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ORIGINAL ARTICLE

Bioavailability, Acceptability and Contribution of Beetroot Powder Processed Under Different Conditions to The Iron Intake of Adolescent Girls Aged 10 To 19 Years

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ABSTRACT

Iron deficiency anemia (IDA) is a prevalent issue among adolescent schoolgirls, significantly affecting their cognitive development and school performance. Beetroot, known for its high iron content, presents a potential solution for mitigating IDA. This study investigated the bioavailability, acceptability, and contribution of beetroot powder, processed under different conditions, to the iron intake of adolescent schoolgirls aged 10-19 years. Two beetroot varieties, Detroit Dark Red and Crimson Globe, were subjected to different processing methods, including boiling, sun drying, oven drying, and freeze drying. The bioavailability of iron was assessed through oxalate-to-iron molar ratios, while sensory acceptability was evaluated using a 9-point hedonic scale. The results revealed that the oxalate-to-iron molar ratios were below 1.0, indicating favorable iron bioavailability. Additionally, beetroot powder contributed between 9.24 mg and 9.5 mg of iron per 100g, equating to more than 50% of the recommended daily allowance (RDA) for adolescent schoolgirls. Sensory evaluation indicated moderate acceptability, with scores ranging from "like slightly" to "like moderately." These findings suggest that beetroot powder, particularly when processed by boiling and sun drying, can serve as a valuable dietary supplement to address IDA in adolescent girls.

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1. Introduction

Micronutrient nutrition has gained global recognition due to the widespread prevalence of micronutrient deficiencies, especially in developing countries. Approximately two billion people, about one-third of the world's population, are deficient in one or more essential micronutrients (Philomena Onwuamaeze, Hedwig, & Dorothy, 2017). Iron deficiency anemia (IDA), in particular, has significant adverse health effects, contributing to growth impairments, weakened immune systems, delayed mental and physical development, and poor reproductive outcomes (Ramakrishnan, 2002). These outcomes often cannot be entirely reversed by nutritional interventions alone. IDA is especially problematic among adolescent schoolchildren (Philomena Onwuamaeze et al., 2017). Vegetables are essential in combating IDA, particularly in developing countries, as they are rich in vital micronutrients such as vitamins, minerals, and dietary fiber (Alfthan et al., 2010). Beetroot, known for its potent anti-anemic properties, has shown efficacy in treating anemia (Beshel, Beshel, & Ante, 2018). Additionally, beetroot contains antioxidants and exhibits anti-inflammatory, anti-carcinogenic, and hepatoprotective activities (Slavov et al., 2013). It also provides health benefits for diabetes, cardiovascular disease, hypertension, and wound healing (Chikara et al., 2019). Consuming beetroot juice or incorporating beetroot as a cooked vegetable in salads has been reported to significantly improve hemoglobin levels, aiding in the treatment of anemia (Priya, 2013; Walker, 2010). In Uganda, beetroot is a significant source of micronutrients, such as zinc, iron, calcium, and vitamins, particularly for those living in urban areas. Plants such as amaranth, rhubarb, spinach, and beet are known to contain these micronutrients (Savage, Vanhanen, Mason, & Ross, 2000). However, despite its nutritional benefits, the absorption of minerals from food is often hindered by the presence of antinutritional factors, such as oxalates. High oxalate content in foods can reduce iron absorption, particularly when the oxalate-to-calcium ratio exceeds a critical threshold (Viteri & Gonzalez, 2002). This inhibitory effect on iron absorption is especially evident in foods with an oxalate-to-iron ratio greater than one, including beet leaves and roots (Sotelo et al., 2010).

IDA remains a critical health issue, but its prevention lies predominantly in food-based solutions rather than in other treatment or preventive measures. Although food-based interventions may not be suitable for immediate treatment, they provide the most desirable and sustainable means of preventing IDA. To implement such interventions, it is essential to understand the nutrient composition and bioavailability of minerals in commonly consumed foods. In Uganda, two varieties of beetroot are widely cultivated, but their nutrient profiles, particularly regarding iron bioavailability, have yet to be fully explored. The bioavailability of dietary minerals, especially in developing countries, is often low due to the presence of absorption inhibitors like oxalates and a limited intake of absorption promoters. Thus, this study aims to develop iron-rich beetroot products and investigate their nutritional value, with a particular focus on iron and oxalate contents. Furthermore, the study seeks to explore the relationship between the oxalate content of Ugandan beetroot varieties and iron absorption, assess the inhibitory effect of oxalates on iron bioavailability, and estimate the contribution of these iron-rich beetroot products to the recommended dietary allowance (RDA) of adolescent schoolgirls aged 10 to 19 years.

2. Materials and methods

2.1 Materials Preparation

Fresh beetroot samples were procured from Kabale at the Habuyonza Trading Centre, directly from local farmers. Mature beetroots were harvested on the same day and transported overnight in aerated wooden baskets to the Department of Food and Biosciences at the National Agricultural Research Laboratories (NARL) in Kawanda. The beetroots were carefully washed with clean potable water and stored in a refrigerator at 8°C prior to further processing. Defective samples were removed during sorting, and the selected beetroots were then washed again under clean running water to eliminate any dirt or foreign materials. After washing, the beetroots were peeled using a ceramic knife and immediately placed in clean water to prevent discoloration.

2.2 Processing of beetroot

The fresh beetroot samples were sliced into 1-2 mm thick pieces and divided into four portions. One portion was reserved as a fresh control sample, while the other three portions were subjected to different drying methods: oven drying (65°C for 48 hours), sun drying on raised plastic mesh, and freeze drying (-80°C for 48 hours). These methods were applied to preserve the beetroot's nutrient content and improve iron bioavailability. A second set of beetroot samples was boiled in distilled water at 90°C for 30 minutes in stainless steel saucepans. The boiled samples were then divided into four portions. One portion was reserved as a boiled control sample, while the remaining three portions were dried using the same methods applied to the fresh samples (oven drying, sun drying, and freeze drying). The fresh beetroot samples were grated into a mash, while the dried samples (sun-dried, freeze-dried, and oven-dried) were ground into powder using a mortar and pestle. The ground powder was passed through a 60 mm plastic mesh sieve and packed into dark, airtight containers for storage prior to further analysis. This procedure was conducted for both the Crimson Globe and Detroit Dark Red beetroot varieties. To extract beetroot juice, the powdered samples were reconstituted by mixing with water at a powder-to-water ratio of 1:7 (38.63 g of powder to 270.41 ml of water), while the fresh beetroot mash was mixed with water at a ratio of 1:2 (200 g of mash to 400 ml of water). The higher ratio used for dried samples facilitated their reconstitution into juice. Sugar syrup was prepared by heating 300 g of granulated sugar in 150 ml of water for 7 minutes to obtain a golden-brown gel, which was added at a 10% concentration to the juice samples. The juice samples were then pasteurized at 85°C for 10 minutes, cooled at room temperature, and stored for sensory evaluation. The same procedure was applied for boiled beetroot samples.

2.3 Oxalate content determination

Oxalate content of the samples was determined as described by Mubajje et al., (2024)

2.4 Minerals Analysis

Mineral content analysis was performed as described by Mubajje at al., (2024).

2.5 Iron (Fe) bioavailability Analysis

Iron bioavailability was determined by calculating the molar ratio of antinutrients (oxalates) to minerals (iron) in the beetroot samples, following the method described by Bagade (2022). Oxalate and iron contents were converted to moles by dividing their respective weights by their molecular weights (oxalate: 88.02 g/mol; Fe: 56 g/mol). The oxalate-to-iron molar ratio was calculated by dividing the moles of oxalate by the moles of iron. This molar ratio was used to predict the inhibitory effect of oxalates on iron absorption.

2.6 Sensory evaluation

Sensory evaluation was conducted with 50 untrained panelists, primarily students from the Department of Food Technology and Nutrition at Makerere University. The panelists evaluated five sensory attributes: taste, color, flavor, mouthfeel, and overall acceptability, using a 9-point hedonic scale (9 = "like extremely," 1 = "dislike extremely") (Meilgaard, Carr, & Civille, 1999). Each panelist was presented with seven samples, labeled with randomly assigned three-digit codes, and 50 ml of each juice sample at room temperature under normal lighting conditions. Water was provided to rinse the mouth between tastings. Reconstituted beetroot juice and control samples were prepared the day before and stored in a refrigerator until sensory evaluation.

2.7 Determination of Contribution to RDA

It was assumed that adolescent schoolgirls (10-19 years) could consume up to 100g of reconstituted beetroot powder juice. Since there were limited references on appropriate quantities of juice for this age group, the contribution of beetroot products to the iron intake of adolescent girls was estimated based on the micronutrient content of the selected best products, serving sizes for the age group, and the RDA of iron for girls aged 10-19 years.

2.7 Statistical data Analysis

One-way ANOVA was used to analyze the significant differences in triplicate results using Statistical Package for Social Science (SPSS) version 29.0. When $P<0.05$, the results were considered statistically significant.

3. Results and Discussion

3.1 Bioavailability of iron in the beetroot products

The molar ratios of oxalate to iron (Fe) in the different beetroot powder products are presented in Table 1. These ratios, which ranged between 0.0002 and 0.0006, were all well below the critical threshold (oxalate: Fe > 1), indicating good bioavailability of iron across all the processed beetroot samples. According to Nissar et al. (2017), an oxalate-to-iron ratio greater than 1 predicts poor iron bioavailability, as oxalates are known to inhibit iron absorption.

Table 1: The molar ratios of oxalate to Iron (Fe) for the different powder products.

Samples	Molar ratio (Oxalate: Iron)
SDR_{Dr}	0.0002 ± 0.00003^a
SDB_{Dr}	0.0002 ± 0.00004^a
SDR_{Lr}	0.0002 ± 0.00003^a
SDB_{Lr}	0.0003 ± 0.00006^a
FDR_{Dr}	0.0004 ± 0.00003^a
FDB_{Dr}	0.0006 ± 0.00001^b
FDR_{Lr}	0.0006 ± 0.00001^b
FDB_{Lr}	0.0001 ± 0.00002^a
ODR_{Dr}	0.0002 ± 0.00006^a
ODB_{Dr}	0.0002 ± 0.00003^a
ODR_{Lr}	0.0004 ± 0.00001^b
ODB_{Lr}	0.0002 ± 0.00004^a

Data are means ± standard deviation from three independent experiments. Mean values are significantly different ($p < 0.05$). SDRDr : Sun dried raw(Detroit dark red), SDBDr : Sun dried boiled (Detroit dark red), SDRLr : Sun dried raw (Crimson Globe), SDBLr : Sun dried boiled (Crimson globe), FDRDr : freeze dried raw(Detroit dark red), FDBDr : freeze dried boiled(Detroit dark red), FDRLr : freeze dried raw (Crimson Globe), FDBLr : Freeze dried boiled(Crimsone Globe), ODRDr : Oven dried raw(Detroit dark red), ODBDr: Oven dried boiled (Detroit dark red), ODRLr : Oven dried raw (Crimson Globe), ODBLr: Oven dried boiled (Crimson Globe)

Antinutritional factors, such as oxalates, can reduce the absorption of essential minerals, including iron, by forming insoluble complexes that hinder nutrient utilization (Gemede, 2014). High concentrations of oxalates, often found in plant-based foods, interfere with the body's ability to absorb iron efficiently, which may exacerbate micronutrient deficiencies (Hurrell, 2004). The molar ratios in all the beetroot samples analyzed in this study were significantly below 1, indicating that despite the presence of oxalates, the beetroot products provided favorable iron bioavailability (Table 1). The importance of food as a source of bioavailable minerals like iron, zinc, and calcium depends on both the total mineral content and the levels of antinutritional factors present in the food (Adeyeye et al., 2000). In this study, all the beetroot products demonstrated excellent bioavailability of iron, as evidenced by the low oxalate-to-iron molar ratios. This supports the potential use of beetroot powder as a valuable iron source in addressing iron deficiency, particularly in adolescent girls.

3.2 Sensory acceptability of the iron-rich beetroot products

The sensory evaluation of the beetroot juice powders is summarized in Table 2. Overall acceptability scores ranged from 5.00 to 6.00, indicating moderate consumer acceptability for both Detroit Dark Red and Crimson Globe beetroot varieties. Specifically, fresh juice from both varieties received the highest scores for flavor, taste, and overall acceptability, with ratings between 6.00 and 7.00, reflecting the panelists' preference for fresh juices over dried powder products. Although the processing method influenced sensory attributes, the boiled, sun-dried, and freeze-dried products of the Crimson Globe variety performed favorably in terms of flavor and mouthfeel. These results are consistent with findings by Grubben (2004), who reported that beetroot can enhance the flavor of beverages and food products. The fresh juices from both beetroot varieties were noted for their leafy vegetable-like flavor, which contributed to their overall high acceptability. In terms of color, there were significant differences ($p < 0.05$) among the various beetroot products. However, for other sensory attributes such as flavor, taste, and mouthfeel, the differences were not significant. The beetroot juice samples generally scored well for flavor, with ratings above 4.00, reinforcing beetroot's potential as a flavoring agent (Banigo et al., 2015). The findings indicate that beetroot products processed through sun or oven drying could be viable for producing refreshing, nutrient-rich drinks with acceptable sensory properties.

3.3 Contribution of the iron-rich beetroot products to the RDA (Iron) of adolescent school girls aged 10-19 years

Table 3 shows the percentage contribution of the beetroot products to the RDA of iron, calcium, magnesium, zinc, and phosphorus for adolescent schoolgirls aged 10 to 19 years. A serving of 50g of the boiled, sun-dried beetroot product was found to contribute 31.70% of the iron RDA, 6.35% of the calcium RDA, 21.27% of the magnesium RDA, and 33.07% of the zinc RDA. These results suggest that beetroot products, particularly from the Crimson Globe variety, provide substantial nutritional benefits.

The results indicate that consuming 50g of the boiled, sun-dried beetroot product would significantly contribute to the iron requirements of adolescent schoolgirls. This is particularly important in addressing iron deficiency anemia, which is common in this age group. Additionally, beetroot products were found to contribute to other essential nutrients, including magnesium and zinc, making them a valuable dietary supplement. Although the contribution of the Crimson Globe variety was slightly higher than that of Detroit Dark Red, both varieties were effective in meeting a significant portion of the RDA for iron and other micronutrients. Thus, incorporating these beetroot products into the diets of adolescent girls could play a role in reducing iron deficiency anemia and improving overall nutritional status.

Conclusion

This study demonstrated the potential of beetroot powder, processed under various conditions, to serve as a viable dietary supplement for improving iron intake and addressing iron deficiency anemia (IDA) in adolescent schoolgirls aged 10-19 years. The bioavailability of iron in the beetroot products was favorable, with all samples exhibiting low oxalate-to-iron molar ratios, indicating minimal inhibition of iron absorption. This suggests that beetroot powder can provide a significant source of bioavailable iron. In addition to iron, the beetroot products contributed to the intake of other essential minerals such as calcium, magnesium, and zinc, further enhancing their nutritional value. Sensory evaluation revealed that the beetroot juices were generally well accepted by the panelists, particularly the fresh and boiled, sun-dried products from the Crimson Globe variety, which received high ratings for flavor, taste, and overall acceptability. Overall, the findings support the use of beetroot powder as a nutrient-dense, sensory-acceptable, and cost-effective solution for reducing iron deficiency among adolescent girls. The inclusion of beetroot powder in school feeding programs or as part of regular dietary intake could substantially contribute to meeting the recommended daily allowance of iron and other essential nutrients. Additionally, the ease of processing and storage of beetroot powder makes it a convenient and long-lasting alternative to fresh beetroot, especially in regions where iron deficiency is prevalent.

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Conflict of interest

The authors declare that there is no conflict of interest concerning the publication of this research.

Tables 2: Sensory acceptability of the beetroot juice powder (n=50)

Sample	Attribute									
	Color		Taste		Flavor		Mouth feel		Overall Acceptability	
	DetR	CrimG	DetR	CrimG	DetR	CrimG	DetR	CrimG	DetR	CrimG
FDR	5.00 ± 2.4^{b}	4.00 ± 2.3^{d}	5.00 ± 1.7^{b}	5.00 ± 2.2^{b}	5.00 ± 1.8^{a}	5.00 ± 2.1^{a}	5.00 ± 2.1^{b}	5.00 ± 2.2^{b}	5.00 ± 1.9^{b}	5.00 ± 2.1^{b}
FDB	5.00 ± 2.4^{b}	5.00 ± 2.3^{c}	5.00 ± 2.1^{b}	5.00 ± 2.0^{b}	5.00 ± 2.2^{a}	5.00 ± 2.1^{a}	5.00 ± 2.1^{b}	5.00 ± 2.2^{b}	5.00 ± 2.2^{b}	5.00 ± 2.0^{b}
FJ	7.00 ± 1.9^{a}	7.00 ± 1.8^{a}	6.00 ± 2.1^{a}	5.00 ± 2.1^{b}	5.00 ± 2.2^{a}	5.00 ± 2.1^{a}	6.00 ± 2.1^{a}	5.00 ± 2.4^{b}	6.00 ± 2.0^{b}	6.00 ± 2.2^{a}
ODR	6.00 ± 2.1^{c}	5.00 ± 2.2^{c}	5.00 ± 1.7^{b}	5.00 ± 2.0^{b}	5.00 ± 1.9^{a}	5.00 ± 2.1^{b}	5.00 ± 2.1^{b}	5.00 ± 2.0^{b}	5.00 ± 1.8^{b}	5.00 ± 1.9^{b}
ODB	6.00 ± 1.8^{c}	5.00 ± 2.1^{c}	5.00 ± 2.0^{b}	4.00 ± 1.8^{c}	5.00 ± 2.0^{a}	4.00 ± 2.3^{b}	5.00 ± 2.0^{b}	5.00 ± 1.9^{b}	5.00 ± 1.8^{b}	5.00 ± 2.0^{b}
SDR	6.00 ± 1.8^{c}	6.00 ± 2.1^{b}	5.00 ± 2.1^{b}	5.00 ± 2.1^{b}	5.00 ± 2.1^{a}	5.00 ± 2.1^{a}	5.00 ± 1.9^{b}	5.00 ± 1.9^{b}	5.00 ± 2.0^{b}	5.00 ± 2.0^{b}
SDB	6.00 ± 1.9^{c}	6.00 ± 1.9^{b}	5.00 ± 1.9^{b}	6.00 ± 1.9^{a}	5.00 ± 2.1^{a}	5.00 ± 1.8^{a}	5.00 ± 2.1^{b}	6.00 ± 1.9^{a}	5.00 ± 1.9^{b}	6.00 ± 1.8^{a}

Values are means ± standard deviation (n = 64). Mean values in the same row with different superscripts (a – d) are significantly different ($p < 0.05$). DetR: Detroit dark red, CrimG: Crimson globe variety. Freeze dried raw: FDR, freeze dried boiled: FDB, Oven dried raw: ODR, Oven dried boiled: ODB, Sun dried Boiled: SDB, Sun dried raw: SDR, Fresh juice: FJ.

Table 3: Percentage Contribution of the Products to the RDA of adolescent School girls aged 10 to 19 Years

Minerals (mg)	RDA mg/Day	Content (mg/kg)		Content in 50g		% Contribution to RDA	
		DetR	CrimG	DetR	CrimG	DetR	CrimG
Fe	15	92.48	95.09	4.62	4.75	30.83	31.70
Ca	1300	1651.86	1280.52	82.59	64.03	6.35	4.93
Mg	360	1531.71	1296.36	76.59	64.82	21.27	18.01
Zn	9	59.52	46.06	2.98	2.30	33.07	25.59
P	1250	1668.03	1558.8	83.40	77.94	6.67	6.24

Values are means of triplicate measurements. DetR: Detroit dark red, CrimG: Crimson globe variety

References

Adeniyi, S. A., Orjiekwe, C. L., & Ehiagbonare, J. E. (2009). Determination of alkaloids and oxalates in some selected food samples in Nigeria. *African Journal of Biotechnology*, *8*(1), 110–112.

Adeyeye, E. I., Arogundade, L. A., Akintayo, E. T., Aisida, O. A., & Alao, P. A. (2000). Calcium, zinc and phytate interrelationships in some foods of major consumption in Nigeria. *Food Chemistry*, *71*(4), 435–441. https://doi.org/10.1016/S0308-8146(00)00159-X

Alfthan, G., Aspila, P., Ekholm, P., Eurola, M., Hartikainen, H., Hero, H., … Aro, A. (2010). *Nationwide supplementation of sodium selenate to commercial fertilizers: History and 25-year results from the finnish selenium monitoring programme*. *Combating Micronutrient Deficiencies: Food-based Approaches*. https://doi.org/10.1079/9781845937140.0312

Bagade, P., Pant, V., Commodities, N., & Services, M. (2022). Effect of phytate on bioavailability of select nutrients and simple techniques to reduce phytate in finger millet (Eleusine coracana), *7*(3), 7–8.

Banigo, E.B., Kiin-Kabari, D.B., & Owuno, F. (2015). No Title. *Physicochemical and Sensory Evaluation of Soy/Carrot Drinks Flavoured with Beetroot*, *6*(5), 136–140.

Berghofer, E., & Schoenlechner, R. (2002). Grain Amaranth. *Pseudocereals and Less Common Cereals*, 219–260. https://doi.org/10.1007/978-3-662-09544-7_7

Beshel, F. N., Beshel, J. A., & Ante, E. E. (2018). The Ethanolic Extract of Beetroot (Beta Vulgaris) Ameliorates Some Red Cell Parameters In Phenylhydrazine-Induced Anaemic Rats. *IOSR Journal of Nursing and Health Science (IOSR-JNHS)*, *7*(4), 27–30. https://doi.org/10.9790/1959-0704102730

Chhikara, N., Kushwaha, K., Sharma, P., Gat, Y., & Panghal, A. (2019). Bioactive compounds of beetroot and utilization in food processing industry: A critical review. *Food Chemistry*, *272*, 192–200. https://doi.org/10.1016/J.FOODCHEM.2018.08.022

Durowoju, O., & Popoola, O. (2014). Oxalate content of some Nigerian tubers using titrimetric and UV- Spectrometric methods. . *Academia Journal of Agricultural Research*, *2*(February), 54–57.

Fekadu Gemede, H. (2014). Antinutritional Factors in Plant Foods: Potential Health Benefits and Adverse Effects. *International Journal of Nutrition and Food Sciences*, *3*(4), 284. https://doi.org/10.11648/j.ijnfs.20140304.18

Fekadu, H. (2013). Effect of Traditional Processing Methods on Nutritional Composition and Anti-nutritional Factors of Anchote (Coccinia Abyssinica (lam.) Cogn) Tubers Grown in Western Ethiopia. *Journal of Food Processing & Technology*, *04*(07). https://doi.org/10.4172/2157-7110.1000249

Norman,W. W. (2024). Fresh Vegetable and Fruit Juices. Google Books. (n.d.). Retrieved August 24, 2024, from https://books.google.co.ug/books

Gergely, V., Kubachka, K. M., Mounicou, S., Fodor, P., & Caruso, J. A. (2006). Selenium speciation in Agaricus bisporus and Lentinula edodes mushroom proteins using multi-dimensional chromatography coupled to inductively coupled plasma mass spectrometry. *Journal of Chromatography A*, *1101*(1–2), 94–102. https://doi.org/10.1016/j.chroma.2005.09.061

Hough, G., & Garitta, L. (2012). Methodology for sensory shelf-life estimation: A review. *Journal of Sensory Studies*, *27*(3), 137–147. https://doi.org/10.1111/j.1745-459X.2012.00383.x

Hurrell, R. F. (2004). Phytic acid degradation as a means of improving iron absorption. *International Journal for Vitamin and Nutrition Research*, *74*(6), 445–452. https://doi.org/10.1024/0300-9831.74.6.445

Israr, B., Frazier, R. A., & Gordon, M. H. (2013). Effects of phytate and minerals on the bioavailability of oxalate from food. *Food Chemistry*, *141*(3), 1690–1693. https://doi.org/10.1016/j.foodchem.2013.04.130

Lee, C.-Y., Park, J.-E., Kim, B.-B., Kim, S.-M., & Ro, H.-S. (2009). Determination of Mineral Components in the Cultivation Substrates of Edible Mushrooms and Their Uptake into Fruiting Bodies. *Mycobiology*, *37*(2), 109. https://doi.org/10.4489/myco.2009.37.2.109

Mian Kamran Sharif, Masood Sadiq Butt, H. R. S. and M. N. (2011). Sensory Evaluation and Consumer Research. *Alcoholic Beverages*, 42–47. Retrieved from https://books.google.hr/books

Morten C. Meilgaard, B. Thomas Carr, G. V. C. (1999). *Sensory Evaluation Techniques* (3rd Editio). Boca Raton.

Mubajje, M. S., Lubowa, M., Yeoh, S., Acham, H., Tumuhimbise, G. A., & Matovu, M. (2024). Effect of Preparation and Drying Techniques on the Physicochemical, Functional and Nutritional Properties of products from Beetroot (Beta Vulgaris L.) varieties. Journal of Experimental Biology and Agricultural Sciences, 12(3), 399–407. https://doi.org/10.18006/2024.12(3).399.407

Nissar, J., Ahad, T., Naik, H. R., & Hussain, S. Z. (2017). A review phytic acid: As antinutrient or nutraceutical. *Journal of Pharmacognosy and Phytochemistry*, *6*(6), 1554–1560.

Philomena Onwuamaeze, N., Hedwig, A., & Dorothy, N. (2017). Acceptability, Nutritional Quality and Contribution of Vegetable-Enriched Products to Nutrient and Energy Requirements of School Children Aged 5 to 13 Years. *Food and Nutrition Sciences*, *08*(02), 242–266. https://doi.org/10.4236/fns.2017.82016

Priya, N. G. (2013). Beet root juice on haemoglobin among adolescent girls. *IOSR Journal of Nursing and Health Science*, *2*(1), 09–13. https://doi.org/10.9790/1959-

0210913

Ramakrishnan, U. (2002). Prevalence of micronutrient malnutrition worldwide. *Nutrition Reviews*, *60*(5 II). https://doi.org/10.1301/00296640260130731

Savage, G. P., Vanhanen, L., Mason, S. M., & Ross, A. B. (2000). Effect of Cooking on the Soluble and Insoluble Oxalate Content of Some New Zealand Foods. *Journal of Food Composition and Analysis*, *13*(3), 201–206. https://doi.org/10.1006/jfca.2000.0879

Slavov, A., Karagyozov, V., Denev, P., Kratchanova, M., & Kratchanov, C. (2013). Antioxidant activity of red beet juices obtained after microwave and thermal pretreatments. *Czech Journal of Food Sciences*, *31*(2), 139–147. https://doi.org/10.17221/61/2012-cjfs

Sotelo, A., González-Osnaya, L., Snchez-Chinchillas, A., & Trejo, A. (2010). Role of oxate, phytate, tannins and cooking on iron bioavailability from foods commonly consumed in Mexico. *International Journal of Food Sciences and Nutrition*, *61*(1), 29–39. https://doi.org/10.3109/09637480903213649

Ugwu, F. M., & Oranye, N. A. (2006). Effects of some processing methods on the toxic components of African breadfruit (Treculia africana). *African Journal of Biotechnology*, *5*(22), 2329–2333.

Viteri, F. E., & Gonzalez, H. (2002). Adverse outcomes of poor micronutrient status in childhood and adolescence. *Nutrition Reviews*, *60*(5 II). https://doi.org/10.1301/00296640260130795