Determination of Essential Elements in Selected Nuts Produced in Kenya

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ABSTRACT

Nuts, when eaten regularly, have been shown to reduce the risk of developing obesity, diabetes, and cardiovascular disease. They contain healthy fats such as monounsaturated fatty acids and are high in protein, vitamins, fiber, phenolics, phytosterols, and essential minerals. Essential minerals are important in preserving good health and body immunity against infections. They are categorized as macro minerals or microminerals. This study intends to determine the essential elements present in macadamia nuts and peanuts and explain the importance of these nuts to human health and the intake suitable for consumption. The two nuts were collected in triplets from each study area and transported to the University of Nairobi, Department of Chemistry laboratory. The moisture content of the nuts was determined by the gravimetric method. The samples were then wet digested followed by determination of the essential elements using atomic absorption spectroscopy (AAS). Moisture content results were as follows: Macadamia nuts recorded an average moisture content of 15.68% while that of peanuts was 3.89%. The spectrum of correlation coefficients extends from +1 to 0.9036. The results indicated that macadamia nuts from Magumoni had the highest levels of Ca (15.25 ± 0.35 mg/kg), Na (10.99 ± 0.17 mg/kg), Fe (6.96 ± 0.18 mg/kg), Mn (0.465 ± 0.276 mg/kg) and Cu (1.01 ± 0.45 mg/kg). Peanuts from the Kangemi market had the highest levels of Mg (49.45 ± 4.71 mg/kg), K (46.95 ± 0.35 mg/kg), and Zn (0.49 ± 0.01 mg/kg). Mg was the most abundant essential element in both nut samples. Comparing the results with WHO/FAO permissible limits for essential elements in food, the concentration of Fe, Zn, and Cu were within the recommended limits. The levels of K, Na, Mn, Ca, and Mg were below the recommended limits by WHO.

Article info

Keywords: Peanuts, Samples, Macadamia nuts, Essential elements, Moisture content, Atomic Absorption Spectroscopy, WHO, and Permissible limits

INTRODUCTION

Nuts are a highly concentrated source of nutrients that are vital to the establishment of a nutritious human diet. They provide significant amounts of protein, vitamins, fiber, phenolics, and phytosterols, as well as beneficial fats including monounsaturated fatty acids and polyunsaturated fatty acids [1]. In general, they can be classified into two main groups: tree nuts and peanuts [2]. The regular consumption of nuts has been found to potentially contribute to the decrease of obesity and diabetes, as well as mitigate the risks associated with cardiovascular illnesses [3]. The health advantages of tree nuts can be primarily ascribed to the existence of unsaturated fatty acids.

A notable proportion of fat is present in several types of nuts, such as macadamia nuts (66%), peanuts (55%), and walnuts (60%). Additionally, nuts generally exhibit a favorable protein content within the range of 10-30% [4]. It is worth noting that only a limited number of nuts possess a considerably high starch content. According to De, L.C. et al. (2020), they also serve as a valuable source of vital minerals and antioxidants. Furthermore, tree nuts are known to contain substantial amounts of amino acids, calcium, iron, zinc, and non-sodium minerals, including L-arginine [6]. As a result, tree nuts, including macadamia nuts, are widely consumed globally as nutritious snacks, either in their natural state or after being roasted.

Essential elements refer to minerals that are necessary for the body to carry out various processes related to structure, regulation, and immunity [7]. Regrettably, endogenous synthesis of these minerals does not occur in the human body, necessitating their acquisition through the consumption of various food sources including animal organs, grains, legumes, green vegetables, nuts, and dietary supplements [8, 9]. To prevent deficiencies, it is advisable to consume these substances consistently and in recommended quantities. They are divided into two groups: Macrominerals which are needed by the body in larger amounts and include Na, Mg, Fe, and K; microminerals which are needed by the body in small amounts and include Zn, Cu, Mn, and Se [10].

These minerals are required in different amounts and play different roles in the body. For instance, macronutrients such as potassium, calcium, and magnesium are very important in building and maintaining healthy bones. High intake of magnesium, calcium, and Potassium, accompanied by a low sodium intake, is associated with protection against bone demineralization, insulin resistance, arterial hypertension, and overall cardiovascular risk [11]. Zinc is also important in the maintenance of general body health and immunity against diseases. Zinc is also important in the healing of wounds and the synthesis of DNA [12].

Figure 1: Image of Macadamia nuts.

The macadamia nuts are grown on the macadamia tree, an indigenous species found in the rainforests of Eastern Australia [13]. Originally native to Australia, this particular tree species has successfully expanded its distribution to several nations, including Kenya. Australia serves as the primary hub for commercial cultivation, yielding over 40,000 tons of Macadamia nuts annually [14]. Several South American countries, including Brazil, Costa Rica, and Bolivia, along with regions such as Hawaii, New Zealand, and Africa, engage in the commercial cultivation of macadamia nuts [14].

The fat content of these nuts accounts for about 70% of their total weight. Over 80% of the composition consists of unsaturated fatty acids, including polyunsaturated fatty acids and monounsaturated fatty acids [15, 16]. In addition to their nutritional composition, macadamia nuts are found to be rich in critical minerals including potassium, magnesium, selenium, calcium, iron, and phosphorous. Furthermore, these nuts are also a source of several vitamins such as retinol, niacin (B3), riboflavin (B2), and thiamine [14]. Furthermore, these substances are enriched with antioxidants such as squalene, tocopherols, tocotrienols, and phytosterols [17].

Figure 2: Ground nuts that were analyzed.

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The peanut, scientifically identified as Arachis hypogaea, belongs to the family Fabaceae and is categorized as a legume plant [18]. Irrespective of their botanical categorization, peanuts exhibit a nutritional composition akin to that of tree nuts, such as cashew nuts and macadamia nuts [19]. Peanuts provide a significant nutritional value due to their abundance of proteins, bioactive substances, lipids, vitamins (including soluble B vitamins and vitamin E), and vital minerals such as zinc, magnesium, potassium, and iron [20]. Peanuts contain many water-soluble B vitamins, including Thiamine (B1), Folic acid (B9), Pantothenic acid (B5), Pyridoxine (B6), Niacin (B3), and Riboflavin (B2) [18].

The initial cultivation of peanuts is thought to be in Central and South America, with subsequent diffusion to various regions across the globe [20]. Peanut seeds are widely recognized in numerous nations for their substantial nutritional value, owing to their high protein content, lipids, and fatty acid composition [22]. Peanuts possess the versatility to be ingested in several preparations, including raw, roasted, boiled, or included in a highly nutritious porridge by combining them with other components. Additionally, peanuts can undergo processing methods such as being transformed into peanut butter or crushed to yield peanut oil [22]. The antioxidant content of roasted peanut kernels is significant. This is because Maillard reaction products are formed [23].

The objective of the study is to determine and quantify the moisture content and concentration of specific elements in the macadamia nuts and peanuts by employing gravimetric method and atomic absorption spectrometry (AAS) technique. AAS is an analytical technique used for the qualitative and quantitative analysis of trace metals in a variety of samples. The fundamental concept underlying atomic absorption spectroscopy (AAS) is the quantification of light absorption by the atoms of the analyte element present in the sample [24]. Subsequently, the amount of absorption is quantified, and the concentration of the analyte element is determined by applying the Beer-Lambert law [25].

STATEMENT OF THE PROBLEM

Nuts possess significant nutritional value for human health when consumed in appropriate quantities. Nevertheless, understanding and studying the nutritional advantages associated with nuts have largely been overlooked in Kenya, where nuts are mostly cultivated as food crops intended for international trade. Consequently, a significant portion of the population remains unaware of the remarkable health advantages associated with the use of nuts. Therefore, it is anticipated that the outcomes of this research will provide more information regarding the concentrations of crucial elements found in various types of nuts cultivated in Kenya.

MAIN OBJECTIVE

This study intends to determine the essential elements present in macadamia nuts and peanuts and explain the importance of these nuts to human health and the intake suitable for consumption.

3.1: Specific Objectives

The specific objectives of this study were:

i. To determine the essential minerals present in macadamia nuts and peanuts.

ii. To determine the concentrations of the identified essential minerals in each nut sample.

iii. Compare the concentrations of each essential in the two nut samples.

3.2: Justification of the Study.

Nuts provide a rich nutritional profile as a result of their diverse array of macronutrients and microelements. Nuts can serve as a supplementary source of trace minerals, including zinc, copper, selenium, and manganese, which are essential for maintaining normal bodily functions. The inclusion of these micronutrients is crucial for bolstering the body's immune system and facilitating optimal growth during the stages of childhood and adolescence. These trace minerals exhibit favorable physiological effects when consumed in modest quantities; nevertheless, excessive intake of these minerals can have adverse health consequences. Hence, it is imperative to ascertain the concentrations of these micronutrients and compare them against the required daily dietary intakes established by health regulatory authorities.

MATERIALS AND METHODS

4.1 Project Design

The study involved; identifying the study area, sample collection and transportation, sample preparation, and sample analysis.

4.2: Area of Study

The research was conducted in Kangemi Market and Magumoni. The selection of the research field was spurred by the presence of macadamia nuts and peanuts, as well as the limited number of scientific investigations conducted in these regions about these crops.

Kangemi Market is located in Westlands Constituency in Nairobi County which is the capital city of Kenya. Kangemi is a major market where food, clothes, and other household commodities are the main goods sold. It serves as the most populated place in the surrounding settlements. Farm produce from different parts of the country finds its way here.

Magumoni is an agricultural area located on the slopes of Mount Kenya in Tharaka-Nithi County in Kenya. Macadamia is one of the major cash crops grown in the area including tea and coffee. The area has volcanic soils rich in mineral contents suitable for the growth of macadamia.

4.3: Sample Collection and Transportation

The peanut sample was purchased from Kangemi Market in March 2023 at 11.30 a.m. while the Macadamia nuts were collected from Magumoni and put in a synthetic bag in March 2023 at 2.45 p.m. The samples were then wrapped in aluminum foil, labeled, and transported to the Department of Chemistry laboratory at the University of Nairobi where extraction and analysis took place.

4.4: Apparatus Used

The apparatus that was used in this study included; 50ml volumetric flasks, a drying oven, a muffle furnace, beakers, filter papers, storage bottles, 10ml and 50ml measuring cylinders, stirring rods, conical flasks, analytical weighing balance, mortar and pestle, desiccator, crucibles, atomic absorption spectrophotometer (AAS).

All glassware used was of analytical grade and was thoroughly washed with distilled water before use. Reagents and standards used were; 65% HNO_3, 30% H_2O_2, distilled water, Fe standard, Zn standard, Cu standard, Mn standard, Ca standard, Na standard, Mg standard, K standard, Se standard.

Figure 3: Atomic Absorption Spectrometry instrument used for analysis.

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4.5: Sample Preparation

4.5.1: Drying of samples

Three samples, each weighing 2.00 g, were measured and put into a clean 100 ml beaker. Subsequently, the samples underwent a drying process in an oven set at a temperature of 105˚C for a duration of 12 hours, after which their weights were measured again. The dried samples were stored in a desiccator to prevent moisture absorption from the environment, as they awaited acid digestion.

Figure 4: Image of the samples while being dried.

4.5.2: Acid Digestion of Samples

From the ground dry sample, 0.4g was measured in triplicate for each nut sample and put in conical flasks. A mixture of 6ml 65%nitric acid and 30%hydrogen peroxide was added and the mixture was heated for 2 hours at 80 degrees Celsius. This was to allow for a complete dissolution of minerals. The mixture was then filtered using filter paper placed in a funnel. The filtrate was made up to 20ml by adding distilled water and put in sample bottles awaiting analysis.

4.6: Determination of the Percentage of Moisture Content.

The moisture content of the nuts was expressed in terms of weight as the ratio of the weight of water in the nit samples to the weight of the respective dry sample [26]. The weight of water was the difference between the weight of the wet and dry nut samples. The moisture content percentage was calculated by employing the equation below.

$$\text{Moisture content} = \frac{W_{ws} - W_{ds}}{W_{ds}} \times 100$$

(Equation 1)

That is:

W_{ws} = Weight of the wet nut sample.

W_{ds} = Weight of the dry nut sample.

4.7: Calibration of the AAS machine

The calibration was done by introducing de-ionized water as blank to adjust the reading of the instrument. The standard working solutions of metals Zn, Mn, Fe, Cu, Mg, Na, K, and Ca that had been prepared were analyzed using different wavelengths.

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4.8: Sample Analysis

After calibration, each digested sample was introduced into the AAS instrument until a steady reading was obtained. The readings obtained were recorded. After each analysis, deionized water was introduced to wash and return the instrument's reading to zero. It was also used as a blank solution.

Table 1: Absorption radiation wavelength and gas used during analysis.

Element	**Wavelength (nm)**	**Graphite furnace atomization**
Zn	213	Argon air
Mn	279	Air-acetylene
Cu	324	Air-acetylene
Mg	598	Air-acetylene
Na	589	Air-acetylene
K	767	Air-acetylene
Ca	6324	Air-acetylene

RESULTS AND DISCUSSION

5.1: Introduction

This chapter presents the findings of the analysis conducted on peanuts and macadamia nuts, focusing on the important ingredients and moisture content. The acquired data is displayed in the format of mean ± standard deviation.

Table 2: The concentration of the essential elements in the peanut samples from Magumoni.

Element/site	**1**	**Recommended levels (WHO)**
Na	10.65±0.28	2300
K	47.20±0.35	4700
Ca	7.00±0.07	743
Mn	BDL	2.3
Mg	46.12±4.71	26-270
Fe	6.41±0.01	5-59
Cu	0.72±0.01	0.9
Zn	0.50±0.01	0.8-20

Table 3: The concentration of the essential elements in the peanut samples from Kangemi market.

Element/site	**2**	**Recommended levels (WHO)**
Na	10.25±0.28	2300
K	46.70±0.35	4700

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Ca	7.10±0.07	743
Mn	BDL	2.3
Mg	52.78±4.71	26-270
Fe	6.55±0.01	5-59
Cu	0.73±0.01	0.9
Zn	0.48±0.01	0.8-20

The nut samples exhibited the highest quantity of Magnesium, whereas the concentration of zinc was observed to be the lowest in both samples. The measured concentration levels in macadamia samples were found to follow the order of magnesium (Mg) > potassium (K) > calcium (Ca) > sodium (Na) > iron (Fe) > copper (Cu) > manganese (Mn) > zinc (Zn). The observed order of concentration levels in peanut samples was found to be Mg>K>Na>Ca>Fe>Cu>Zn>Mn (ND).

Table 4: The concentration of the essential elements in the macadamia nut samples from Magumoni.

Element/site	1	Recommended levels (WHO)
Na	11.11±0.17	2300
K	36.70±0.64	4700
Ca	15.00±0.35	743
Mn	0.27±0.28	2.3
Mg	41.26±1.31	26-270
Fe	7.09±0.18	5-59
Cu	1.33±0.45	0.9
Zn	0.17±0.0.06	0.8-20

Table 5: The concentration of the essential elements in the macadamia nut samples from Kangemi market.

Element/site	2	Recommended levels (WHO)
Na	10.87±0.0.17	2300
K	36.60±0.64	4700
Ca	15.50±0.35	743
Mn	0.66±0.28	2.3
Mg	43.11±1.31	26-270
Fe	6.83±0.18	5-59
Cu	0.69±0.45	0.9
Zn	0.09±0.06	0.8-20

The readings of different concentrations of each standard solution were recorded and the correlation coefficient and a regression equation were calculated using M.S Excel. The spectrum of correlation coefficients extends from +1 to 0.9036. A correlation coefficient of 1 denotes a complete positive connection, whereas a coefficient of 0.9036 implies the absence of a linear relationship. The element magnesium demonstrated the highest correlation coefficient (r = 1). The element sodium exhibited the smallest correlation coefficient, with a value of 0.9036. The table below displays the correlation coefficients (r values) for all key minerals analyzed in the study.

Table 6: Correlation Coefficient of the Essential Trace Elements.

Parameter	**Instrument**	**r 2**	**Regression Equation**
Ca	AAS	0.9999	y = 0.0006x - 0.0005
Fe	AAS	0.9966	y = 0.0053x + 0.0081
Mg	AAS	1	y = 0.0102x + 0.1749
Mn	AAS	0.9930	y = 0.0146x + 0.0075
K	AAS	0.9168	y = 0.0058x + 0.8281
Cu	AAS	0.9998	y = 0.0251x + 0.0070
Na	AAS	0.9036	y = 0.00142x + 1.3644
Zn	AAS	0.9816	y = 0.0078x + 0.0342

5.2: Percentage of Moisture Content

The macadamia nut samples had the greatest recorded moisture level of 17.04%, whilst the peanut samples demonstrated the lowest recorded moisture content of 3.80%. The moisture level of macadamia nut samples was found to be the greatest, with recorded values of 14.81%, 15.18%, and 17.04%. In contrast, peanut samples exhibited the lowest moisture content, with recorded values of 3.80%, 3.93%, and 3.93%, as depicted in Figure 5.

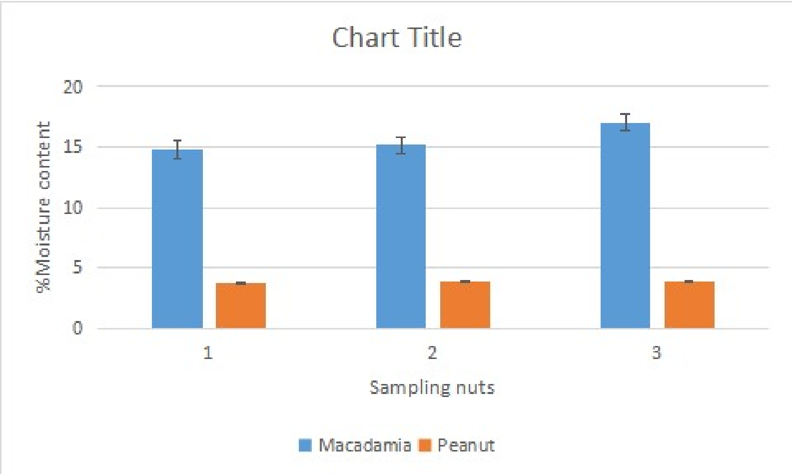

Figure 5: % Moisture content in the nut samples.

5.3: The Essential Elements' Concentration Results

The essential element levels in the macadamia and peanut samples that were analyzed in this study are shown in Table 2, Table 3, Table 4, and Table 5.

5.3.1: Copper

The data presented in Table 2, Table 3, Table 4, and Table 5 demonstrate that the macadamia nut samples obtained from Magumoni exhibited the highest levels of copper concentration, ranging from 0.69±0.45mg/kg to 1.33 ± 0.45 mg/kg. In contrast, the peanut samples collected from the Kangemi market displayed concentration levels ranging from 0.72 ± 0.01 to 0.73 ± 0.01 mg/kg. The concentrations observed were found to be consistent with the recommended daily dietary intake of 0.9 mg/day as established by the World Health Organization in 1983.

5.3.2: Zinc

The macadamia samples obtained from the Kangemi market exhibited concentration levels of 0.09 ± 0.06 mg/kg, whereas the macadamia samples from Magumoni displayed concentration levels of 0.17 ± 0.06 mg/kg. The peanut samples obtained from the Kangemi market exhibited concentrations of 0.48 ± 0.01 mg/kg, while the samples from Magumoni displayed concentration levels of 0.50 ± 0.01 mg/kg, as presented in Table 2 and Table 3. The concentrations observed in the study were found to be lower than the daily dietary intake levels recommended by the World Health Organization (WHO) in 1983, which vary depending on factors such as age, sex, and lactation status.

5.3.3: Manganese

Manganese was observed to be present in macadamia nuts at relatively low levels, ranging from 0.27 ± 0.28 to 0.66 ± 0.28 mg/kg. Manganese concentration levels in the two peanut samples were below the detection limits of the AAS instrument used. The macadamia sample labeled as M1, obtained from Magumoni, exhibited the lowest concentration levels, whereas the sample labeled as M2, obtained from the Kangemi market, exhibited the highest concentration levels. The concentration levels observed were found to be lower than the daily dietary intake recommended by the World Health Organization (WHO) in 1983, which was set at 2.3mg per day.

5.3.4: Iron

The concentration levels of macadamia nut samples collected from the Magumoni and Kangemi markets were found to be 7.09 ± 0.18 mg/kg and 6.83 ± 0.18 mg/kg, respectively, as indicated in Table 2, Table 3, Table 4, and Table 5. The concentration levels of the peanut samples collected from the Magumoni and Kangemi markets were found to be 6.41 ± 0.10 mg/kg and 6.55 ± 0.10 mg/kg, respectively. The observed levels of concentration were found to be within the recommended daily dietary intake range of 5 - 59 mg/day, as stipulated by the World Health Organization in 1983. The observed levels exhibited variations influenced by factors such as age, gender, and lactation status.

5.3.5: Magnesium

According to the data presented (Table 2, Table 3, Table 4, and Table 5), magnesium exhibited the highest concentration levels among the essential minerals that were analyzed. The peanut samples exhibited the highest recorded concentration levels ranging from 46.12 ± 4.71 to 52.78 ± 4.78 mg/kg. The macadamia samples exhibited concentrations ranging from 41.26 ± 1.31 to 43.11 ± 1.31 mg/kg, as observed in the recorded data. The concentration levels that were recorded fell within the range of the recommended daily dietary intake of 26 – 270 mg/day as established by the World Health Organization in 1983.

5.3.6: Potassium

Potassium was found in both the peanut and macadamia samples, exhibiting the second-highest levels among all samples, following magnesium. The peanut samples, denoted as P1 from Magumoni and P2 from Kangemi market, exhibited the highest concentration levels of 47.20 ± 0.35 mg/kg and 46.70 ± 0.35 mg/kg, respectively. These findings are presented in Table 2, Table 3, Table 4, and Table 5. The concentration levels of macadamia samples M1 obtained from Magumoni and M2 obtained from the Kangemi market were recorded as 36.70 ± 0.64 mg/kg and 37.60 ± 0.64 mg/kg respectively, as shown in Figure 4.7. The concentrations that were recorded corresponded to the daily dietary intake recommended by the World Health Organization in 1983, which is 4700mg per day.

5.3.7: Calcium

The concentration levels of calcium (Ca) in the macadamia nut sample obtained from Magumoni were measured to be 15.00 ± 0.35 mg/kg, whereas the concentration levels in the macadamia nut sample obtained from the Kangemi market were found to be 15.50 ± 0.35 mg/kg. The concentration levels of the peanut samples were determined to be 7.00 ± 0.70 mg/kg for the Magumoni sample and 7.10 ± 0.70 mg/kg for the Kangemi market sample, as depicted in Figure 4.8. The macadamia sample M2 obtained from the Kangemi market exhibited the highest concentration level, whereas the peanut sample P1 obtained from Magumoni demonstrated the lowest concentration level. The concentration levels that were documented were found to be lower than the daily dietary intake recommended by the World Health Organization (WHO) in 1983, which was set at 743mg per day.

5.3.8: Sodium

The concentration levels of sodium (Na) in the macadamia nut samples were determined and are presented in Table 2, Table 3, Table 4, and Table 5. The Magumoni sample exhibited a concentration of 11.11 ± 0.17 mg/kg, while the Kangemi market sample had a concentration of 10.87 ± 0.17 mg/kg. The concentration levels of the peanut samples were determined to be 10.65 ± 0.28 mg/kg for the Magumoni sample and 10.25 ± 0.28 mg/kg for the Kangemi market sample. The macadamia samples exhibited the highest concentration levels, with sample M1 from Magumoni displaying the highest concentration levels. Conversely, the peanut sample P2 from the Kangemi market demonstrated the lowest concentration levels. The concentrations measured were found to be lower than the daily dietary intake recommended by the World Health Organization (WHO) in 1983, which was set at 2300mg per day.

CONCLUSION AND RECOMMENDATION

6.1: Conclusions

Nuts serve as a valuable dietary source of essential elements that are necessary for overall bodily health. The findings of the study revealed that both samples of nuts exhibited magnesium as the predominant essential mineral. The magnesium concentration levels (41.26 ± 1.81 - 52.78 ± 4.78 mg/kg) observed in all samples fell within the range of the recommended daily dietary intakes of 26 – 270 mg/day as established by the World Health Organization (WHO). The levels of essential elements exhibited distinct variations across the different samples. The peanut samples exhibited higher concentrations of essential elements such as magnesium (Mg), potassium (K), and zinc (Zn), whereas the macadamia samples displayed higher concentrations of calcium (Ca), sodium (Na), manganese (Mn), iron (Fe), and copper (Cu). The macro essential elements exhibited the highest concentrations in all of the samples.

The moisture content of the macadamia samples was found to be 15.68%, which was observed to be higher than the moisture content of the peanut samples, which measured at 3.89%. The observed disparity in the growth of the two crops may be attributed to variations in climatic conditions during cultivation or discrepancies in the post-harvest treatment applied to the respective nuts.

6.2: Recommendation

The matter of insufficient nut consumption can be effectively tackled through the dissemination of educational materials to the wider population, highlighting the numerous health advantages associated with regular nut consumption and their incorporation into a balanced diet. These benefits primarily stem from the antioxidant properties and essential mineral content of nuts. The study's findings yield the following recommendations:

1. Both macadamia nuts and peanuts contain enough zinc and should be incorporated into the general diet to supplement these essential microelements.

2. A further analysis of the two nuts to study more on their other nutritional composition such as proteins and bioactive compounds.

3. Further studies on other nuts produced in the country such as coconuts and cashew nuts to provide wider information on their nutritional composition and benefits.

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