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Quantitative Analysis of Calcium, Magnesium, and Sodium Concentrations in The Peels of Potato (*Solanum tuberosum* L.)

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Abstract

Plant-based wastes are organic materials primarily derived from agricultural activities, food production, horticulture, and the processing of forest products. These wastes include plant-derived components such as stems, leaves, roots, peels, residues, and fruit/vegetable scraps. Potato peel waste is one of the by-products generated during the processing of potatoes. This waste, resulting from processes such as peeling, processing, and slicing in the food industry, is often regarded as waste; however, it actually represents a significant resource from nutritional, economic, and environmental perspectives. Although potato peel is generally considered an agricultural waste, it is a by-product rich in certain minerals. In this study, the calcium (Ca), magnesium (Mg), and sodium (Na) contents of potato peel were analyzed, and their respective concentrations were determined as 319-320 mg/kg, 148-150 mg/kg, and 74-75 mg/kg. These values were compared with the findings of other researchers, taking into account the countries in which the studies were conducted. The results revealed that these mineral contents vary significantly depending on countries and cultivation conditions.

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Patates (*Solanum tuberosum* L.) Kabuklarındaki Kalsiyum, Magnezyum Ve Sodyum Konsantrasyonlarının Belirlenmesi

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Patates (*Solanum tuberosum* L.), patates kabuğu, bitki atıkları, mineral içerik

Öz

Bitkisel atıklar, tarımsal faaliyetler, gıda üretimi, bahçecilik ve orman ürünlerinin işlenmesi sonucunda ortaya çıkan, genellikle bitki kaynaklı organik materyallerdir. Bu atıklar, bitkisel kökenli sap, yaprak, kök, kabuk, posalar ve meyve/sebze artıkları gibi bileşenleri içerir. Patates kabuğu atığı, patatesin işlenmesi sırasında oluşan yan ürünlerden biridir. Gıda endüstrisinde patatesin soyulması, işlenmesi ve dilimlenmesi gibi işlemler sonucunda ortaya çıkan bu atık, genellikle çöp olarak değerlendirilmesine rağmen, aslında besinsel, ekonomik ve çevresel açıdan önemli bir kaynaktır. Patates kabuğu, genellikle tarımsal atık olarak görülse de bazı mineraller açısından oldukça zengin bir yan üründür. Bu araştırmada, patates kabuğunun Kalsiyum (Ca), Magnezyum (Mg) ve Sodyum (Na) içerikleri incelenmiş ve sırasıyla bu içeriklerin 319-320 mg/kg, 148-150 mg/kg ve 74-75 mg/kg olduğu tespit edilmiştir. Bu içeriklerin diğer araştırıcıların buldukları sonuçlar ile ülkeleri de dikkate alınarak karşılaştırmalar yapılmıştır. Bu içeriklerin ülkeler ve yetiştirme koşullarına göre önemli farklılıklar gösterdiği belirlenmiştir.

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Introduction

Plant nutrients are vital for various functions, including forming cell structures and metabolites, regulating osmotic balance and turgor pressure, facilitating energy transfer reactions, driving enzyme-catalyzed processes, and supporting plant reproduction. The efficient execution of these roles is crucial for optimal plant productivity. A plant nutrient may be considered beneficial if it does not meet the criteria of essentiality, but can be shown to benefit plant growth and development or the quality attributes of a plant or its harvested product (Kasap et al. 1999; Demirkiran, 2009; Demirkiran and Uslu, 2010; Demirkiran and Cengiz, 2010a,b; Kara et al. 2012; Demirkiran et al, 2012; Surucu et al. 2013; Ates et al., 2019; Surucu et al, 2020). The concentrations of different elements vary between plant species and have been known and researched for many years (Nacaroglu et al. 2009; Surucu and Demirkiran 2013; Boydak et al. 2021; Uslu et al. 2021).

Although different plant species may accumulate different nutrients to different extents, the environment and nutrients, and cultural application also affect their uptake and relative proportions in plants (Nacaroglu et al. 2009; Demirkiran and Uslu, 2010; Demirkiran 2021). In the science, regulation, commercialization and use of fertilizers and other sources of plant nutrients, the definition of an 'essential elements' has considerable importance for plant growth, namely carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), sulfur (S), calcium (Ca), magnesium (Mg), chlorine (Cl), boron (B), zinc (Zn), manganese (Mn), iron (Fe), copper (Cu), molybdenum (Mo), and nickel (Ni). Others, such as sodium (Na), silicon (Si), selenium (Se), aluminum (Al), cobalt (Co) or iodine (I), are known to also beneficially impact plant growth.

Minerals such as magnesium, calcium, and sodium play vital roles in various physiological processes of plants. Calcium is an essential element for plant growth. It is an important component of plant cell walls and membrane permeability. It is necessary for cell division and elongation. Calcium is immobile in plant tissue (Rao, 2009). While overall potato calcium levels are modest when compared to dairy or leafy greens, the unique composition of the peel might result in a higher localized concentration of calcium. Magnesium is a critical structural component of the chlorophyll molecule and plays an essential role in many enzymatic processes, including energy and protein metabolism in plants. The amount of Mg taken up for the growth of crops is generally somewhat lower than for Ca (Rao, 2009). In potatoes, magnesium is typically present in moderate amounts. Some studies have suggested that stress conditions, which also influence phenolic synthesis, might affect magnesium distribution in plant tissues (Chandrasekara and Kumar, 2016). Magnesium is relatively mobile in plants. There is a potential that potato peel, which is more actively involved in plant defense, might retain a differential magnesium profile compared to the inner parts of the tuber. Sodium is involved in osmotic (water movement) and ionic balance in plant metabolism. Sodium is used in place of K for certain plant functions. Sodium is relatively mobile in plants. (Rao, 2009). It does not contain information about the specific sodium content in potato peel.

Potato peel is an agricultural by-product that is often considered waste but is rich in certain elements. In this study, the calcium, magnesium, and sodium contents of potato peel were determined and compared with previous studies.

Material and Method

In this study, potato (*Solanum tuberosum* L.) peels were utilized as a representative plant-based waste material for the determination of calcium (Ca), magnesium (Mg), and sodium (Na) contents. The potato samples were obtained from local markets and grocery stores in Wolverhampton, England, to reflect

commonly consumed food products and enhance the relevance of the study to typical dietary waste streams. Following procurement, the peels were manually separated from the tubers and subjected to a two-step cleaning process. Initially, surface impurities and loosely bound contaminants were removed by rinsing with tap water. This was followed by a secondary wash with distilled water to eliminate potential ionic or particulate contaminants that could interfere with subsequent analyses. The cleaned peels were then cut into small, uniform segments to ensure homogenous drying. Drying was carried out in a forced-air oven at 70 °C until constant weight was achieved, indicating complete dehydration. Precisely 2.5 grams of each dried sample was weighed and transferred into porcelain crucibles, which were subsequently placed in a muffle furnace. The temperature was gradually increased to 650 °C, and samples were ashed over a period of 16 hours to ensure complete combustion and mineral residue formation. The resultant ash was treated with 5 mL of 25% (v/v) nitric acid (HNO_3) to solubilize the mineral constituents. The acid digests were filtered through blue band filter paper to remove insoluble particles, and the filtrates were diluted to 25 mL with distilled water. Quantitative analysis of Ca, Mg, and Na concentrations in the diluted solutions was performed using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) in The School of Architecture and the Built Environment at the University of Wolverhampton (UK) a sensitive and widely accepted technique for elemental analysis in plant-based matrices (Jarvis et al., 1992).

Results and Discussion

This study was carried out to determine the Ca, Mg, and Na concentrations of potato peel in England (Wolverhampton) and comparisons with data of previous studies. Although potato peel is generally considered an agricultural waste, it is a by-product that is quite rich in certain minerals. Various studies have investigated the calcium (Ca), magnesium (Mg), and sodium (Na) contents of potato peel, revealing that these mineral contents show significant variations between countries and possibly due to cultivation conditions (Tables 1, 2, 3). In this study, Ca contents of potato peel were determined among 319 mg/kg to 327 mg/kg and compared with previous studies (Table 1).

Table 1. Comparison of Calcium (Ca) Content in Potato Peels (PP)

Mean Ca content (mg/kg)	Country of PP origin	References
2	Nigeria	Abdullahi et al. (2021)
67	Romania	Cozma et al. (2024)
70	Nigeria	Yusuf et al. (2017)
130	Bulgaria	Zhivkova (2021)
240	India	Singh et al. (2022, 2023)
300	General value, EU	Anonymous 1 (2025)
319-327	England	Result of this study
600-750	Brazil	Nascimento et al. (2024)
660-1100	Lithuania	Vaitkevičienė (2019)
730	Pakistan	Khattak and Rahman (2017)
1000	Nigeria	Akinsulie et al. (2021)
1600	Nigeria	Jekayinfa (2015)
1610	Egypt	Zoair et al. (2016)
1600-2000	Romania	Cozma et al. (2023)
900-3000	General value, USA	Chandrasekara and Kumar (2016)
14000	Egypt	Wahba et al. (2023)

In the previous studies, the calcium content in potato peel similarly can vary between 2 mg/kg and 14000 mg/kg (1.4%) level. High Ca content is observed in countries such as Egypt, Romania, Nigeria, Pakistan, and Lithuania with general value of USA. Moderate Ca levels of PP investigated were found in countries like Brazil, England, and India, which also represent the general average of EU. Low Ca values were recorded in countries such as Bulgaria, Romania, and again Nigeria.

Table 2 presents the Magnesium (Mg) composition of potato (*S. tuberosum* L.) peel in the different studies and comparison with this research. The composition of potato (*S. tuberosum* L.) peel is generally rich in calcium and magnesium (Table 2, 3). Magnesium is the most abundant element, known for its role in cell wall stability and signal transduction of plants. In this study, Mg contents of potato (*S. tuberosum* L.) peel were found between 148 mg/kg and 150 mg/kg. The range of Mg content was found to be between 11 mg/kg and 6000 mg/kg. High Mg content is observed in countries such as Egypt, Romania, Nigeria, Pakistan, India, Brazil and Lithuania. Moderate Mg levels were found in countries like Nigeria, Bulgaria, Romania, and England, which also represent the general average. Low Ca values were recorded in countries such as Egypt and again Nigeria.

Table 2. Comparison of Magnesium (Mg) Content in Potato Peels (PP)

Mean Mg content (mg/kg)	Country of PP origin	References
11	Nigeria	Abdullahi et al. (2021)
80	Nigeria	Yusuf et al. (2017)
91	Egypt	Zoair et al. (2016)
148-150	England	Result of this study
200	Romania	Cozma et al. (2024)
210-250	General value, USA	Chandrasekara and Kumar (2016)
230	General value, EU	Anonymous 1 (2025)
300	Bulgaria	Zhivkova (2021)
500	Nigeria	Jekayinfa (2015)
1190-1600	Lithuania	Vaitkevičienė (2019)
1000-1400	Brazil	Nascimento et al. (2024)
1300	India	Singh et al. (2022, 2023)
1420	Pakistan	Khattak and Rahman (2017)
1200-1900	Romania	Cozma et al. (2023)
1600	Nigeria	Akinsulie et al. (2021)
6000	Egypt	Wahba et al. (2023)

In Table 3, Sodium (Na) contents of this research were shown among 74-75 mg/kg in the potato peel with comparing previous studies. In this study and other related research, the sodium contents of potato peel were examined, and it was determined that these contents vary significantly depending on countries and cultivation conditions. The sodium content was found to range between 18 mg/kg and 2060 mg/kg. High Na levels were observed in countries such as Pakistan, Romania, Egypt, and Nigeria. Moderate Na levels were recorded in countries like India, England, and Romania. Additionally, global average values (USA, EU) were present within these ranges. Countries with low Mg content were identified as Nigeria and Bulgaria.

Table 3. Comparison of Sodium (Na) Content in Potato Peels (PP)

Mean Na content (mg/kg)	Country of PP origin	References
18	Bulgaria	Zhivkova (2021)
42	Nigeria	Yusuf et al. (2017)
56	Nigeria	Abdullahi et al. (2021)
70	Romania	Cozma et al. (2024)
74-75	England	Result of this study
186	General value, EU	Anonymous 2 (2025)
258	India	Singh et al. (2022)
275	India	Singh et al. (2023)
160-550	General value, USA	Chandrasekara and Kumar (2016)
400	Nigeria	Jekayinfa (2015)
500	Nigeria	Akinsulie et al. (2021)
599	Egypt	Zoair et al. (2016)
386-823	Romania	Cozma et al. (2023)
2060	Pakistan	Khattak and Rahman (2017)

Potato peel is generated in massive quantities as a byproduct of industrial potato processing. This residue, typically discarded or underutilized, is now garnering attention for its potential use as a source of natural food ingredients and nutraceuticals. Although much research has focused on potato peel's enhanced phenolic and antioxidant capacity, emerging studies suggest that peel also retain a considerable proportion of the potato's overall mineral content (Chandrasekara and Kumar 2016). Ca and Mg contents of potato peel in Wolverhampton, England (this research) are consistent with some other studies but fall in the lower to moderate range. Sodium content in this study is relatively low compared to other studies. Differences between studies may arise from factors such as potato cultivar, growing conditions, environmental effects, and soil characteristics.

Conclusions

The results presented in this study provide a comparative overview of the elements (Ca, Mg, and Na) of various potato peels. Based on the comparative analysis of these peels, the key findings can be summarized as follows:

- Our analysis correlates with some previous investigations, which revealed that the structural components of potato peels consist of an assemblage of inorganic elements, e.g., Ca, Mg, Na, in its ash fraction along with aromatic and non-aromatic organic compounds of peels.
- Potato peel contains relatively high levels of calcium and magnesium elements, but sodium elements were found at lower concentrations.
- Furthermore, this study reaffirms that plant-based waste, compared to other household organic waste, possesses substantial economic value and can be recycled into high-value-added products that contribute significantly to the circular economy.
- It is emphasized that plant residues should be promoted as raw materials, especially in agriculture, as well as in various industrial sectors.

- Plant residues should be collected, dried, and packaged based on scientific principles without harming biodiversity, and small-scale processing industries should be established to utilize these residues.
- The composition of plant-based kitchen waste should be identified and separated at the source according to its potential for utilization.
- Domestic organic waste should be reused as fertilizer, particularly in small-scale family farming systems.

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