are influenced by various factors, including breed, breeding system, season, age, and diet. Taking these factors into account, the aim of this study is to highlight how the quantity and quality of the feed that is supplied have an effect on the mineral and vitamin content of the meat of brown trout. The biological material was represented by 30 specimens of brown trout. At the end of the research, among the analysed minerals, the highest values were found in the case of phosphorus (P), which was in the range of 1775.83-2228.39 $g.kg^{-1}$, and copper (Cu) was in last place, with average values that varied in the range of 0.65-0.91 $g.kg^{-1}$. In terms of fat-soluble vitamins present in the meat, the highest concentration was of vitamin E, whereas vitamin D3 exhibited the lowest levels across all batches.

Key words: *brown trout, feed, mineral, vitamin content.*

INTRODUCTION

Brown trout *Salmo trutta* (Linnaeus 1758), also referred to as native or mountain trout, belong to the family of fish known as Salmonidae, being the most widespread species from the salmon family in Romania. It is widespread in the upper courses of mountain rivers and in mountain lakes; sometimes it is also present in watercourses in hilly areas and is highly appreciated by fishermen (Kaya & Erdem, 2009). Being a fish with highly appreciated meat (Kayim et al., 2011), is extensively cultivated in specialised trout farms, despite the preference for the more rapidly growing rainbow trout.

Fish meat has always been a staple product in human nutrition throughout the evolution of humanity, contributing significantly to the provision of necessary protein sources. Globally, 15% of eaten animal protein derives from fish and fish products being recommended for daily consumption (Pariser & Wallerstein, 1980; Novikov et al., 1997; Tocher et al., 2003; Osibona et al., 2009; Sabetian et al., 2012; Bissih, 2021; Mendivil, 2021; Chen et al., 2022), due to the fact that protein requirements of individuals can be met with only 400 grams of fish (Vranici et al., 2011).

The variations in the chemical composition of trout meat are influenced by a number of factors such as breed, genetic factors, sex, age, fishing season, environment, water salinity, temperature and its pH, feeding intensity, fodder type and quality, amount of natural food, breeding type (Shirai et al., 2002; Yeannesa & Almandos, 2003; Solvik and Rustad, 2005; Toppe et al., 2007; Hadzhinikolova & Atanasova, 2007; Erdem et al., 2009; Sabetian et al., 2012; Tkaczewska & Migdał; 2012; Teodorowicz 2013; Kaya et al., 2014; Sirakov, 2015; Siemianowska et al., 2016; Bayir et al., 2018; Rasul et al., 2021; Imtiaz et al., 2022; Sandu et al., 2023; Cocan et al., 2024).

Fish meat includes elevated levels of minerals, including phosphorus, calcium, magnesium, potassium, and substantial quantities of vitamins (Celik et al., 2008; Stoyanova, 2016; Mendivil, 2021) and their presence has biological significance, as numerous minerals participate in metabolic processes in all life forms (Tilami & Sampels, 2017), and their insufficiency can induce severe disorders in human body.

Minerals accumulate in trout meat not only from the administered feed but also from the natural environment through the gills and skin (Lall, 2002); however, their final content is influenced by environmental conditions and season (Bayir et al., 2018) and can even serve as an indicator of water contamination with heavy metals

(Alibabic et al., 2007; Alberto et al., 2021; Milošković et al., 2023).

MATERIALS AND METHODS

The aim of this paper was to assess the chemical composition in general of brown trout meat and, in particular, to highlight the mineral and fat-soluble vitamin content of it. There is available information regarding the meat quality of brown trout, but concerning the mineral and vitamin content, data from the specialised literature are limited.

Research took place in three trout farms from Suceava County in which different breeding and feeding strategies are applied.

In the first trout farm (F1), an extensive breeding system is applied, fish being raised in earth ponds, their feeding being based on the natural productivity of the ponds and an additional morning ratio of a conventional feed.

In the second farm (F2), a semi-intensive breeding system is used, trout's being bread similarly in earth ponds, being fed twice a day with a conventional feed.

At the third farm (F3), an intensive breeding system is practiced in concrete ponds, trout's being fed twice a day with a similar conventional feed as in the case of the second farm.

The chemical composition of the feed used in the feeding of trout from the three farms is presented in Table 1.

Table 1. Chemical composition of the used feed

Specification	Farm 1	Farm 2	Farm 3
Proteins (%)	42.00	40.00	42.00
Lipids (%)	12.00	22.00	22.00
Ash (%)	7.00	5.00	4.00
Cellulose (%)	2.7	3.0	2.00
Phosphorus (%)	0.8	1	-
Calcium (%)	0.7	0.7	-
Sodium (%)	0.2	0.2	-
Iron (mg/ kg)	40.0	40.0	-
Zinc (mg/ kg)	90.0	90.0	-
Copper (mg/kg)	5.0	6.0	-
Vitamin A (IE)	2500	10000	20000
Vitamin D3 (IE)	500	1500	2000
Vitamin E (mg)	100	200	200

As can be seen, there are differences between the main chemical constituents, especially with regard to lipid and vitamin content. In the case of the third feed, the mineral content was not stated on the label.

The biological material was of 30 brown trout, 10 fishes of both sexes were randomly picked from each farm during August-September of 2024 with a mass ranging from 215 to 381 grams. To determine the physical and chemical composition, samples were gathered from the fish muscles. Analyses were performed in duplicate.

Determination of the main chemical compounds was carried out as described by Nistor et al., 2014; 2019. Water and dry matter content was conducted using the drying method in an oven at +105°C until a constant weight is achieved. The determination of protein involves decomposing the analysed sample by heating it with sulphuric acid in the presence of catalysts, which reduces organic nitrogen to ammonium ions that can be quantified by distillation/titration. The equipment employed is the Kjeltec Auto 2300-Tecator, Sweden, which is a semi-automatic version of the crude protein Kjeldahl determination. The determination of lipid content was carried out using the Soxhlet method, which entails the extraction of fat from the analysed sample using petroleum ether with the Velp Scientifica SER 148 device.

Mineral determination was performed using a Shimadzu AA 6300 spectrophotometer in accordance with SR EN 14082/2003. 2 grams of samples were burnt at 550°C, dissolved, precipitated, filtrated and diluted to a desired volume, followed by aspiration into the air-acetylene flame of the atomic absorption spectrometer as described by Pagu et al. (2014), at different wavelength.

For phosphorus determination of, 1 g of sample was calcined in an oven at 550°C, hydrochloric acid solution was added for dissolution, filtered and made up to the mark with double-distilled water, introduced into the test tube together with the vanadium-molybdenum reagent. The absorbance measurement was made on a Shimadzu UVmini-1240 spectrophotometer at a wavelength of 430 nm by comparison with the reference solution in accordance with ISO 13730:1996 and SR ISO 2294:2009.

Determination of fat-soluble vitamins was carried out using a Shimadzu HPLC LC-20A equipped with analytical column. All samples underwent a 1:10 methanol dilution prior to filtration using a 0.2 µm filter. Analytical parameters for High-Performance Liquid

Chromatography (HPLC) were C18 5 µm x 4.6 mm ID x 250 mm, column temperature 40°C, mobile phase was acetonitrile: methanol 60:40 (v/v), flow rate 1 ml/min., injection volume 10 µl. Detection was at 265 nm, 280 nm and 325 nm.

The statistical analysis software utilized was SPSS. Mean, standard deviation, and statistical significance of the differences between batches were calculated.

RESULTS AND DISCUSSIONS

The quality of brown trout meat is determined not only by its sensory characteristics but also by its content of nutrients and micronutrients.

The chemical composition of brown trout depending on the farm system and feeding levels is presented in Table 2.

Table 2. Chemical composition (%) of brown trout meat depending on system and feeding ratio

Specification	Farm 1	Farm 2	Farm 3
Moisture	78.23 ± 1.12^{c}	77.34 ± 0.68^{b}	76.77 ± 0.52^{a}
Dry matter	21.97 ± 1.83^{c}	22.66 ± 1.21^{b}	23.23 ± 0.34^{a}
Proteins	$18.3 \pm 0.76^{b,c}$	17.77 ± 0.32^{a}	17.65 ± 0.21^{a}
Lipids	2.31 ± 0.84^{a}	3.60 ± 0.68^{b}	4.26 ± 0.34^{c}
Ash	1.16 ± 0.07^{a}	1.29 ± 0.06^{a}	1.32 ± 0.03^{a}

*Means in the same row with the same letter do not significantly differ at the level p<0.05.

It is observed that there are significant differences between all the major chemical constituents, except ash content, in the three systems of breeding and feeding applied on farms.

The dry matter content differed among the three breeding systems, with values spanning from 21.97% in the first farm to 23.23% in the third farm, suggesting that trout receiving two daily rations exhibited a higher dry matter content than those receiving a single ration. This result indicates that feeding frequency may influence the dry matter content.

Comparing the results to other research regarding brown trout (wild and in different breeding systems) it can be observed that in the dry matter case, are similar to those reported by Kayim et al. (2011), Nistor et al. (2014; 2019), Kaya et al. (2014), Sirakov (2015), Akhan et al., (2016), Barylo & Loboiko, (2018), Antão-Geraldes et al. (2018). However, they are lower than those documented by Koskela et al. (1997), Yeşilayer & Genç (2013), Bosco et al. (2013), Tilami et al. (2018), Erdem et al. (2020), and Alberto et al. (2021).

In the present study, the protein content ranged from 17.65% to 18.3%. Similarly, the protein content across the three farms was influenced by diet. However, in the case of Farm 2, despite the protein level of the feed being lower (40%) than that of Farm 3 (42%), the protein content of the trout meat was higher. Possible explanations for this discrepancy include differences in the type of breeding ponds (earth versus concrete) and/or the natural productivity of the basin. Despite receiving a single feed ration, the trout in the first farm displayed the highest protein content in their meat. This phenomenon may be attributed to the natural productivity of the pond and the occurrence of cannibalism among the trout.

The obtained results are higher than those reported by Koskela et al. (1997), and Kaya et al. (2014), similar to findings from several other studies, including those by Koskela et al. (1997), Kayim et al. (2011), Yeşilayer & Genç (2013), Nistor et al. (2014; 2019); Kaya et al. (2014), Sirakov (2015), Akhan et al. (2016), Barylo & Loboiko (2018), Antão-Geraldes et al. (2018), Tilami et al. (2018), Erdem et al. (2020), and Alberto et al. (2021). However, they are lower than those found by Bosco et al. (2013), and Akhan et al. (2016).

Lipids exhibited values ranging from 2.31% for samples from Farm 1 to 4.26% for samples from Farm 3, indicating that both the number of rations and the lipid content of the feed influence the final lipid content of the meat.

The results obtained are higher than those reported by Sirakov (2015), Akhan et al. (2016) and Antão-Geraldes et al. (2018) and, while they are similar to those of Kaya & Erdem (2009), Kayim et al. (2011), Yeşilayer & Genç (2013), Bosco et al. (2013), Nistor et al. (2014; 2019), Kaya et al. (2014), Akhan et al. (2016), Barylo & Loboiko (2018), Tilami et al. (2018), and Alberto et al. (2021). However, they are lower than those reported by Koskela et al. (1997), and Erdem et al. (2020).

Ash content was the only chemical parameter that did not differ significantly in all the experimental farms. The obtained results (1.16-1.32%) were similar to those researches mentioned above (1.09-1.6%), except the studies of Koskela et al. (1997), and Alberto et al. (2021).

Minerals are important for the proper functioning of the human body. They play key roles in various metabolic processes (Mishra, 2020). The mineral content of brown trout samples is presented in Table 3.

Table 3. Mineral content (mg.kg^{-1}) of brown trout meat depending on system and feeding ratio

Minerals	Farm 1	Farm 2	Farm 3
Calcium	220.73±0.45^{a}	247.88±0.35^{ab}	222.81±0.26^{bc}
Magnesium	134.69±1.55^{a}	231.62±1.63^{b}	168.12±1.72^{ac}
Sodium	156.53±1.47^{ab}	113.68±0.92^{ab}	96.35±0.79^{a}
Potassium	2623.1±1.33^{a}	2788.6±1.23^{bc}	2438.1±1.66^{c}
Zinc	9.7±0.92^{a}	7.1±0.83^{ab}	6.3±0.41^{bc}
Iron	16.68±1.15^{a}	5.28±0.23^{ab}	2.84±0.41^{abc}
Copper	0.71±1.51^{a}	0.91±1.23^{bc}	0.65±1.33^{b}
Phosphorus	1775.83±1.08^{a}	2228.39±1.66^{ab}	1994.1±1.15^{abc}

*Means in the row with different letters are significantly different at the level $p<0.05$.

As it can be observed, there are significant differences between elements depending of farming systems and feeding ratio, which is in correlation with the observation of Siemianowska et al., 2016.

Calcium is an essential mineral for the development, growth, and maintenance of bones and teeth and carries out many important roles in blood clotting and circulation, regulating muscle contractions, heart rhythm, and normal functioning of many enzymes.

The calcium levels were between 220.73 mg.kg^{-1} at Farm 1 and 247.88 mg.kg^{-1} at Farm 2, which are higher than what Alibabic et al. (2007), Kayim et al. (2011), Sirakov (2015), and Bayir et al. (2018) reported. However, these results are similar to those presented by Tidball et al. (2017), for wild brook trout. For rainbow trout raised in various systems, calcium levels reported by other authors ranged from 2.66 mg.kg^{-1} (Baskaya et al., 2023) to 632 mg.kg^{-1} (Gokoglu et al., 2004).

Magnesium, similar to calcium, is an essential macronutrient, playing an important role in nerve transmission, neuromuscular conduction, blood pressure, muscular contraction, and is even a cofactor in proteins, DNA, and RNA synthesis.

The magnesium content of brown trout meat ranged from 134.69 mg.kg^{-1} in samples from Farm 1 to 231.62 mg.kg^{-1} in samples from Farm 2. These values are comparable to those reported by Kayim et al. (2011), and Sirakov (2015) but lower than the values obtained by Bayir et al. (2018). Similar variation in data can be observed for other trout species. Tidball et al. (2017), found that wild brook trout had a magnesium level of 280 mg.kg^{-1}, while at rainbow trout magnesium levels ranged between 59.5 mg.kg^{-1} (Brucka-Jastrzebska & Kawczuga, 2011) up to 409 mg.kg^{-1} (Gokoglu et al., 2004).

Sodium is one of the important electrolytes in the body and plays a variety of fundamental roles in the body, being essential for the body's acid-base and fluid balance, being an active transport mechanism, and, along with potassium, is responsible for balancing nerve stimulation and muscle contraction.

In this study, the values obtained varied from 96.35 mg.kg^{-1} in samples from Farm 3 to 156.63 mg.kg^{-1} in samples from Farm 1, which are lower than those reported in other studies for brown trout. For wild brook trout, Tidball et al. (2017), found a sodium content of 450 mg.kg^{-1}, whereas for rainbow trout, values ranged from 19.53 mg.kg^{-1} (Baskaya et al., 2023) to 718.2 mg.kg^{-1} (Siemianowska et al., 2016).

Potassium is an essential mineral, playing a fundamental role in various metabolic proce-sses, including regulating fluid and electrolyte balance, nerve signalling, cell integrity and muscle contractions.

In terms of potassium content in brown trout meat, results ranged from 2438.1 mg.kg^{-1} in samples from Farm 3 to 2788.6 mg.kg^{-1} in those from Farm 2. Other researchers reported lower values, such as Bayir et al. (2018), or similar results, such as Kayim et al. (2011), and Sirakov (2015). However, these results are substantially lower than those found for other trout species.

Even though zinc plays an essential role in our biological system in skin and nail health, pre-venting retarded growth, loss of taste, together with vitamin A, forms melanin, immune function and other conditions (Sivaperumal et al., 2007), higher levels of zinc may lead to health problems (Kayim et al., 2011).

Zinc content in this study varied from 6.3 mg.kg^{-1} at Farm 3 to 9.7 mg.kg^{-1} at Farm 1. These results are higher than those reported by Vitek et al. (2007), and Alberto et al. (2021), and similar to findings by Alibabic et al. (2007), and Kayim et al. (2011). However, they are lower compared to the values observed by Sirakov (2015), Bayir et al. (2018), and Mona et al. (2011). Similar variations in data have been noted for other trout breeds. Tidball et al. (2017), found that wild brook trout had a zinc content of 5.5 mg.kg^{-1}, while rainbow trout had zinc levels ranging from 2.96 mg.kg^{-1} (Karimian-Khosroshahi et al., 2016) to 19.1 mg.kg^{-1} (Apines-Amar et al., 2004).

Copper is a vital mineral with several important functions in the human body. It is involved in red blood cell production, nerve cell health, and immune system support and is a cofactor for several enzymes. Furthermore, copper plays a role in collagen formation, iron absorption, and energy production. It possesses anti-infectious, antiviral, and anti-inflammatory properties, aiding the body in combating microbial threats.

Copper levels in this study ranged from 0.65 mg.kg^{-1} at Farm 3 to 0.91 mg.kg^{-1} at Farm 2. These findings are higher than those reported by Linde et al. (2004), Vitek et al. (2007), Mona et al. (2011), and Can et al. (2012), and are similar to results from Kayim et al. (2011), and Alibabic et al. (2007). However, they are lower than those reported by Sirakov (2015), Bayir et al. (2018), and Alberto et al. (2021). A similar variability is evident for rainbow trout, with data ranging from 0.05 mg.kg^{-1} (Bajc et al., 2005) to 8.19 mg.kg^{-1} (Celik et al., 2008).

Iron is crucial for human health, being essential for producing haemoglobin, a protein in red blood cells that carries oxygen throughout the body. Iron also supports various vital functions, including energy production, concentration, and gastrointestinal processes.

The iron content of the analysed samples exhibited significant variation: at Farm 1, the average value was 16.68 mg.kg^{-1}; at Farm 2, was 5.28 mg.kg^{-1}; at Farm 3, was 2.84 mg.kg^{-1}. This variability is consistent with findings from other studies concerning brown trout. For brook trout, Tidball et al. (2017), reported a value of 3.8 mg.kg^{-1}, while Varol et al. (2017), noted a range of 2.53 mg.kg^{-1} to 13.29 mg.kg^{-1} for rainbow trout.

Phosphorus is an essential mineral vital for several bodily functions, being a key component of bones and teeth, supporting energy production and muscle function. It also contributes to DNA structure, ATP synthesis, and various cell signalling pathways.

The phosphorus content of the analysed samples ranged from 1775.83 mg.kg^{-1} on Farm 1 to 2228.39 mg.kg^{-1} at Farm 2 samples. These results are higher than those reported by Alibabic et al. (2007), and Kayim et al. (2011), and are similar to findings by Sirakov (2015), Bayir et al. (2018), and Tidball et al. (2017), who reported a value of 2460 mg.kg^{-1} for brook trout. In the case of rainbow trout phosphorus content, it ranged from 1104 mg.kg^{-1} (Pagu et al., 2014), to 4640 mg.kg^{-1} (Apines-Amar et al., 2004).

Fat-soluble vitamins (A, D3, E, and K2) are crucial for human health. They're absorbed alongside dietary fats and play key roles in vital processes. Vitamin A supports vision, vitamin D is essential for bone health, vitamin E acts as an antioxidant, and vitamin K2 is important for blood clotting. These vitamins contribute to immune regulation and mental health. Unlike water-soluble vitamins, which the body excretes, excessive intake of these vitamins, stored in the body's fat tissues, can lead to toxicity.

The values of A, D3, E, K2 vitamins are shown in Table 4.

Table 4. Mineral content (μg.100 g^{-1}) of brown trout meat depending on breeding system and feeding ratio

Vitamins	Vitamin A	Vitamin D3	Vitamin E	Vitamin K2
Farm 1	14.51±2.46	11.69±3.48	1551.03±3.64	509±2.17
Farm 2	15.66±1.48	12.77±3.88	2156.66±1.74	692.64±0.52
Farm 3	37.34±0.15	17.66±0.21	2235.45±0.65	878.33±0.98

All analysed samples are sources of fat-soluble vitamins. The values obtained vary according to the rearing system and daily feed ration, with the highest values recorded in samples from Farm 3 and the lowest from Farm 1.

No research specifically addressing the vitamin content of brown trout was found; thus, comparisons will be drawn with studies related to rainbow trout.

In terms of vitamin A, results ranged from 14.51 μg.100 g^{-1} to 37.34 μg.100 g^{-1}. Similar findings were reported by Stancheva et al. (2010; 2014), and Harlioğlu (2012), although these were higher than those noted by Dias et al. (2003). Nonetheless, the results obtained are lower than those reported by Dobreva et al. (2017), and Ural et al. (2017).

The content of vitamin D3 in brown trout meat was found to range from 11.69 μg.100 g^{-1} to 17.66 μg.100 g^{-1}. These resuls are comparable to those reported by Dias et al. (2003), Stancheva et al. (2010; 2014), Harlioğlu (2012), and Dobreva et al. (2017); however, they are lower than the values reported by Ural et al. (2017).

The vitamin K content in brown trout meat ranged from 1151.03 μg.100 g^{-1} to 2235.45 μg.100 g^{-1}. These values are higher than the 392 μg.100 g^{-1} reported by Harlioğlu (2012), but lower than the findings of Ural et al. (2017), which ranged from 5220 μg.100 g^{-1} to 13760 μg.100 g^{-1}.

The vitamin E content was found to be the highest in brown trout meat with values ranging from 1551.03 μg.100 g^{-1} in case of Farm 1 samples to 2235.45 μg.100 g^{-1} at Farm 3 samples. This observation aligns with findings from other researchers regarding rainbow trout (Dias et al., 2003; Stancheva et al., 2010, 2014; Harlioğlu, 2012; Dobreva et al., 2017; Ural et al., 2017).

CONCLUSIONS

The investigated brown trout in this study were characterised by a good nutritional quality, a high amount of protein, mineral and vitamin content and a low level of lipid content.

The nutritional profile of fish varies depending of farming practices, and dietary differences.

Breeding type and feed influence the mineral content of brown trout meat. According of this study, fish rearing in semi-intensive breeding farm system contained higher mean concentrations of most of the mineral elements compared to trout from the other farms.

Brown trout meat is an important source of phosphorus and potassium in the human diet, providing a significant proportion of the daily recommended intake of these nutrients.

The addition of vitamins to fish feed increases the vitamin content found in the meat. The vitamin E content found in brown trout meat highlights its nutritional significance.

Future research concerning the mineral and vitamin content of trout meat are of great interest because there are insufficient data on this matter.

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