

Article

Comparative Study of the Bioactive Compound Content of Sweet Potato Varieties Grown in Hungary

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Abstract

Sweet potato (*Ipomoea batatas* (L.) Lam.) is increasingly recognized as a functional crop due to its rich content of health-promoting phytochemicals. This study compared the phenolic compound profiles of four sweet potato varieties differing in flesh colour (purple, orange, white, and pale yellow) cultivated in three distinct regions of Hungary. The objective was to evaluate the relative effects of pigmentation and growing location on antioxidant capacity. Tubers were collected in triplicate and analyzed spectrophotometrically (UV–Vis) for vitamin C, total flavonoids, and total polyphenols. Statistical analysis using two-way ANOVA and Tukey's HSD revealed that flesh colour had a significant effect on all antioxidant parameters ($p < 0.05$), whereas geographic origin did not. Purple-fleshed tubers exhibited markedly higher levels of vitamin C (21.6 mg/100 mL), flavonoids (378.7 mg/100 mL), and polyphenols (37.0 mg/100 mL) compared with the other colour groups. These findings indicate that pigmentation is a stronger determinant of antioxidant potential than cultivation region. The results highlight the promising nutritional value of Hungarian purple-fleshed sweet potato varieties, supporting their use in functional food development and sustainable agricultural diversification strategies.

Keywords: sweet potato; antioxidant capacity; bioactive compounds; pigmentation; functional foods; UV–Vis spectrophotometry



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1. Introduction

Sweet potato (*Ipomoea batatas* (L.) Lam.) is a widely cultivated root crop of growing importance in both tropical and temperate regions owing to its remarkable adaptability and nutritional composition [1–4]. Unlike *Solanum tuberosum*, it belongs to the *Convolvulaceae* family and is characterized by a highly diverse phytochemical profile [3]. Pigmented cultivars are particularly valued for their health-promoting bioactive compounds: orange-fleshed types are rich in carotenoids such as β -carotene [5], which acts as provitamin A and contributes to visual, immune, and cellular protection functions. Regular consumption of β -carotene-rich varieties can therefore improve vitamin A status and help prevent deficiency-related disorders, as demonstrated in human intervention studies [6,7].

Purple-fleshed varieties, by contrast, accumulate high concentrations of anthocyanins, flavonoids, and phenolic acids with potent antioxidant and anti-inflammatory activity [2,4,5,8–10]. Experimental studies confirmed that purple sweet potato anthocyanin

extracts alleviate inflammation and oxidative stress in vivo, for example, by reducing colitis symptoms in mouse models [11]. According to recent reviews, the consumption of purple-fleshed cultivars may also provide cardiovascular, hepatic, and neuroprotective benefits due to their strong radical-scavenging capacity [12].

The accumulation of these phenolic and anthocyanin compounds is strongly influenced by environmental and agronomic factors. High light intensity, temperature stress, or nutrient limitation can enhance phenolic biosynthesis as part of the plant's protective response [12]. Similarly, soil composition, mineral availability (notably nitrogen and phosphorus), and water regime may modulate secondary metabolite pathways; nitrogen limitation, for instance, can increase phenolic accumulation by redirecting carbon flux toward defence-related metabolites [7].

Among lighter-fleshed cultivars, such as pale-yellow or white varieties, the pigment content is markedly lower, yet their polyphenolic precursors and flavonoid derivatives can still contribute significantly to the nutritional value, particularly when grown under mild environmental stress that stimulates phenolic metabolism [12]. These genotypes are also more tolerant of low-input production systems and nutrient-poor soils, which broadens their relevance for sustainable agriculture.

In Central Europe, including Hungary, commercial cultivation of sweet potato is expanding rapidly; however, phytochemical information on locally adapted cultivars remains scarce [3]. This knowledge gap limits their inclusion in targeted breeding programmes and regional food innovation strategies. Moreover, cross-study comparisons are often constrained by methodological variability. Although advanced chromatographic techniques (HPLC, LC–MS) provide detailed compound-specific profiling, UV–Visible spectrophotometry remains the most practical and cost-effective approach for rapid antioxidant screening [9,10]. Yet, inconsistencies in reagents, protocols, and data normalization hinder reproducibility, highlighting the need for standardized FW-based quantification and validated colorimetric assays.

The biosynthesis of phenolic compounds can be strongly influenced by environmental factors such as soil composition, light exposure, and temperature [13–21]. Nevertheless, it remains uncertain whether these external variables exert greater influence on antioxidant capacity than intrinsic genetic traits such as pigmentation. To address this question, the present study evaluates total polyphenol, total flavonoid, and total antioxidant capacity (FRAP) values in four flesh-colour groups of Hungarian sweet potato cultivars grown across three agroecological regions. By integrating both genotypic (colour) and environmental (regional) factors using two-way ANOVA, this work aims to generate standardized reference data and provide a reproducible UV–Vis-based benchmarking framework to support cultivar selection, applied breeding, and the development of functional food products within temperate agro-industrial contexts.

The present study aims to determine how genetic factors (tuber flesh pigmentation) and environmental factors (growing region) influence the bioactive compound content and antioxidant capacity of Hungarian sweet potato (*Ipomoea batatas* (L.) Lam.) cultivars. Specifically, the research examines the effect of flesh colour (purple, dark orange, pale yellow, and white) and production site on vitamin C, total flavonoid, and total polyphenol contents. By comparing cultivars grown under different conditions, the study seeks to identify how pigmentation and environment jointly shape their nutritional and functional properties.

Beyond assessing compositional differences, the study provides a scientific basis for the nutritional evaluation and potential functional food development of Hungarian sweet potato cultivars. These findings may support breeding programmes, enhance the evidence-based expansion of domestic production, and ultimately contribute to reducing import dependency while promoting sustainable agricultural innovation in Hungary.

Sweet potato consumption and production have grown considerably in Hungary over the past decade. However, domestic supply is still largely dependent on imports—primarily from Egypt—due to the restricted number of licensed cultivars and limited authorized growers. This underscores the need for scientific evaluation of cultivar selection, quality characteristics, and nutritional value under local production conditions.

The relevance of this research is further strengthened by the climatic and soil differences between Hungary and major exporting regions (e.g., Egypt, Spain, Israel), which likely influence the accumulation of bioactive compounds and antioxidant properties in locally grown tubers. Therefore, this study provides foundational knowledge for the valorization of Hungarian cultivars and supports the sustainable development of national sweet potato production, including cultivar selection, optimization of cultivation practices, and functional food innovation.

2. Materials and Methods

2.1. Sample Collection and Classification

Fresh storage roots of sweet potato were harvested in January 2025 from three agroecological regions of Hungary: Transdanubia (D), the Danube–Tisza Interfluve (D–T), and Tiszántúl (T) (Figure 1). Four cultivars differing in flesh colour—purple (*var. purpurea*), dark orange (*var. aurantiaca*), pale yellow (*var. lutea*), and white (*var. alba*)—were selected for the study.

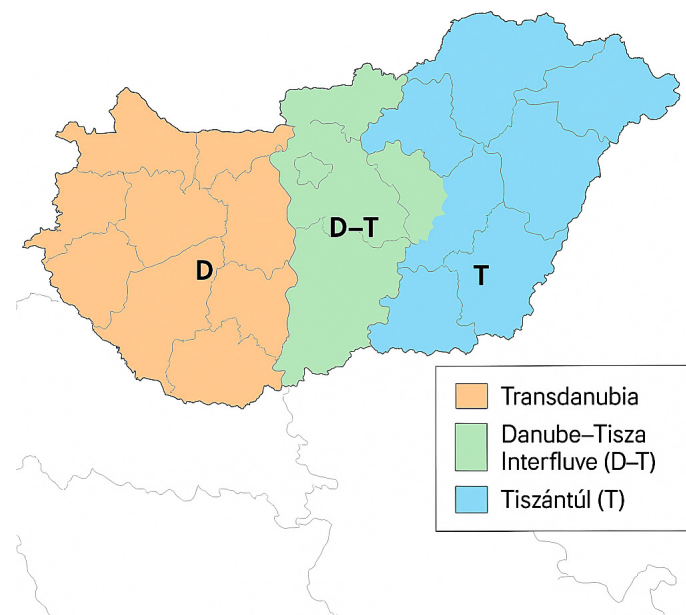


Figure 1. Sampling locations grouped into three agroecological regions of Hungary: Transdanubia (D), Danube–Tisza Interfluve (D–T), and Tiszántúl (T). Base map created by the authors using publicly available cartographic resources.

From each cultivar, four healthy and undamaged roots of comparable size (approximately 200–250 g each) were collected to ensure sample representativeness and to minimize size-related variability in analytical results. Care was taken to include tubers of similar maturity and development stage within each colour group. Immediately after harvest, all samples were cleaned of adhering soil and transported under cooled conditions to the laboratory, where sample preparation and analyses were conducted simultaneously to maintain consistency.

Triplicate composite samples from each region were used, yielding a total of twelve representative sweet potato samples [2,19].

2.2. Sample Preparation and Extraction

All sweet potato roots were thoroughly washed, peeled, and handled under sterile conditions. Each tuber was cut in half, and uniform cubes measuring approximately $1\text{ cm} \times 1\text{ cm} \times 1\text{ cm}$ were taken from the central portion of the flesh to obtain homogeneous samples. The excised tissue was immediately homogenized, and the fresh samples were stored at $4\text{ }^{\circ}\text{C}$ until extraction.

To ensure reproducibility, the same extraction procedure was applied for all cultivars and replicates. From each tuber, 10 g of homogenized central tissue was extracted with 60% (v/v) methanol in distilled water, following validated protocols [22,23]. Extracts were stored at $4\text{ }^{\circ}\text{C}$ for 48 h to improve compound recovery, then sonicated in an ultrasonic bath (Emag Transsonic 570/H, Salach, Germany) for 20 min. Filtrates were collected using Whatman No. 1 filter paper and stored in amber vials at $4\text{ }^{\circ}\text{C}$ until analysis.

2.3. Reagents and Instrumentation

Analytical-grade reagents (Sigma-Aldrich, Merck KGaA, Darmstadt, Germany) included methanol, Folin–Ciocalteu reagent, gallic acid, quercetin, Na_2CO_3 , AlCl_3 , NaNO_2 , NaOH , TPTZ, $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$, and L-ascorbic acid. Instruments: analytical balance (ATY 22H, Shimadzu, Kyoto, Japan), ultrasonic bath (Emag Transsonic 570/H, Salach, Germany), UV–Visible spectrophotometer (UV-1280, Shimadzu, Kyoto, Japan), and standard glassware (ISO 3819) [24].

2.4. Determination of Flavonoid Content

Total flavonoids were quantified by the AlCl_3 colorimetric assay [25–27]. Standard curves were prepared with quercetin (3.125–50 mg/100 mL). For each sample, 1 mL extract was reacted with NaNO_2 (5%), AlCl_3 (10%), and NaOH (1 M). Absorbance was read at 510 nm after 10 min at room temperature. Results are expressed as mg quercetin equivalents per 100 g FW (mg QE/100 g FW) (Figure 2).

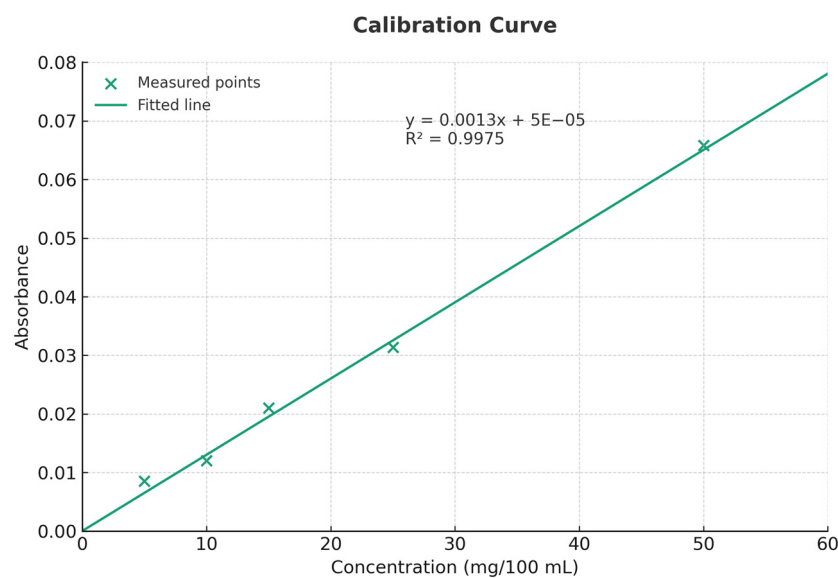


Figure 2. Quercetin standard calibration curve ($R^2 > 0.99$), demonstrating linear absorbance response across the tested range.

2.5. Determination of Phenolic Content

Total phenolics were measured using the Folin–Ciocalteu method [28]. Each extract (0.5 mL) was mixed with Folin–Ciocalteu reagent (10%) and Na_2CO_3 (6%), incubated for

90 min in the dark (25 °C), and read at 765 nm. Results are reported as mg gallic acid equivalents per 100 g FW (mg GAE/100 g FW) (Figure 3).

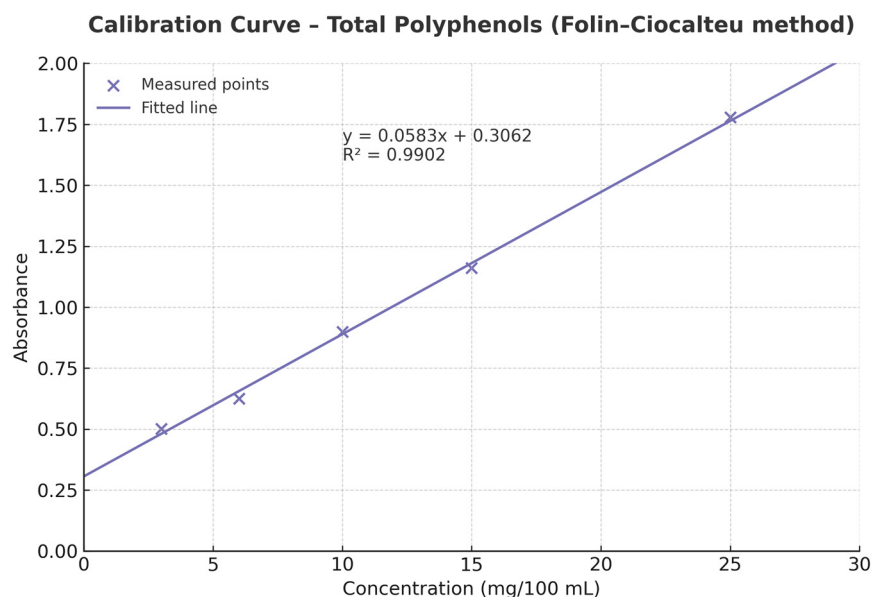


Figure 3. Gallic acid standard calibration curve used for total polyphenol determination, showing excellent linearity ($R^2 > 0.99$).

2.6. Determination of Vitamin C Content

Antioxidant capacity was assessed using the FRAP assay [29]. FRAP reagent was prepared from 300 mM acetate buffer (pH 3.6), 10 mM TPTZ in 40 mM HCl, and 20 mM $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ (10:1:1). Absorbance was measured at 593 nm, with results expressed as mmol Fe^{2+} equivalents/kg FW (Figure 4).

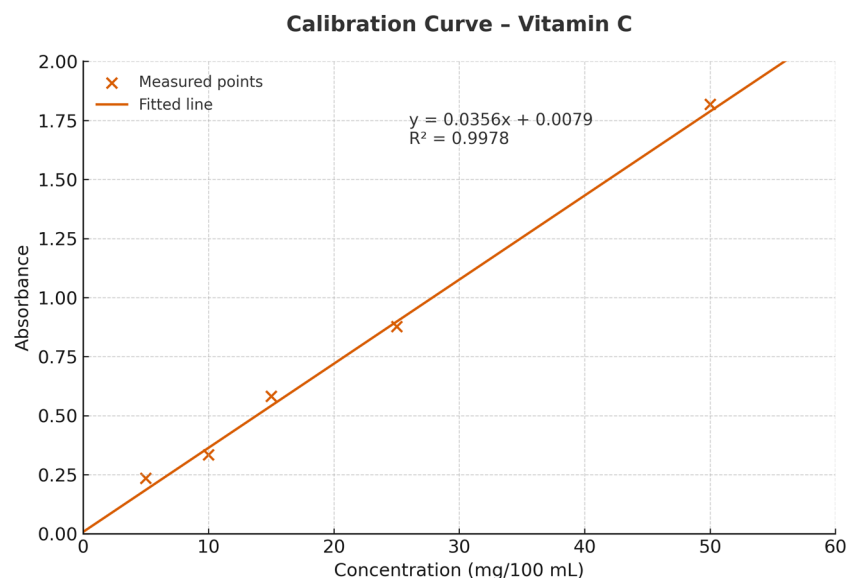


Figure 4. Ascorbic acid standard curve with linear regression ($R^2 > 0.99$).

2.7. Statistical Analysis

Calibration curves ($R^2 > 0.99$) were established for all assays. Limits of detection (LOD), limits of quantification (LOQ), repeatability (intra-day %RSD), and spike-recovery were determined according to standard guidelines [16,17,25,26]. Data were collected in triplicate and analyzed using two-way ANOVA to test the effects of cultivar colour and

growing region, followed by Tukey's HSD post hoc test ($p < 0.05$). Statistical analyses were performed in Microsoft Excel (Version 2305, Microsoft 365) (Figures 2–4).

3. Results

3.1. Influence of Tuber Flesh Colour and Growing Region on Antioxidant Parameters

To evaluate the effects of genotypic (flesh colour) and environmental (growing region) factors on antioxidant composition, a two-way ANOVA was performed on the measured levels of vitamin C, total polyphenols, and total flavonoids.

Flesh colour significantly influenced all three antioxidant parameters: Vitamin C: $p = 0.0027$; Flavonoids: $p = 0.0254$; Polyphenols: $p = 0.0014$.

In contrast, growing region did not have a statistically significant effect: Vitamin C: $p = 0.417$; Flavonoids: $p = 0.4821$; Polyphenols: $p = 0.5086$.

No significant interaction was observed between flesh colour and geographic origin for any parameter ($p > 0.05$), suggesting that the effect of pigmentation was consistent across all regions. These findings indicate that genetic factors—specifically pigmentation—play a more decisive role in determining antioxidant levels under Central European conditions [2,4,13].

3.2. Total Vitamin C Content

The vitamin C content varied considerably among the colour variants. The purple-fleshed sweet potatoes exhibited the highest ascorbic acid levels, with an average of 21.6 mg/100 mL and a maximum value of 25.8 mg/100 mL observed in sample T Purple (6). The orange and pale-yellow varieties showed intermediate concentrations, whereas the white-fleshed samples contained the lowest average level (2.5 mg/100 mL).

Tukey's HSD post hoc analysis confirmed statistically significant differences between purple-fleshed tubers and all other colour groups (mean difference > 16.1 mg/100 mL; HSD = 2.18 mg/100 mL). No significant differences were found among the non-purple groups. These findings are consistent with previous reports indicating that cultivars rich in anthocyanins tend to accumulate higher levels of vitamin C [13,30] (Figure 5).

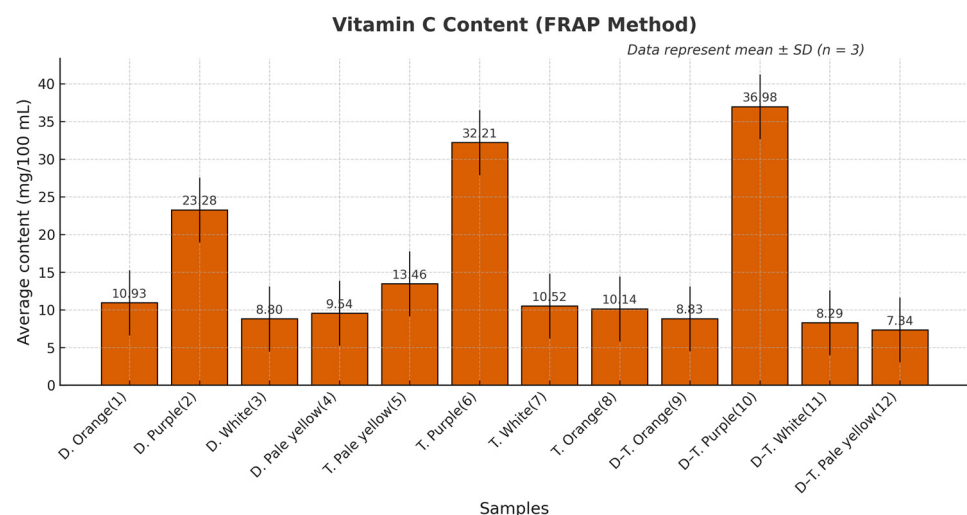


Figure 5. Vitamin C content (mg/100 mL) of sweet potato samples with different flesh colours and geographic origins. Source: Figure by authors, based on own experimental data.

3.3. Total Flavonoid Content

Flavonoid concentrations ranged from 12.70 to 378.68 mg/100 mL, with the highest value observed in sample D-T. Purple (10). Purple-fleshed tubers exhibited markedly higher

average flavonoid content (250.1 mg/100 mL) compared to orange (36.0 mg/100 mL), pale yellow (35.9 mg/100 mL), and white (18.8 mg/100 mL) varieties.

Tukey's HSD test revealed significant differences between the purple group and all non-purple groups (mean differences = 214.1–231.3 mg/100 mL; HSD = 211.05 mg/100 mL). However, no significant differences were observed among the non-purple groups.

These findings are consistent with the known association between anthocyanin pigmentation and increased flavonoid biosynthesis, particularly in darker-fleshed *Ipomoea batatas* cultivars [2,4,9] (Figure 6).

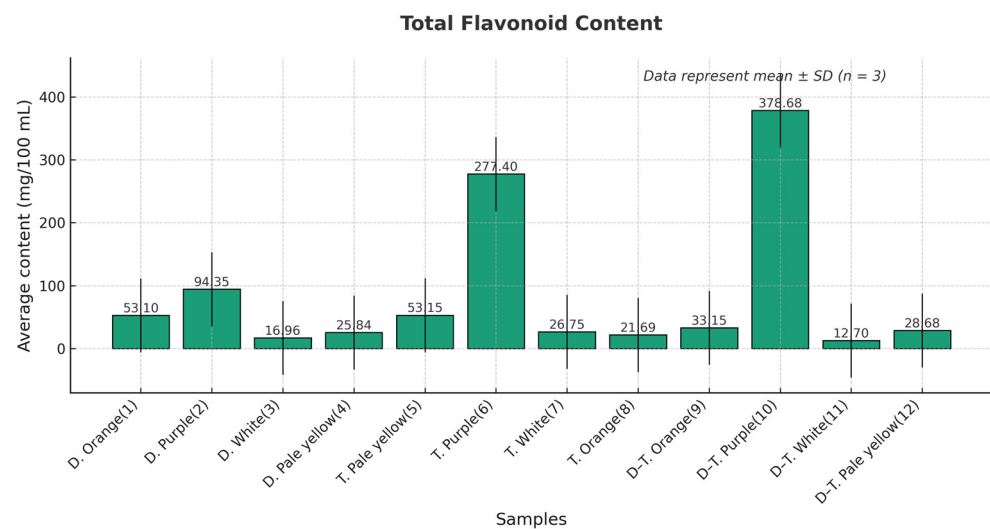


Figure 6. Flavonoid content (mg/100 mL) of sweet potato samples from different flesh-coloured varieties and regions. Source: Figure by authors, based on own experimental data.

3.4. Total Phenolic Content

Phenolic levels followed a pattern similar to that of vitamin C and flavonoids. Purple-fleshed tubers had the highest mean concentration (25.82 mg/100 mL), with the peak value (37.0 mg/100 mL) observed in sample D-T. Purple (10). The lowest polyphenol content was found in D-White(3) (1.02 mg/100 mL).

Tukey's HSD analysis confirmed statistically significant differences between purple and all other colour groups (mean differences > 11.3 mg/100 mL; HSD = 11.35 mg/100 mL). No significant differences were found among the orange, white, and pale yellow groups.

These results reinforce the strong correlation between pigmentation and phenolic compound accumulation (Figure 7) [23,31].

3.5. Summary of Antioxidant Composition by Flesh Colour

When grouped by flesh colour and averaged across all regions, purple-fleshed sweet potatoes exhibited the highest concentrations for all three antioxidant parameters: Vitamin C: 21.55 mg/100 mL; Flavonoids: 250.14 mg/100 mL; Phenolic compounds: 30.82 mg/100 mL.

White-fleshed varieties had the lowest average concentrations, followed by pale yellow and orange cultivars. These patterns were consistently supported by statistical analysis, highlighting pigmentation—particularly purple hue—as a reliable phenotypic marker of antioxidant capacity (Figure 8) [2,4,12]. Calibration curves and analytical validation parameters followed established guidelines [16,17,25,26].

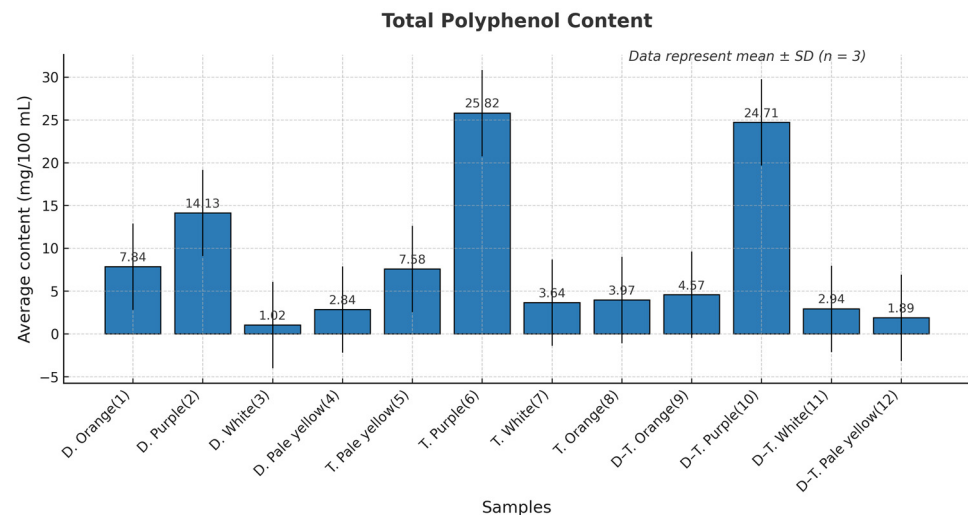


Figure 7. Phenolic content (mg/100 mL) of sweet potato samples from different regions and flesh colours. Source: Figure by authors, based on own experimental data.

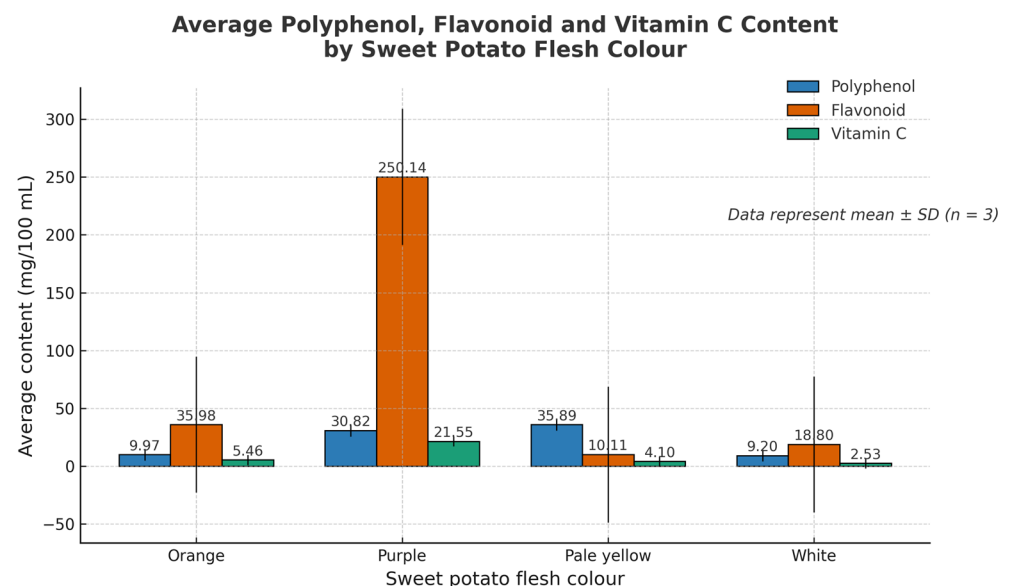


Figure 8. Comparison of average polyphenol, flavonoid, and vitamin C content (mg/100 mL) in sweet potato samples grouped by flesh colour. Source: Figure by authors, based on own experimental data.

3.6. Statistical Validation: Tukey's HSD Post Hoc Analysis

3.6.1. Phenolic Content

Tukey's HSD test showed that phenolic content was significantly higher in purple-fleshed samples than in all other colour groups ($p < 0.05$). Mean differences between purple and non-purple groups ranged from 20.7 to 21.6 mg/100 mL, exceeding the critical HSD value (11.35 mg/100 mL). No statistically significant differences were observed among the orange, pale yellow, and white groups (Table 1).

3.6.2. Flavonoid Content

Significant differences were also found in flavonoid content. Purple-fleshed cultivars had substantially higher values than all other groups, with mean differences ranging from 214.1 to 231.3 mg/100 mL. These exceeded the HSD critical threshold (211.05 mg/100 mL). No significant differences were observed among the orange, pale yellow, and white groups (Table 2).

Table 1. Tukey’s HSD test for total phenolic content by flesh colour. Source: Authors’ statistical analysis, 2025.

Comparison	Mean Difference (mg/100 mL)	HSD Critical Value	Significance
Purple vs. Orange	20.86	11.35	Significant
Purple vs. Pale Yellow	20.71	11.35	Significant
Purple vs. White	21.62	11.35	Significant
Orange vs. Pale Yellow	0.14	11.35	Not significant
Orange vs. White	0.76	11.35	Not significant
Pale Yellow vs. White	0.62	11.35	Not significant

Table 2. Tukey’s HSD test for total flavonoid content by flesh colour. Source: Authors’ statistical analysis, 2025.

Comparison	Mean Difference (mg/100 mL)	HSD Critical Value	Significance
Purple vs. Orange	214.15	211.05	Significant
Purple vs. Pale Yellow	214.25	211.05	Significant
Purple vs. White	231.34	211.05	Significant
Orange vs. Pale Yellow	0.18	211.05	Not significant
Orange vs. White	17.27	211.05	Not significant
Pale Yellow vs. White	17.09	211.05	Not significant

3.6.3. Vitamin C Content

Purple-fleshed tubers also showed significantly higher vitamin C levels than all other groups. Mean differences exceeded the HSD threshold (2.18 mg/100 mL) in all comparisons involving the purple group. No significant differences were observed among the non-purple varieties (Table 3).

Table 3. Tukey’s HSD test for vitamin C content by flesh colour. Source: Authors’ statistical analysis, 2025.

Comparison	Mean Difference (mg/100 mL)	HSD Critical Value	Significance
Purple vs. Orange	16.09	2.18	Significant
Purple vs. Pale Yellow	17.45	2.18	Significant
Purple vs. White	19.02	2.18	Significant
Orange vs. Pale Yellow	1.36	2.18	Not significant
Orange vs. White	2.93	2.18	Not significant
Pale Yellow vs. White	1.57	2.18	Not significant

Collectively, these results confirm that flesh colour—particularly purple pigmentation—is a reliable phenotypic marker of elevated antioxidant capacity in sweet potato tubers. The consistent statistical significance observed across all antioxidant classes highlights the nutritional value of pigmented cultivars and their potential in functional food development. These findings offer a strong foundation for further exploration of purple-fleshed varieties in both breeding efforts and food innovation.

4. Discussion

4.1. Comparative Analysis of Antioxidant Composition Across Cultivars and Regions

The aim of this discussion was to interpret the obtained results in the context of international research data, identifying the biological and environmental mechanisms that may explain the observed variations among different sweet potato colour types. According to previous studies, the quantity and type of bioactive compounds in *Ipomoea batatas* are primarily determined by the activity of pigment-related biosynthetic pathways (anthocyanin,

flavonoid, and carotenoid synthesis), which are jointly influenced by genetic background and abiotic factors such as light intensity, temperature, and water availability [12].

The results demonstrated that tuber pigmentation showed a strong positive relationship with vitamin C, total polyphenol, and total flavonoid contents, as well as with overall antioxidant capacity, consistent with several international observations [27–31]. The high anthocyanin content of purple-fleshed cultivars can be explained by the elevated activity of key enzymes regulating anthocyanin biosynthesis—chalcone synthase (CHS) and UDP-glucose:flavonoid-3-O-glucosyltransferase (UFGT)—while the β -carotene concentration in orange-fleshed varieties indicates a more intense flux through the carotenoid pathway [27–31].

Environmental influences, though less pronounced than pigmentation, may still affect phenolic compound biosynthesis through the induction of key enzymes. Increased light intensity and heat stress are known to elevate phenylalanine ammonia-lyase (PAL) activity, a rate-limiting enzyme in the formation of phenolic acids and flavonoids. This observation aligns with studies on other vegetable species showing that abiotic stress enhances secondary metabolite production [22,23,25].

The levels of antioxidant compounds in Hungarian purple-fleshed sweet potato cultivars—378.7 mg/100 mL of flavonoids and 37.0 mg/100 mL of polyphenols—are consistent with values reported for similar cultivars from China, Poland, and South America [2,4,13,17]. These phytochemicals are the main contributors to antioxidant activity, which is typically quantified using assays such as ABTS, DPPH, or FRAP. Similar high levels of flavonoids and phenolic compounds have been reported in deeply pigmented cultivars grown across diverse agroecological zones [23]. This suggests that the antioxidant-rich profile of Hungarian purple varieties is not regionally constrained and holds relevance for global breeding efforts. Furthermore, anthocyanin-rich sweet potatoes are increasingly recognized for their potential in functional food development. Studies from Asia and Latin America have highlighted the high radical-scavenging activity and thermal stability of acylated anthocyanins in these cultivars [4,12,13,30,31], making them suitable for processing into flours, purées, and shelf-stable products.

The strong parallel between Hungarian and international data reinforces the argument for integrating pigmented cultivars into breeding programmes and the functional food supply chain—both domestically and globally.

4.2. Methodological Considerations and Future Research Directions

While UV–Vis spectrophotometry offered a practical and cost-efficient means for estimating total antioxidant levels, the relatively high standard deviation in flavonoid results suggests the benefit of incorporating more sensitive analytical techniques. High-performance liquid chromatography (HPLC), liquid chromatography–mass spectrometry (LC–MS), or nuclear magnetic resonance (NMR) could enable compound-specific profiling with higher precision [17,18,32].

Future studies should also investigate how common processing techniques—such as boiling, baking, steaming, or drying—affect antioxidant stability and bioavailability. Thermal treatment may degrade vitamin C but enhance the extractability of polyphenols and flavonoids [22,33–36]. Exploring these effects using *in vitro* digestion models or bioaccessibility assays would provide valuable insights into the real-world nutritional impact of these compounds. Additionally, technologies such as nanoencapsulation or microencapsulation may improve the stability and delivery of polyphenols in food matrices [37–40].

To deepen understanding of cultivar-specific antioxidant profiles, integrating metabolomic and transcriptomic approaches could help elucidate gene–compound relationships underlying phenolic biosynthesis [2,17,41,42].

4.3. Local Relevance and Functional Food Applications in Central Europe

The findings of this study are particularly relevant to Hungary and other Central European countries, where sweet potato cultivation is expanding due to favourable climatic conditions and increasing consumer demand for health-promoting foods. Previous work has shown that antioxidant pathways in *Ipomoea batatas* can be activated under moderate environmental stress [3,43]. Purple-fleshed cultivars, with their naturally high levels of flavonoids and vitamin C, may serve as promising local sources of bioactive compounds. Their utilization in functional food development—such as juices, baby foods, or eldercare nutrition—could strengthen domestic food innovation and reduce reliance on imported ingredients.

From an agricultural perspective, promoting regionally adapted, nutritionally dense cultivars supports short supply chains, product differentiation, and dietary diversification, aligning with public health initiatives aimed at lowering chronic disease risk through functional food integration [6,8,44].

4.4. Human Health Implications of Bioactive Compound Profiles

The bioactive profiles measured—particularly the high concentrations of flavonoids, polyphenols, and vitamin C in purple cultivars—align with growing evidence supporting antioxidant intake in chronic disease prevention. Polyphenols such as chlorogenic acid and quercetin reduce oxidative stress and modulate inflammation [36,45–47]. Anthocyanins exhibit neuroprotective and antidiabetic properties, improving glucose metabolism and limiting reactive oxygen species [8,9,13]. Vitamin C acts both as a potent antioxidant and as a cofactor in collagen synthesis, immune function, and iron absorption [48–50].

These combined effects contribute to systemic protection against oxidative stress, and their co-occurrence in purple-fleshed sweet potatoes suggests synergistic nutritional potential. Although this study did not assess bioavailability directly, the measured concentrations fall within health-relevant ranges reported in clinical nutrition studies. Future work should address digestion and absorption dynamics through in vitro or in vivo models to validate these results in real dietary contexts [51,52].

These findings are consistent with current perspectives emphasizing the role of antioxidants in promoting longevity and preventing age-related diseases, further reinforcing their dietary importance [45,46,53–58].

5. Conclusions

This study demonstrates that flesh colour is a key determinant of the antioxidant composition of Hungarian sweet potato cultivars. Darker-fleshed varieties—especially purple and dark orange—showed substantially higher vitamin C, total polyphenol, total flavonoid contents, and overall antioxidant capacity than pale yellow or white cultivars, confirming pigmentation as a reliable indicator of enhanced bioactive potential.

Although the growing region had no statistically significant effect, environmental influences cannot be fully excluded. Nevertheless, pigmentation remained the dominant factor affecting antioxidant levels.

These findings highlight the potential of purple- and dark orange-fleshed sweet potatoes as valuable raw materials for natural colourants, antioxidant-rich ingredients, and functional food applications. Conversely, pale yellow and white cultivars may serve as neutral carriers where minimal colour or flavour impact is needed.

Overall, the results provide a scientific basis for cultivar selection, breeding strategies, and value-added product development in Hungary. Future research using compound-specific analytical methods and technological characterization could further support the

creation of high-quality functional foods and the sustainable expansion of domestic sweet potato production.

6. Limitations

This study has several methodological and practical limitations that should be considered when interpreting the results. First, the UV–Vis spectrophotometric methods applied (Folin–Ciocalteu and AlCl_3 assays) are rapid and cost-effective screening techniques but lack chemical selectivity. These assays measure the combined reactivity of multiple structurally related phenolic compounds, meaning that the reported total flavonoid and total polyphenol values represent aggregated, semi-quantitative estimates rather than compound-specific concentrations. As a consequence, the relative contribution of individual metabolites to antioxidant capacity may be either overestimated or underestimated, particularly in samples with high pigment content.

A second limitation relates to sample classification. Sweet potatoes were grouped based on flesh colour rather than genetically verified cultivar identity. This approach was necessary because commercial sweet potato production in Hungary is licence-restricted, and only a limited number of producers have access to certified, cultivar-specific planting material. As a result, the observed differences reflect phenotypic rather than genotypic variation, limiting the extent to which conclusions can be generalized at the cultivar level.

Taken together, these constraints mean that the findings primarily represent general phytochemical patterns associated with flesh-colour types rather than precise, genotype-specific differences. Therefore, the interpretation of results should take into account the semi-quantitative nature of the analytical methods and the phenotypic classification of samples.

Author Contributions: **Equal contribution:** E.V. and T.J. are considered co-first authors. E.V. conducted the sample collection. T.J., E.V., and J.C. were involved in sample preparation and analysis. T.J. and E.V. performed the statistical analysis. T.S.-R. coordinated and supervised the project. G.P.S. contributed to the proofreading and translation of the manuscript. T.J., E.V., J.C., G.P.S. and T.S.-R. jointly contributed to writing and editing the manuscript. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: All data supporting the findings of this study are available from the corresponding author upon reasonable request. No genetically modified organisms (GMOs) or endangered species were used in this research. All experimental protocols complied with institutional and international guidelines for ethical agricultural research.

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Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

AAE	Ascorbic Acid Equivalents
ANOVA	Analysis of Variance
D	Transdanubian region
D-T	Danube–Tisza Interfluve
FRAP	Ferric Reducing Antioxidant Power
FW	Fresh Weight

GAE	Gallic Acid Equivalents
HSD	Honest Significant Difference
R ²	Determination coefficient
QE	Quercetin Equivalents
SD	Standard Deviation
T	Tiszántúl region
TPTZ	2,4,6-Tri(2-pyridyl)-s-triazine
UV-Vis	Ultraviolet–Visible Spectrophotometry

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