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Evaluation of bioactive substances in different parts of the root in beetroot (*Beta vulgaris* ssp. *esculenta* var. *rubra*)

Mohamed El-Amine Besbas[1,2,*] – Maria Takacs-Hajos[1]

[1]Institute of Horticultural Science
University of Debrecen, Faculty of the Agricultural and Food Sciences and Environmental Management H-4032, Boszormenyi Street 138, Debrecen, Hungary
[2]Kálmán Kerpely Doctoral School
[*]Correspondence: mohamedelaminebesbas@gmail.com

SUMMARY

Beetroot, also known as Beta vulgaris ssp. esculenta var. rubra, is a root vegetable that contains a substantial quantity of bioactive elements, notably antioxidants and anti-inflammatory properties. These bioactive compounds, including betalains, phenolics, and flavonoids, contribute to the health-promoting properties of beetroot. The antioxidant and anti-inflammatory effects of beetroot have been extensively studied in preclinical and clinical settings. The active compounds in beetroot have been reported to provide benefits in reducing the risk of various diseases, our research provides a comprehensive analysis of the bioactive compounds the inner and outer skin parts of the root structure. The findings aim to contribute to a deeper understanding of the potential health benefits associated with specific beetroot root components. Furthermore, the results have implications for optimising beetroot cultivation and processing for enhanced nutritional value. This research not only advances our knowledge of the phytochemical profile of beetroot outer skin but also offers valuable insights into the broader field of plant biochemistry and its applications in promoting human health and nutrition.

Keywords: *beetroot; bioactive compounds; outer skin*

INTRODUCTION

Diets rich in vegetables are strongly encouraged due to their health-enhancing properties. Specifically, vegetables featuring altered root structures, such as edible roots, contain bioactive compounds with a wide range of biological effects, notably exhibiting strong antioxidant properties (Marić et al., 2020). Globally, the consumption of fruits and vegetables remains inadequate, posing a heightened risk of various diseases and cancer. Research indicates that insufficient intake of these food groups contributes to approximately 2.635 million annual deaths. Notably, emphasizing the significance of meeting the recommended daily consumption of 600 g per individual for fruits and vegetables can potentially lead to a 1.8% decrease in the global disease burden (Lock et al., 2005). Root vegetables, exemplified by carrot, sweet potato, turnip, radish, rutabaga, beetroot, and others, typically contain bioactive compounds to varying degrees. The accumulation and retrieval of these bioactive compounds are subject to diverse factors that contribute to their variability (Bashir et al., 2022).

In the past few years, there has been a notable surge in interest surrounding the root vegetable *Beta vulgar*is ssp. *esculenta var. rubra,* commonly referred to as red beetroot, due to its recognized health-promoting properties as a functional food. Although scientific exploration of beetroot has intensified in recent decades, historical records reveal its utilization as a natural remedy dating back to ancient Roman times (Ninfali & Angelino., 2013). Red beetroot, commonly known as beet, garden beet, or table beet, enjoys a rich tradition and widespread popularity across various regions globally. This vibrant red-rooted vegetable is quintessentially linked with the term "beet" and holds a special place in culinary practices. Its popularity is particularly pronounced in Eastern and Central Europe, where it takes center stage as a key ingredient in iconic dishes such as borscht, vinaigrette salad, Russian "herring under fur" salad, and pickled cabbage with beetroot (Neelwarne, 2012). Beetroot contains high amounts of biologically active substances including betalains, carotenoids, phenols, B-vitamins (B1, B2, B3, B6 and B12), folateminerals, fibres, as well as sugars with low energetical value (Kale et al., 2018), and inorganic nitrate (Clifford et al., 2015). Each component of this plant possesses distinct therapeutic applications, serving as an antioxidant, antidepressant, antimicrobial, antifungal, anti-inflammatory, diuretic, expectorant, and carminative agent (Jasmitha et al., 2018). Beet roots serve as a rich reservoir of minerals beneficial for various aspects of health, including manganese for bone health, as well as magnesium, potassium, sodium, phosphorus, iron, zinc, copper, boron, silica, and selenium (Chawla et al., 2016; Masih et al., 2019).

The carotenoid content in beetroot leaves surpasses that of the tubers. This disparity is attributed to the accumulation of carotenoids within the chloroplasts of the green portions of plants, comprising a blend of α- and β-carotene, β cryptoxanthin, lutein, zeaxanthin, violaxanthin, and neoxanthin (Paliwal et al., 2016). The chemical composition differs depending on the red beetroot variety, the distribution of nutritional compounds in red beetroot varies based on the specific anatomical part of the plant, including the leaf, stem, root, and peel (Sawicki et al., 2016).

Beetroot peel, the outer layer of the beetroot, has been the subject of limited research regarding its nutritional value and potential consumption implications. Despite a few studies examining its

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properties, there remains a significant gap in understanding the full spectrum of its chemical composition and the implications of its consumption, as (Kujala et al., 2000) mentioned that the quantity of betanin and phenolic compounds in the beetroot is higher in the peel than in the flesh and crown. According to the findings reported by Shuaibu et al. (2021), the analysis indicates that beetroot peel is a valuable source of carbohydrates, protein, ash, fiber, lipid, and moisture. Additionally, it contains essential minerals such as copper, phosphorus, and iron, vital for effective bodily functions. The study suggests that instead of considering it as waste, the consumption of beetroot peel is encouraged. Investigating the chemical composition of beetroot peel can offer valuable insights into its potential advantages and applications, El-Beltagi et al. (2022) indicate the possibility for the peel's reutilization.

MATERIALS AND METHODS

The experiment took place in the Horticultural Demonstration Garden of the Centre for Agricultural Sciences at the University of Debrecen in 2023. The study involved four beetroot varieties, and the sowing date was on April 26th *(Table 1).* Each plot measured 5 m × 0.5 m and featured 2–2 rows per variety.

Table 1. **The varieties and beetroot types under examination**

Number	Variety	Type of beetroot
1.	Akela	Spherical
2.	Libero	Spherical
3.	Monty F_1	Spherical
4.	Carillon	Cylindrical

Throughout the growth phase, conventional agricultural practices and weeding methods were employed. Plant thinning occurred at the 2–4 leaf stage, and preventive sprays were applied to protect against potential threats such as flea beetles and fungal diseases. Harvesting took place on July 7, 2023. The evaluation of measurements included dry matter content (m/m) %, total polyphenol (mgGAE/100g), flavonoid (mgCAE/100g), and Vitamin C (mg/100g). These analyses were conducted at the Central Laboratory of the University of Debrecen.

The determination of total polyphenol content in beetroot samples utilized the Folin–Ciocalteu method as described by Lamaison & Carnat (1990), with gallic acid (GA) serving as the standard. The results were expressed as milligram gallic acid equivalents (GAE)/100 g fresh matter of beetroot. For flavonoid content, the colorimetric method outlined by Lamaison & Carnat (1990) was followed, with catechin chosen as the standard. The data were expressed as milligram catechin equivalents (CE)/100g of dried beetroot.

Beetroot dehydrating

To assess beetroot measurements, a drying procedure is essential, employing a conventional dehydrator. The protocol initiates by thoroughly cleaning the beetroots and eliminating their stems and leaves. Subsequently, after peeling, the outer portion is retained, and the inner part is sliced. These slices or peels are then arranged on the trays of the dehydrator *(Figure 1, 2).* The beetroot slices are subjected to a drying process in the dehydrator set at 52 °C for approximately 10 hours.

Following the procedure, both the inner slices and the peel appear crisp and completely dry, as depicted in *(Figure 3).*

Figure 1–2. **Inner and peel slices of beetroot before dehydrating**

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Figure 3. **Beetroot results after dehydrating A) Inner part, B) Peel skin**

Following separate dehydration, both the inner slices and peels undergo grinding using a grinder to yield a powdered form. Grinding is a crucial step in preparing samples for laboratory analysis.

Statistical analysis

Statistical analysis was conducted using SPSS software. The data underwent analysis of variance (ANOVA), and Tukey's post hoc test was employed to identify significant differences among means (n=3) at a probability level of 0.05 and 0.5.

RESULTS AND DISCUSSION

Comprehensive comparison of our four distinct beetroot varieties Akela, Libero, Monty F1, and Carillon is provided, delineating characteristics between the outer and inner portions in *(Table 2)*.

Dry matter content exhibits variability, with outer varieties ranging from 92.8% to 94.4% (mean 93.5%) and inner varieties ranging from 90.3% to 93.2% (mean 92.1%). Notably, the outer layer of Carillon stands out with the highest dry matter content at 94.4%. In terms of bioactive compounds, outer varieties generally showcase elevated levels: total polyphenols range from 1819 to 2867 mg GAE/100g (mean 2421.5 mg GAE/100g), flavonoids from 358 to 600 mg CAE/100g (mean 503.3 mg CAE/100g), and vitamin-C from 311 to 413 mg/100g (mean 363.6 mg/100g). Monty F_1 in the outer group particularly excels, recording the highest levels of total polyphenols (2867 mg GAE/100g), flavonoids (600 mg CAE/100g), and vitamin C (413 mg/100g).

Conversely, inner varieties generally exhibit lower levels: total polyphenols range from 1046 to 1364 mg GAE/100g (mean 1174.4 mg GAE/100g), flavonoids from 133 to 233 mg CAE/100g (mean 179.2 mg CAE/100g), and vitamin C from 217 to 250 mg/100g (mean 231.3 mg/100g). Libero in the inner group shows notable higher levels, particularly in total polyphenols (1364 mg GAE/100g) and flavonoids (233 mg CAE/100g).

Table 2. **Examining the bioactive components in different parts of beetroot verities**

Varities	Dry matter (m/m)%	Total polyphenol (mgGAE/100g)	Flavonoids (mgCAE/100g)	C-vitamin (mg/100g)
1. Akela	92.8	2512	524	374
2. Libero	93.6	2488	532	356
3. Monty F_1	93.1	2867	600	413
4. Carillon	94.4	1819	358	311
Outer - mean	**93.5**	**2421.5**	**503.3**	**363.6**
1. Akela	90.3	1046	133	217
2. Libero	93.2	1364	233	250
3. Monty F_1	92.1	1090	154	218
4. Carillon	92.67	1198	196	240
Inner – mean	**92.1**	**1174.4**	**179.2**	**231.3**

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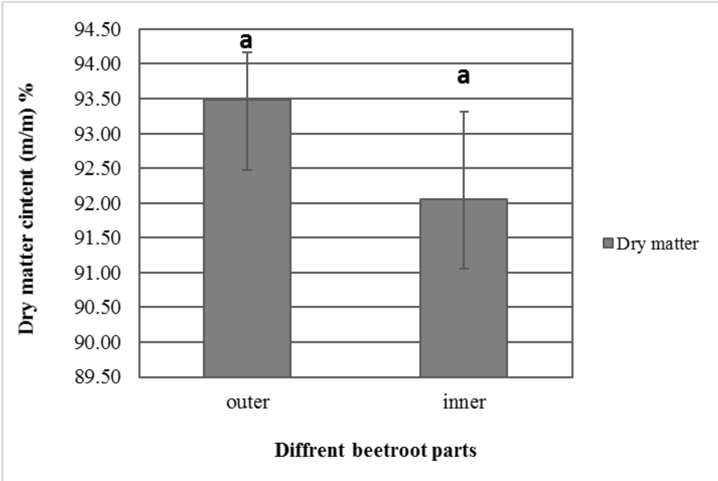
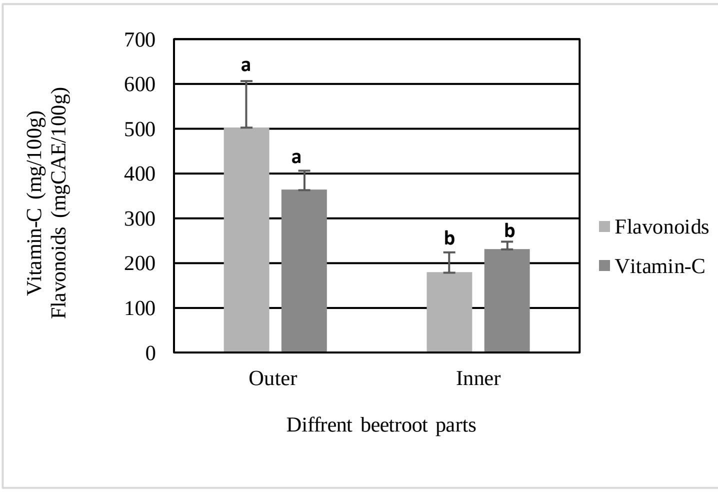
The bar chart in (*Figure 4*) depicting the mean dry matter content of outer and inner varieties of beetroot reveals a notable similarity between the two groups. The absence of a significant difference in dry matter content suggests that, on average, both outer and inner beetroot varieties exhibit comparable levels of solid content.

Figure 4. **Evaluation of dry matter content in the outer and inner part of beetroot in the mean of varieties**



The mean dry matter content for the outer varieties is recorded at 93.5%, which falls within the range 96.65% obtained by (Raziya et al., 2017) when the proximate and mineral analysis of beetroot and Indian black berry (*Syzygium cumini*) juice was carried out the beetroot peels were dried at room temperature. This reduced its water content. Moisture content of a dried sample means its shelf life; samples with high moisture deteriorate on storage. While the inner varieties exhibit a slightly lower mean of 92.1%. The negligible difference suggests that, on average, both outer and inner beetroot varieties share similar dry matter compositions. The mean flavonoid and vitamin C content in outer and inner varieties of beetroot clearly illustrates a substantial and statistically significant difference between the two groups *(Figure 5*). Khattack and Rahman (2016) conducted an analysis on vegetable peels as a natural reservoir of vitamins and minerals. Their research findings indicated the presence of vitamins within these peels.

Figure 5. **Evaluation of Vitamin-C and flavonoids content in the outer and inner part of beetroot in the mean of varieties**



Notably, the outer varieties exhibit markedly higher mean levels of flavonoids and vitamin C compared to the inner varieties. The mean flavonoid content for the outer varieties is recorded at 503.3 mg CAE/100g, while the inner varieties show a lower mean of 179.2 mg CAE/100g. Similarly, the mean vitamin C content for the outer varieties is notably higher at 363.6 mg/100g, compared to the inner varieties, which have a lower mean of 231.3 mg/100g. These findings underscore the richness of flavonoids and vitamin C in the outer part of beetroot, emphasizing its potential as a valuable source of these beneficial compounds.

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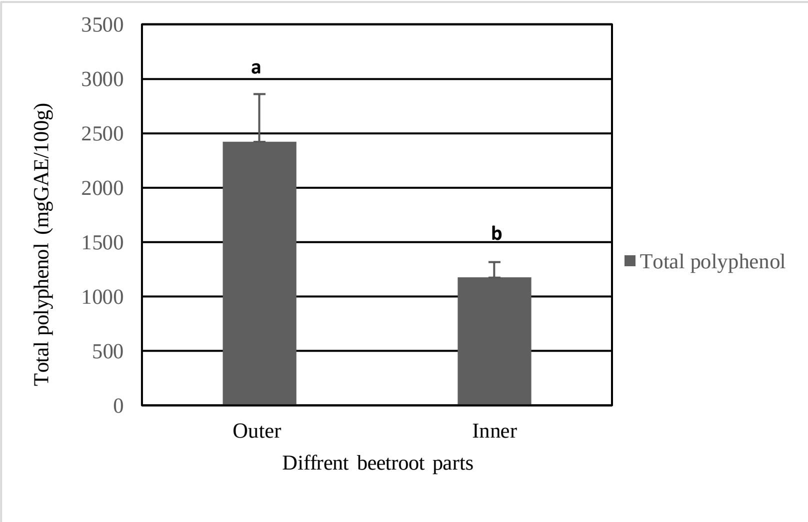
Assessment of the total polyphenol content in outer and inner varieties of beetroot presents a distinctive profile, with a significant disparity between the two groups *(Figure 6)*.

Specifically, the outer varieties demonstrate a robust mean total polyphenol content of 2421.5 mg GAE/100g, surpassing the inner varieties, which exhibit a comparatively lower mean of 1174.4 mg GAE/100g, which compared favorably with the results obtained by (Lazăr et al., 2022) showing beetroot peels exhibit elevated levels of dietary fibers and minerals, boasting an impressive 50% phenolic content, whereas the flesh contains only 13%. This significant difference underscores the outer portion of beetroot as a considerably more abundant source of total polyphenols. These findings underscore the potential health benefits associated with consuming the outer portion of beetroot, given its elevated polyphenol content.

Figure 6. **Evaluation of total polyphenol content in the outer and inner part of beetroot in the mean of varieties**



CONCLUSIONS

The analysis results reveal that beetroot peel, often considered as waste, possesses substantial nutritional value and can be deemed fit for consumption by both animals and humans. The proximate composition analysis indicates that the peel contains appreciable levels of essential nutrients. Furthermore, elemental analysis highlights elevated levels of total polyphenols, flavonoids, and vitamin C in the peel. These compounds are recognized for their roles in antioxidant and anti-inflammatory activities, cellular protection, and the maintenance of healthy skin, blood vessels, and bones. Consequently, the findings suggest that beetroot peel, with its beneficial compositions, should be considered a viable and nutritious option for consumption, akin to the pulp. This insight promotes a broader perspective on utilizing beetroot peel, potentially minimizing waste while harnessing its nutritional benefits for overall health and well-being.

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