Determination of Iron Concentration in Selected Vegetables in Auckland, New Zealand

Daniel Smith*. and Emily Johnson
University of Auckland, New Zealand
*Corresponding author: daniel.smith2024@gmail.com

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ABSTRACT
This study aimed to determine the concentration of iron in selected vegetables grown in Auckland, New Zealand, and to examine the relationship between iron levels in vegetables and their corresponding soils. Four types of leafy vegetables—amaranth, spinach, pumpkin leaves, and sweet potato leaves—were analyzed using Atomic Absorption Spectrophotometry (AAS). A total of 24 samples (12 vegetable and 12 soil samples) were collected and analyzed.
The results showed that iron concentrations in vegetables ranged from 293.743 mg/kg to 489.431 mg/kg, with the highest concentration found in amaranth and the lowest in sweet potato leaves. Soil iron concentrations ranged from 2836.548 mg/kg to 4798.923 mg/kg. The findings indicate that iron content in vegetables is influenced by soil composition. This study highlights the nutritional importance of leafy vegetables as sources of iron and their role in addressing iron deficiency.
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Keywords: Atomic Absorption Spectrophotometer, anemia, Iron, vegetables, soil

Introduction

Iron is considered an essential element for almost all forms of life, including humans, due to its involvement in numerous metabolic processes such as oxygen transport, DNA synthesis, and electron transfer (Gupta, 2014). It naturally occurs in a wide variety of foods, is added to certain food products, and is also available as a dietary supplement. Iron plays a vital role in the formation of hemoglobin in red blood cells (RBCs), which are responsible for transporting oxygen throughout the body. Without sufficient iron, the body cannot produce healthy RBCs, making it an essential micronutrient (Wessling-Resnick, 2014).

Although iron is one of the most abundant elements in the Earth's crust (Kamble et al., 2013), iron deficiency remains a widespread health issue. This deficiency is less common among non-vegetarians due to the consumption of heme iron from animal sources, which is more readily absorbed (Pawlak and Bell, 2017). In contrast, vegetarians are more prone to iron deficiency anemia because they consume non-heme iron, which requires conversion before absorption (Slywitch et al., 2021).

For this reason, assessing the iron content in vegetables is important, particularly for populations that rely heavily on plant-based diets. Previous studies have demonstrated that iron levels in environmental samples such as soil, water, and plant materials fall within acceptable recovery ranges (98.71–101.51%) (Kassem and Amin, 2013). Additionally, research by Swamy et al. (2016) reported that iron concentrations in cooked vegetables ranged from 0.041 ppm to 0.43 ppm, with variations observed among different vegetable types. Similarly, Mandal et al. (2015) found that iron concentrations in black tea ranged between 21.3 mg/kg and 37.6 mg/kg.

Based on these findings, the present study aims to determine the concentration of iron in selected vegetables. The spectrophotometric method is employed to quantify iron levels in both vegetable and soil samples collected from the cultivation site. Furthermore, the study investigates the relationship between iron accumulation in vegetables and biological concentration factors influencing nutrient uptake, along with discussing the implications of iron deficiency and possible prevention strategies.

Materials and Methods

Study Area
This study was conducted in Auckland, New Zealand, where selected vegetable and soil samples were collected from a local agricultural site over a period of three months.

Sample Collection
Four types of leafy vegetables were selected for analysis: amaranth, spinach, pumpkin leaves, and sweet potato leaves. A total of 24 samples were collected, including 12 vegetable samples and 12 corresponding soil samples. Each vegetable sample was obtained from three different locations within the same cultivation area along with its respective soil. Soil samples were collected at a depth of 0–30 cm and stored in aluminum foil for transportation to the laboratory.

Sample Preparation
All samples were transported to the laboratory for analysis. Each sample (15 g) was oven-dried at 105°C for 24 hours to remove moisture. The dried samples were then ground using a mortar and pestle and sieved through a 2 × 2 mm mesh to obtain a fine powder.

Approximately 0.5 g of each powdered sample was transferred into separate test tubes. Then, 2 mL of aqua regia solution (a mixture of concentrated hydrochloric acid and nitric acid in a ratio of 3:1) was added to each sample for digestion (Uddin et al., 2016). The samples were heated in an oven at 94°C for 1 hour, cooled for

10 minutes, and diluted with 10 mL of distilled water. The mixtures were left for 10 hours before filtration to obtain clear solutions.

Preparation of Standard Solutions

A stock solution of 0.001 M $FeCl_3$ was prepared by dissolving approximately 0.162 g of $FeCl_3$ in distilled water, followed by the addition of concentrated HCl. The solution was diluted to 1 L and used for calibration purposes. Working standard solutions with concentrations of 2×10^{-4} M, 4×10^{-4} M, and 6×10^{-4} M were prepared by appropriate dilution of the stock solution.

Instrumental Analysis

The iron concentration in the samples was determined using an Atomic Absorption Spectrophotometer (AAS, Perkin Elmer A Analyst 100). The analysis was performed at a wavelength of 480 nm. The instrument operates on the principle that free atoms in the ground state absorb light at specific wavelengths unique to each element. A calibration curve was established using standard solutions, and sample absorbance values were used to determine iron concentrations in mg/L. These values were then converted to mg/kg using the following equation:

Metal (mg/kg) = [Concentration (mg/L) × Volume (mL)] / [Sample weight (kg) × 1000]

Biological Concentration Factor (BCF)

The biological concentration factor (BCF) was calculated to evaluate the accumulation of iron in vegetables relative to soil:

BCF = Iron concentration in vegetable / Iron concentration in soil

This factor indicates the ability of plants to absorb and accumulate iron from the soil.

Statistical Analysis

The obtained data were analyzed using IBM SPSS software. A two-way ANOVA test was performed to determine the statistical significance of differences among samples, with a significance level set at $p < 0.05$.

Results and Discussion

The results revealed significant variation in iron concentration among the selected vegetables. Amaranth exhibited the highest iron concentration, while sweet potato leaves showed the lowest values (Figure 1, Table 1). The iron content in vegetables ranged from 293.743 mg/kg to 489.431 mg/kg, corresponding to sweet potato leaves and amaranth, respectively.

The analysis also demonstrated that soil plays a crucial role in determining the iron content of vegetables. Iron concentrations in soil samples ranged from 2836.548 mg/kg to 4798.923 mg/kg, with the lowest values associated with sweet potato soils and the highest with pumpkin soils (Figure 2, Table 2). These findings indicate a clear relationship between soil iron availability and plant uptake.

The variation in iron concentration among vegetables can be attributed to several factors, including root structure, root hair density, plant growth characteristics, soil properties, and environmental conditions such as temperature.

The results obtained in this study differ from those reported by Abolayo et al. (2022), who found significantly higher iron levels (up to 18000 mg/kg) in contaminated soils. Additionally, the iron concentration in spinach (approximately 373 mg/kg) was lower than values reported by Sharma et al. (2016), which ranged between 600–800 mg/kg. These discrepancies may be due to differences in soil composition, environmental conditions, or agricultural practices.

Furthermore, the ability of plants to absorb iron varies among species, leading to differences in bioaccumulation. The Biological Concentration Factor (BCF) analysis indicated that amaranth had the highest capacity to accumulate iron compared to the other vegetables studied. This highlights its potential nutritional importance.

Statistical analysis using two-way ANOVA showed that the differences in iron concentrations between soil and vegetable samples were statistically significant ($p = 0.006$, $p < 0.05$). This confirms that soil composition has a significant influence on iron uptake in plants.

Overall, the iron concentrations observed in both soil and vegetable samples fall within the permissible limits established by the World Health Organization (WHO) (Akhtar et al., 2022). Additionally, the increasing interest in indigenous leafy vegetables is supported by their recognized nutritional and therapeutic value, particularly for populations in both urban and rural settings (Gockowski et al., 2003).

Table 1: Summary of Iron Concentration

Vegetable	**Iron in Vegetables (mg/kg)**	**Iron in Soil (mg/kg)**
Amaranth	489	3084
Spinach	373	4162
Pumpkin Leaves	360	4798
Sweet Potato Leaves	293	2836

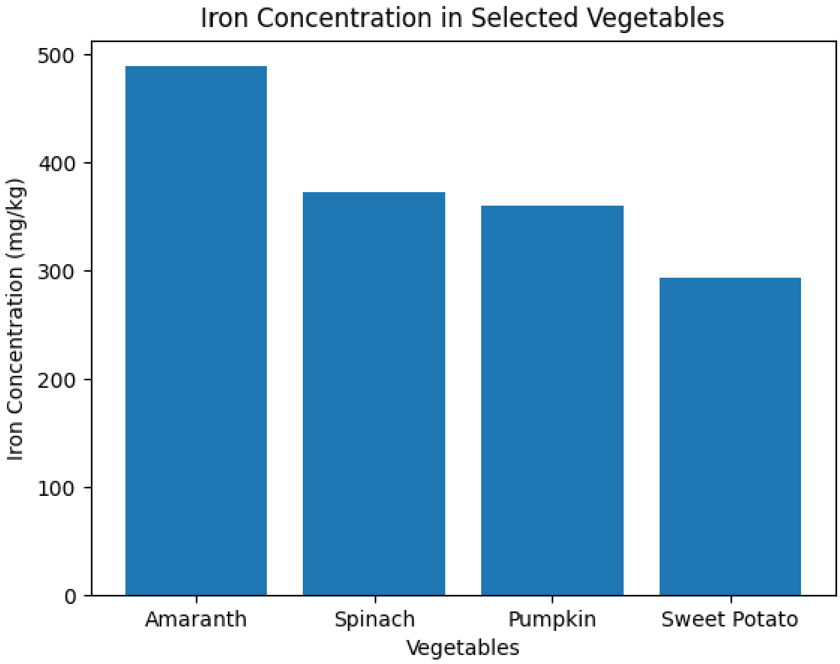

Figure 1: Iron Concentration in Vegetables

Conclusions

Leafy vegetables are widely recognized for their nutritional and therapeutic value due to their rich phytochemical composition and essential micronutrients. In this study, four commonly consumed vegetables—amaranth, spinach, pumpkin leaves, and sweet potato leaves—were analyzed for their iron content.

The results demonstrated that iron concentration varies significantly among different vegetable species, with amaranth showing the highest levels. The use of Atomic Absorption Spectrophotometry (AAS) enabled accurate determination of iron concentrations in both soil and plant samples.

Furthermore, the findings confirmed that soil composition plays a significant role in influencing iron accumulation in vegetables. This highlights the importance of soil quality in improving the nutritional value of crops.

Overall, the study emphasizes the potential of leafy vegetables as important dietary sources of iron. Further research is recommended to explore additional plant species and to investigate other nutritional and therapeutic properties of these vegetables.

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