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Determination of Levels of Essential Elements in Avocado Waste from Selected Areas in Nairobi and Kiambu Counties, Kenya

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Abstract: Avocado is a pear-shaped fruit that is produced by tropical evergreen trees. The most common avocado specie grown in Kenya include Hass and Fuerte. Hass avocado is the is the most popular one that is available all the year round. It has oily and nutty flavour and spherical in shape. It has green skin that turns purplish black when ripe, while Fuerte variety is distinctly pear shaped with an oily texture, avocado is highly nutritious. Due to its high nutritional value there is an increasing demand for avocado consumption which has led to a vast generation of waste products. Despite the high nutritional value of avocados, the waste generated from their processing poses a significant environmental challenge, where only the avocado pulp is employed for commercial applications, while other fruit parts including the seed and peels have no practical use and are disposed to the environment. Therefore, the development of a sustainable approach to avocado waste management is a major concern. The study aimed at determining the levels of essential elements in avocado peels waste as potential mineral which will help to address the green valorization of avocado waste, which is an essential aspect of sustainable development in the face of increasing environmental challenges providing an opportunity to convert waste into valuable products while reducing environmental impact. Avocado samples were purchased from Gikomba and Githurai markets in Nairobi and Kiambu Counties respectively. The aim of the study was to identify and classify avocado varieties sold in Nairobi and Kiambu counties and determine the levels of essential elements in different avocado peels waste products. The avocado variety were taken to the University of Nairobi Herbarium for taxonomic identification, whereas the remaining ones were taken for analysis at the Department of Chemistry laboratory, University of Nairobi. The avocado samples were analyzed to determine the levels of essential elements zinc (Zn), iron (Fe), magnesium (Mg), manganese (Mn), copper (Cu), calcium (Ca), potassium (K), sodium (Na) and phosphorus (P). The levels of the essential elements were determined using the Atomic Absorption Spectroscopy (AAS). The main avocado varieties sold in Nairobi and Kiambu Counties were Hass and Fuerte. Hass avocado was the most commonly used than Fuerte. The average metal element concentrations in the Hass avocado peels waste samples from Nairobi and Kiambu Counties were found to range between (0.03±0.002mg/g) and (3.04±0.06mg/g) respectively. Potassium had the highest concentration while calcium had the lowest concentration. The Fuerte variety concentration ranged between (0.01±0.0002mg/g) and (3.43±0.015mg/g) respectively. Potassium had the highest concentration while calcium had the lowest. Hass variety is the most nutritious variety since it has the highest concentration of essential elements. The study findings could have an implication for the green valorization of avocado peels waste into valuable by products hence reduction in environmental pollution.

Keywords: *Avocado Waste, Essential Trace Elements, Green Valorization, Pollution, Environment.*

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I. INTRODUCTION

Avocado (Persea americana Mill) is a member of the Lauraceae family, it is a fruit that is rich in essential elements including iron (Fe), magnesium (Mg), potassium (K), manganese (Mn), phosphorus (P), and due to its nourishment value, the demand of the fruit has gone up in the market (Araujo,2018). Avocado is mainly grown in the Kenya Subtropical environments.

Avocado production thrives in Kenya due to favourable agro-ecological zones in western, eastern, central and coastal regions with 70 % of the produce originating from the former Central and Eastern Provinces (Wasilwa *et al*., 2007). The size and shape of an avocado vary according to the variety, it

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is generally green in the immaturity stages, becoming brownish when ripe (Araujo 2018). The avocado contains of three main parts, the pulp, which constitutes the largest portion with 65-73% of the fruit; a large and rounded seed that represents around 16-20 % and finally the peel with 11-15 % w/w (Teresa, 2023)

The main species of avocado grown in Kenya include; Hass and Fuerte varieties. Hass is the main export variety and Fuerte is preferred for processing. Avocado is consumed primarily as fresh product. Due to its high nutritional value the demand for the avocado production and the processing of this fruit leads to an increment of avocado waste generation. Avocado waste generation is directly related to the harvested amounts. The waste produced during its processing, including the peel, seeds and pulp which are disposed off into the environment causing ecological problems such as effects greenhouse gas, gas emissions, soil and water pollution and also attracting pests and rodents. Avocado waste represents environmental challenge that requires urgent attention towards the challenge, which has diverse effect to the environment (Teresa,2023)

➢ *Specific Objectives*

- Determine the essential elements levels in Hass avocado peels waste samples sold in Gikomba and Githurai Markets.
- Asses the essential elements levels in Fuerte avocado peels waste samples sold in Gikomba and Githurai Markets.
- Assess essential element levels in Hass avocado waste samples sold in Gikomba and Githurai markets
- Compare levels of essential elements in Avocado waste to that of WHO and KEBS

II. LITERATURE REVIEW

➢ *Sources of Avocado Waste*

The processing of avocado leads to the production of large quantities of peels and seeds that are typically disposed of as waste without any further applications. Due to avocado high nutritional value, the rate of consumption has increased therefore more avocado production. The wastes are generated from the high rate of consumption, inappropriate storage of avocado which leads to rotting of avocado hence creation of avocado waste (Gonzalez, 2018).

➢ *Essential Elements in Avocado Waste*

The essential elements in avocado waste include; Iron, sodium, magnesium, calcium, Manganese, zinc and phosphorus.

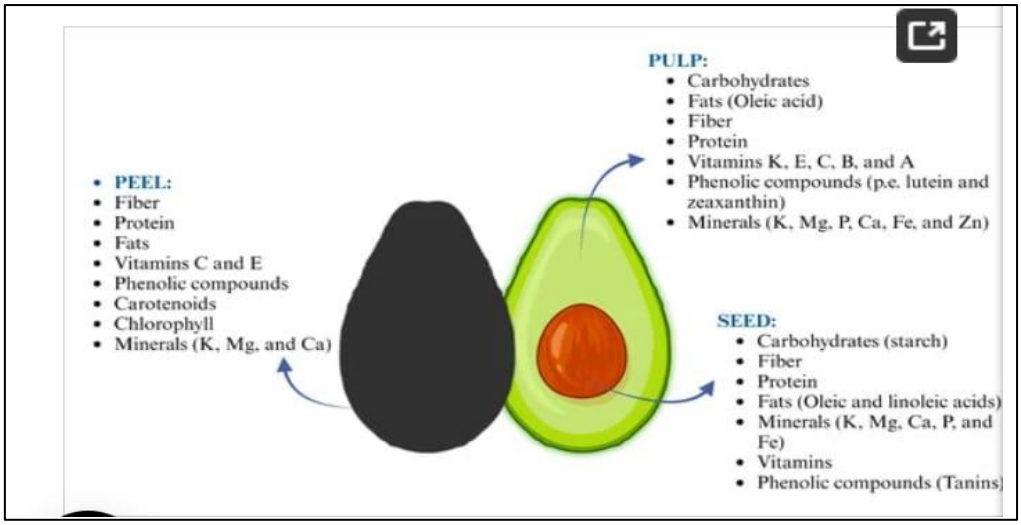


Fig 1 Parts of Avocado, the Elements and Nutrients

➢ *Magnesium*

Magnesium is a chemical element that belongs to group IIA in the periodic table. The symbol for the element is Mg. It has an atomic number of 12 and an atomic weight of 24.305 amu, the electronic configuration of magnesium is [Ne] $3s^2$.

Magnesium which is a cofactor in more than 300 enzyme systems that regulates diverse biochemical reactions in in the body including protein synthesis, muscle and nerve functioning, blood glucose control and blood pressure regulation. magnesium is required for energy production, oxidative phosphorylation and glycolysis (NIH, 2021)

➢ *Sodium*

Sodium is a chemical element of an alkali metal group 1A of the periodic table. The symbol for the element is Na. It has an atomic number of 11 and atomic weight of 22.989769 amu, the electronic configuration of sodium is [Ne]$3s^1$.

Sodium is used to conduct nerve impulses, contract and relax muscles and maintain proper balance of water and mineral (Pasquale, 2014)

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➢ *Manganese*

Manganese is chemical element that belongs to group VIIB in the periodic table. The symbol for the element is Mn. It has an atomic number of 25 and an atomic weight of 54.938044 amu. Manganese is a transition metal element with an electronic configuration of $[Ar]3d^5 4s^2$.

Manganese is used to form connective tissues, blood clotting factors, bones and sex hormones. It is required for normal brain and nerve function. Manganese controls blood sugar levels thus it may prevent or cure diabetes (Shenkin, 2003)

➢ *Iron*

Iron is a chemical element that belongs to group VIIB in the periodic table. The element symbol is Fe. It has an atomic number of 26 and atomic weight of 55.845 amu. Iron has an electronic configuration $[Ar]3d^6 4s^2$

Iron is involved in the formation of white blood cells in the bone marrow. The iron element takes part in the synthesis of new blood cells (Mindell & Mundis, 2004). Iron combines with haemoglobin for transportation of oxygen (Al-Fartusie & Mohssan, 2017)

➢ *Zinc*

Zinc is a chemical element that belongs to group IIB in the periodic table. The element symbol is Zn. It has an atomic number of 30 and atomic weight of 65.38 amu. Zinc has an electronic configuration of $[Ar]3d^{10} 4s^2$. Zinc is a cofactor in metabolic and cell growth enzymes (Younus, 2018)

➢ *Calcium*

Calcium a chemical element that belongs to group IIB of the periodic table. The element symbol is Ca. The atomic number is 20 and atomic weight of 40. 078u.Calcium has an electronic configuration of $[Ar]4s^2$.Calcium is used in squeezing and relaxing muscles, sending and receiving nerve signals, building strong bones and teeth and blood clotting (Reginald, 2023)

➢ *Phosphorus*

Phosphorus is a chemical element that belongs to group IIB of the periodic table. The element symbol is P. The atomic number is 15 and atomic weight of 30.973762 amu. Phosphorus is used to make fertilizers, animal feeds, rust remover and corrosion preventer (Reginald, 2023)

➢ *Potassium*

Potassium is a chemical element that belongs to group IA of the periodic table. The element symbol is K. It has an atomic number of 19 and atomic weight of 39.0983 AMU. Potassium is used in industries in manufacture of soaps, detergents, gold mining, dyes and glass production, Potassium regulates blood pressure (NIH, 2021) and is used in manufacture of fertilizers.

➢ *Ultraviolet -Visible (UV-vis) Spectroscopy*

Ultraviolet -visible or Uv -Vis Spectrometry. It is a qualitative, quantitative and analytical technique that compares a sample with a blank or reference sample to measure the amount of discrete ultraviolet and visible light absorbed or transmitted through a particular sample using Beer Lamberts law (Prativa ,2023)

➢ *Atomic Absorption Spectroscopy (AAS)*

Atomic Absorption Spectroscopy (AAS) is an analytical technique used for both qualitative and quantitative analysis. The method is widely used in analytical technique that involves the measurement of the absorption of electromagnetic radiation by atoms in the gas phase.

Spectrophotometry is a scientific technique that involves the determination of the concentration of elements present in a liquid sample by measuring the amount of energy absorbed from specific wavelengths of light, typically ranging from 190-900 nm.

Atomic absorption spectrophotometers are commonly equipped with a flame burner that serves to vaporize the sample, which is typically a hollow cathode lamp. Additionally, these instruments include monochromator and photon detector (Kabita, 2023). The atoms comprising the analyte exhibit a constant and unaltered quantity of electrons. When flame containing a particular is exposed to specific wavelength, the electrons located in distinct energy levels referred to as orbitals, undergo excitation to higher energy levels by absorbing a particular wavelength. The relationship between the quantity of ground state atoms present in the flame and degree of absorption.

In AAS, the sample is atomized (converted into ground state free atoms in the vapor state) and a beam of electromagnetic radiation emitted from the excited sample. The greater the number of atoms the more the radiation is absorbed. A calibration curve is constructed for several samples where the number of standards absorbed is compared calibration curve hence the concentration can be calculated. The change in the amount of light passing through the sample can best be described by Beer Lamberts law where there is a linear relationship between the concentration and the absorbance of the solution as shown by equation 1

Formula

$A = \varepsilon bc$ ---------- equation 1

Where,

A = Absorbance

Ɛ = Molar absorptivity

b = length of light path

c = Concentration

The excitation of the valence shell electrons provide different techniques in which atomic spectroscopy can also occur. The atomic emission spectroscopy employs fluorescence as an approach, where the lowest energy state (ground state) exhibits greater stability in comparison to

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higher energy state (excited state). The electrons exhibit a spontaneous tendency to return to their ground state and emits an equivalent quantity of radiant energy (Deon, 2021).

A. Statement of the Problem

Avocado demand and consumption have increased globally. Avocado waste generation is directly related to harvested amounts and hence can be substantial, the avocado waste which can be generated as huge amount of the by products in the form of seeds, rotten fruits, peel and pulp (Teresa, 2023). Avocado wastes contain important nutrients and minerals, minerals such as phosphorus, calcium, magnesium, iron, manganese, zinc and sodium that can be recovered and used in the food, agriculture and in fertilizer industries for manufacture of fertilizers.

This study aimed at determining the levels of potential elements in avocado waste from samples purchased from Nairobi and Kiambu counties.The levels of essential elements in avocado waste for the two species were then compared .Also the types of avocado fruits sold in Nairobi and Kiambu counties were identified and classified in this study. . Avocado production and processing generate large amounts of wastes that lead to environmental pollution since they take long periods to degrade (Araujo *et al*., 2018).

III. MATERIALS AND METHODS

The sampling points that were selected in this study were Gikomba and Githurai Markets which are peri-urban regions with high consumption of avocado. Gikomba market is situated in Nairobi County, while Githurai is in Kiambu county. Nairobi County is the capital city of Kenya and lies along latitude (1’ 17 11 S) and longitude (36’ 49’ 20’ E). It occupies an area of 696 km^2. It is the main commercial Centre of the country and has well developed infrastructure including modern financial and communication systems. It also has a well-developed industrial base and the principal product include processed food, automobiles, soap construction materials and chemical industries among others. Kenya has rich agricultural outskirts, which provide employment opportunities to its residents and the entire nation (Irungu *et.al*, 2015).

Kiambu County is also one of the counties in the country and it lies at 1 S and 36 E latitude and longitude respectively. It occupies an area of 2449 km^2. Kiambu County is situated in the fertile highlands of the country and hence favours the agriculture sector which ranges from crop farming mainly tea, avocado and coffee farming, dairy farming, poultry and horticulture farming. It holds a high percentage of the country’s gross domestic products (GDP).

➢ *Sampling Frame*

Drying oven, Centrifuge and centrifuge tubes, Analytical balance to be able to accurately weigh weighing to 0.0001g, weighing balance, UV-vis spectrophotometer, Atomic Absorption Spectroscopy (AAS), Digestion vessels, graduated cylinders funnel and filter paper, heating mantles.

65% Nitric acid (HNO_3), 37 % Hydrochloric acid (HCl), H_2SO_4, Analytical grade NaCl, KH_2PO_4, $CaCO_3$, KCl, $MnCl_2.4H_2O$, $FeCl_3.6H_2O$, ZnO, Deionized water.

➢ *Sampling Procedure*

Avocado waste samples were purchased from Gikomba markets in Nairobi County, while those from Kiambu were from Githurai market. The avocado waste was collected and placed in a polythene bags, labeled and then transported to the University of Nairobi, Department of Chemistry laboratory for extraction and analysis.

➢ *Chemical Reagents and Solvents*

65% Nitric acid (HNO_3), 37 % Hydrochloric acid (HCl), H_2SO_4, Analytical grade NaCl, KH_2PO_4, $CaCO_3$, KCl, $MnCl_2.4H_2O$, $FeCl_3.6H_2O$, ZnO, Deionized water.

➢ *Equipment and Apparatus*

Drying oven, Centrifuge and centrifuge tubes, Analytical balance to be able to accurately weigh weighing to 0.0001g, weighing balance, UV-vis spectrophotometer, Atomic Absorption Spectroscopy (AAS), Digestion vessels, graduated cylinders funnel and filter paper, heating mantles.

➢ *Sample Collection*

Avocado waste samples were purchased from Gikomba markets in Nairobi County, while those from Kiambu were from Githurai market. The avocado waste was collected and placed in a polythene bags, labeled and then transported to the University of Nairobi, Department of Chemistry laboratory for extraction and analysis.

➢ *Sample Treatment*

The avocado peel waste samples were washed using distilled water to remove any unwanted particles. The samples were cut into pieces using a pre-cleaned stainless kitchen knife. The samples were dried at 100 °C for 24 hours. After drying the samples were crushed into fine powder using a mortar and a pestle, placed in a self- sealing polythene bags, labelled and preserved.

➢ *Cleaning of Glassware and Sample Containers*

All sampling containers and glassware used were washed using a liquid detergent in tap water, then soaked in 10 % analytical grade nitric acid for 24 hours to leach out absorbed metal ions. After soaking they were rinsed with using distilled water. Glassware were dried using the oven while plastics bottles were dried in an open rack. The apparatus was stored in dry and clean lockable drawers.

➢ *Sample Digestion*

2.0 g of each sample was weighed and then transferred to a beaker, 65 % of 15ml of concentrated nitric acid was added to the sample then followed with addition of 5 ml of 37 % hydrochloric acid, then heated on a hot plate for 2 hours. After heating, the sample was allowed to cool. After cooling the sample was filtered using a Whitman 47 mm diameter 0.45± 0.02 µm pore size filter paper through and funnel in a 50 ml volumetric flask and topped to the mark. The samples were prepared in triplicates.

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➢ *Preparation of Standard Solution*

Analytical grade iron, magnesium, zinc, calcium, sodium, phosphorus, metals of 99.9% purity were used to prepare stock solutions. The metal standards were first dried at 105°C, cooled in desiccators before weighing, then transferred into a 250 ml volumetric flask. The Zinc stock solution were prepared by dissolving 0.25 g of zinc metal in 40 ml hydrochloric acid (1:1) and diluting it to the mark using distilled water to make 1000 ppm. The other elements were also prepared using the same procedure as that of zinc stock solution. The stocks were stored in plastics bottles and labelled correctly and the working standards were prepared from dilution of stock solutions

➢ *Preparation of Metal Stock Solution*

Metal stock standard solutions were prepared from the following chemicals, $MgCl_2.6H_2O$ (99.9 %), NaCl (98.0 %), $MnCl_2.4H_2O$ (99.9% purity), ZnO, $FeCl_3.6H_2O$ (98% purity), K_2SO_4 (99.0 %), KH_2PO_4, (99.9 %), and KCL (99.0 %).

The avocado peel waste samples were analysed to determine the levels of essential elements zinc (Zn), iron (Fe), manganese (Mn), calcium (Ca), potassium (K), sodium (Na), phosphorus (P) and magnesium (Mg). The stock standard solutions were prepared in subsections 3.10.1 -3.10.8 respectively. The levels of the essential metal elements were determined using the Atomic Absorption Spectroscopy (AAS) while that of phosphorous was done by UV-VIS.

➢ *The Analytical Stock Standard Solutions and Calibration Curves Preparation*

Analytical stock standard solution for each of 1000 ppm of zinc, iron, manganese, calcium, potassium, sodium, phosphorous and magnesium were respectively prepared and the calibration curves were made from each standard solution.

➢ *Preparation of Zinc Standard Solution*

1000-ppm zinc standard stock solution was prepared by weighing and dissolving 1.24533g of zinc oxide (ZnO) with 5 mL of H_2SO_4 in 1Litre volumetric flask and made to the make with deionized water.

➢ *Preparation of Iron (III) Standard Solutions*

1000-ppm standard solution of iron was prepared by dissolving 4.8400 g of iron (III) chloride ($FeCl_3.6H_2O$) in 200 ml of deionized water then made to 1000 mL in a volumetric flask using deionized water.

➢ *Preparation of Manganese Standard Solution*

Manganese stock solution of 1000-ppm standard solution prepared by dissolving 3.6077g of manganese chloride ($MnCl_2.4H_2O$) in 50 ml concentrated hydrochloric acid. The solution was then diluted with deionized water to 1000 ml in volumetric flask.

➢ *Preparation of Calcium Standard Solution*

To prepare 1000 ppm stock standard solution of calcium, 2.497g of calcium carbonate ($CaCO_3$) was weighed and transferred into 1litre volumetric flask, 50 mL of hydrochloric acid (6 mol/L) was added until the salt dissolved, 200 mL of deionized water was added and boiled for a few minutes to expel carbon dioxide, the solution was made to the mark.

➢ *Preparation of Potassium Standard Solution*

To prepare 1000 ppm stock solution of potassium, 1.9069 g of dry potassium chloride (KCl) (99.0%) was dissolved in 50 ml of dilute nitric acid in a one litre volumetric flask and then made to the mark with distilled water

➢ *Preparation of Sodium Standard Solution*

Sodium stock standard solution of 1000 ppm was prepared by weighing 2.542 g of sodium chloride (NaCl) salt and transferred into 1litre volumetric flask and dissolved in 50 mL deionized water and made to the mark.

➢ *Preparation of Phosphorous Standard Solution*

The 1000 ppm stock phosphorous standard solution was prepared by dissolving 4.3937 g of the dried KH_2PO_4 in 50 mL in 1 litre volumetric flak then made to the make.

➢ *Preparation of Magnesium Standard Solution*

In the preparation of 1000 ppm magnesium metal ion stock standard solution, 3.916g of magnesium chloride (MgCl2.6H2O) was dissolved in 200 mL deionized water in 500 mL beaker and transferred to 1 litre volumetric flask and made to the mark

➢ *The Calibration Curves Preparation*

The AAS instrument was calibrated using distilled water as a blank solution to adjust the readings of the instrument, using freshly prepared working standards from the stock solutions in subsections 3.10.1-3.9.7 respectively using the wavelengths in Table 3.2 for each metal ion, through the. nebulizer into the flame and Ultraviolet -visible (UV-vis) spectroscopy for phosphorus ion. The graphs of absorbance against concentration (ppm) for each element was plotted.

IV. RESULTS AND DISCUSSIONS

A total of ---- leaf samples of different brand of Hass and Fuerte were purchased from Gikomba and Githurai markets, with the objective of determining the metal levels of minerals namely, magnesium, sodium, manganese, zinc, iron, calcium, potassium and phosphorous. All measurements were carried out in triplicate. Results of the parameters determined were expressed as a mean and standard deviation of the triplicates samples. The data was analyzed using the one-way analysis of variance (ANOVA) and excel test under the Statistical Package (STATA) software (Miller & Miller, 2005).

The essential elements in avocado peels waste samples for Hass and Fuerte varieties obtained from Gikomba Market and Githurai Markets were analysed in this study. Gikomba and Githurai markets are situated in Nairobi and Kiambu Counties respectively in Kenya. The following essential elements were analysed using the Atomic Absorption Spectroscopy (AAS)Zinc, Calcium, Magnesium, Manganese, Potassium, Sodium and Iron from each avocado peel waste variety, while Phosphorus was analyzed using Ultraviolet

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visible (UV-vis) Spectroscopy. The correlation coefficient (R^2) and regression equation for the analyzed elements are shown in Table 1**.** The graphs of absorbance against concentration (mg/kg) for each element was plotted as calibration curves and are shown in appendix 1, Figures 1A-1H respectively.

Table 1 Correlation Coefficient (R2) and Regression Equation for the Analyzed Elements

Element	Correlation Coefficient (R^2)	Regression equation
Zinc	0.9953	y = 0.0081x ± 0.001
Iron	0.9797	y = 0.0102x-0.001
Manganese	0.9971	y = 0.0526x-0.0027
Calcium	0.9872	y = 2.6977x+1.6512
Potassium	0.9996	y = 0.1523x- 0.0023
Sodium	0.9950	y = 1.6186x- 0.5773
Magnesium	0.9927	y =0.0281x +0.0059
Phosphorous	0.9964	y = 0.7575x-0.2719

The data in Table 1 above shows that ≥ 99.1% of the response correspond to the concentration which shows that the method of analysis used was reliable (Dabas et al., 2019)

- *Essential Metal Levels in the Hass Peels Waste from Gikomba and Githurai Markets*

The essential element levels were determined in Hass avocado peels from Gikomba and Githurai markets as shown in Table 2

Table 2 Essential Elements Levels (mg/g) in Hass Waste Peels from Gikomba and Githurai Markets

Element/site	Zn	Mn	K	Na	P	Mg	Fe	Ca
Gikomba	0.07±0.02	0.92±0.007	2.80±0.06	0.087±0.02	0.50±0.02	0.28±0.002	1.50±0.02	0.03±0.002
Githurai	0.06±0.005	0.91±0.02	3.04±0.06	0.13±0.02	0.40±0.007	0.035±0.007	1.70±0.03	0.04±0.002
LOD	0.04	0.02	0.04	0.05	0.02	0.04	0.06	0.01
RECOMMENDED LEVELS								
WHO(mg/kg)	8.0-11..0	1.8-2.3	8.0-18.0	8.0-18.0	4.0-7.0	8.0-18.0	8.0-18.0	
KEBS (mg/kg)	8.0-11.0	1.8-2.3	8.0-18.0	8.0-18.0	4.0-7.0	8.0-18.0	8.0-18.0	

WHO 2020, KEBS 2022.

- *Zinc Levels in Hass Avocado Peels waste from Gikomba and Githurai Markets*

Zinc levels in Hass avocado ranged from 0.06±0.005 mg/g- 0.70±0.02 mg/g (Table 2). Gikomba market had high zinc levels than Githurai (Table 2).

From the data given in Table 3 above the calculated F-Value is greater than the critical value hence the null hypothesis was rejected, the levels of Zinc mineral in avocado waste from Nairobi and Kiambu counties differed significantly. The recommended levels for zinc by WHO (2020) and KEBS (2022) is between 8.0-11.0 mg/day respectively but the levels of zinc in avocado peels waste ranged between 0.06±0.005mg/g- 07 ± 0.02 mg/g the levels are below stipulated values of 8.0 by WHO and 11 mg/g by KEBS.

Table 3 Calculate Value of F for Zinc Element.

p-value	F-value	F-critical
0.14	4	9.55

- *Iron Levels in Hass Avocado Peels Waste from Gikomba and Githurai Markets*

The levels of Iron essential element in Hass avocado peels waste are shown in Table 3 Iron levels ranged from 1.5 ±0.02 mg/g – 1.70± 0.03 mg/g. Githurai market had high iron levels than those from Gikomba. The data in Table 4, the critical F -value was smaller than the calculated F-value, hence the null hypothesis was rejected. This shows that there was a significant difference in the concentration of iron essential element in avocado peels waste from Nairobi and Kiambu counties from the avocado varieties analyzed. The levels of iron metal levels in the sample were found to be below the recommended levels of 8.0mg/day by WHO (2020) and 18.0 mg/day by the KEBS (2022).

Table 4 Shows the Calculated F-Value for Iron

P-Value	F-Value	F-Critical
0.94	0.05	18.51

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➢ *Manganese Levels in Hass Avocado Peels Waste from Gikomba and Githurai Markets*

The levels of Manganese element in Hass avocado peels waste are shown in Table 4.

From the data given in Table 5 the calculated F-value is greater than the critical F-value, the null hypothesis was rejected. The levels of Manganese mineral between the avocado peels waste samples from Nairobi and Kiambu counties differ significantly. The recommended WHO (2020) and KEBS (2022) value for manganese ranges between 1.8 - 2.3 mg/day but in this study the levels of manganese ranged from 0.6±0.09 mg/g - 0.8±0.012mg/g hence manganese levels are below the WHO and KEBS recommended levels.

Table 5 Showing the Calculated Value of F-Value for Manganese.

P-value	F-value	F-critical
0.37	1.38	9.55

➢ *Calcium Levels in Hass Avocado Peels Waste from Gikomba and Githurai Markets*

The levels of calcium element in Hass avocado peels waste are shown in Table 5.

In Table 4. The average levels of calcium range 0.03±0.002 mg/g -0.04±0.002mg/g in Nairobi and Kiambu respectively. The recommended WHO (2020) and KEBS (2022) value for calcium ranges between 8.0to -18.0 mg/day.

➢ *Potassium Levels in Hass Avocado Peels Waste from Gikomba and Githurai Markets*

The levels of Potassium essential element in Hass avocado peels waste are shown in Table 6. The levels of Potassium essential element in avocado peels waste ranged from 2.8±0.06 mg/g -3.04±0.06 mg/g. The critical F-value was smaller than the calculated F-value, the null hypothesis was rejected, there was significant difference in the potassium levels in avocado peels waste samples from Nairobi and Kiambu Counties. The potassium levels in the avocado peels waste sample was below the recommended 8.0-18.0mg/day levels by WHO (2020) and 8.0-18.0 mg/day by KEBS (2022)

Table 6 Showing the Calculated Value of F-Value for Potassium.

P-Value	F-Value	F-critical
0.99	9.43E-08	18.51

➢ *Sodium Levels in Hass Avocado Peels Waste from Gikomba and Githurai Markets*

The levels of Sodium element in Hass avocado peels waste are shown in Table 7 showing the average sodium levels ranged from 0.087±0.02 mg/g -0.13±0.02 mg/g. The critical F-value was smaller than the calculated F-value, the null hypothesis was rejected meaning there was significant difference in the Sodium levels in avocado peels waste samples from Nairobi and Kiambu Counties. The sodium levels in the avocado peels waste sample the recommended 8.0-18.0mg/day levels by WHO (2020) and -8.0-18.0 mg/day by KEBS (2022)

Table 7 Showing the Calculated Value of F-Value for Sodium

P-Value	F-Value	F-critical
	-4E-16	9.55

➢ *Magnesium Levels in Hass Avocado Peels Waste from Gikomba and Githurai Markets*

The analysis of magnesium levels in avocado peels waste samples from Nairobi and Kiambu counties are shown in Table 4.3. The Magnesium levels in avocado peels waste samples ranged from 0.028±0.002 mg/g-0.035±0.007 mg/g. Using the ANOVA to analyze the data above the calculated F-value was greater than the critical F-value hence the null hypothesis was rejected meaning that the levels of magnesium mineral between the avocado peel waste samples from Nairobi and Kiambu counties differed significantly. The recommended magnesium levels of 8.0 mg/day by the WHO (2020) and 18.0 mg/day for KEBS (2022). The magnesium levels in the avocado peels waste samples in this study were below the required levels by WHO and KEBS respectively.

➢ *Phosphorus Levels in Hass Avocado Peels Waste from Gikomba and Githurai Markets*

The analysis of Phosphorus levels in avocado peels waste samples from Nairobi and Kiambu Counties are shown in Table 8. The phosphorus levels in avocado peels waste samples ranged from 0.4±0.007mg/g-0.5±0.02 mg/g (Table 8). The calculated F-value is greater than the critical F-value hence the null hypothesis was rejected, the levels of phosphorus mineral from the avocado peels waste samples from Nairobi and Kiambu counties. The recommended levels for phosphorus by WHO (2020) and KEBS (2022) are 4.0 mg/day and 7.0 mg/day respectively, but the phosphorus levels in avocado peels waste samples in this study were below the recommended levels by WHO and KEBS

➢ *Essential Metal Levels in the Fuerte Peels Waste from Gikomba and Githurai Markets*

The essential element levels were determined in Fuerte avocado peels from Gikomba and Githurai markets as shown

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Table 8 Essential Metal Levels in the Fuerte Peels Waste from Gikomba and Githurai Markets

Element/site	Zn	Mn	K	Na	P	Mg	Fe	Ca
Gikomba	0.09±0.05	0.09±0.05	3.43±0.15	1.60±0.02	0.400±0.003	0.07±0.02	1.80±0.09	0.010±0.002
Githurai	0.08±0.02	0.08±0.02	3.10±0.31	0.40±0.02	0.70±0.02	0.04±0.12	1.60±0.04	_
LOD	0.04	0.02	0.04	0.05	0.02	0.04	0.06	0.01
RECOMMENDED LEVELS								
WHO(mg/kg)	8.0-11..0	1.8-2.3	8.0-18.0	8.0-18.0	4.0-7.0	8.0-18.0	8.0-18.0	
KEBS (mg/kg)	8.0-11.0	1.8-2.3	8.0-18.0	8.0-18.0	4.0-7.0	8.0-18.0	8.0-18.0	

- *Zinc Levels in Fuerte Avocado Peels Waste from Gikomba and Githurai Markets.*

Zinc levels in Fuerte avocado ranged from 0.08±0.02mg/g -0.09±0.05mg/g as shown in table 9.Gikomba market had the highest levels of Zinc than Githurai. From the data the calculated F value is greater than the critical value hence the null hypothesis was rejected, the levels of Zinc mineral in avocado waste from Nairobi and Kiambu counties differed significantly. The recommended levels for Zinc by WHO 2020 and KEBS 2022 is between 8.0-11.0mg/day respectively ,but the levels of Zinc in avocado were within the stipulated values of 8.0 by WHO and 11mg/g by KEBS as shown in table 9.

Table 9 Shows the Calculated F-Value for Zinc in Fuerte Avocado Waste

P-Value	F-value	F critical
0.12	4.5	9.55

- *Magnesium Levels in Fuerte Avocado Peels Waste from Gikomba and Githurai*

The levels of Magnesium element in Fuerte avocado peels waste is shown in Table 10. From the table the average levels of Magnesium ranged from 0.04±0.12 to 0.07±0.02mg/day. The calculated F value was smaller than the critical F value hence the null hypothesis was rejected meaning there was a significant difference in the Magnesium levels in the avocado waste peels. The recommended Magnesium levels of 8.0mg/day by WHO AND 11.0 mg/day by KEBS 2022.The Magnesium levels in the avocado waste peels samples were below the required levels by WHO AND KEBS.

Table 10 Shows the Calculated F-Value for Magnesium in Fuerte avocado waste

P-Value	F-value	F critical
0.93	0.07	9.55

- *Sodium Levels in Fuerte Avocado Peels Waste from Gikomba and Githurai Market.*

The analysis of Sodium levels in avocado peels wastes samples from Nairobi and Kiambu Counties are shown in table 11.The sodium levels were in avocado peels waste samples ranged from 0.40±0.02 to 1.60±0.02mg/g. Using the anova to analyses the data above the Calculated F value was lower than the critical F value hence the null hypothesis was rejected meaning that the levels of Sodium differed significantly the avocado waste peels from Nairobi and Kiambu counties. The recommended sodium levels of 8.0mg/g by WHO 2020 and 18.0 mg/g by KEBS were below the recommended levels.

- *Potassium Levels in Fuerte Avocado Peels Waste from Gikomba and Githurai Market*

The levels of Potassium essential element in Fuerte avocado waste peels are shown in table 11.From the table the average Potassium levels ranged from 3.1±0.31 to 3.43±0.15mg/g. The critical F-Value was smaller than the calculated F-value, the null hypothesis was rejected, there was a significant difference in the Potassium levels in the avocado waste samples from Nairobi and Kiambu Counties. The potassium levels in the avocado waste peels samples were below the recommended levels of 8.0 mg/g by WHO 2020 and 18.0mg/g by KEBS 2022.

- *Manganese Levels in Fuerte Avocado Peels wastes from Gikomba and Githurai Markets*

The levels of Manganese in the Fuerte avocado waste peels are shown in the table 11. From the data given the calculated F value is greater than the critical F-Value, the null hypothesis was rejected. The levels of Manganese mineral between the avocado peels waste from Nairobi and Kiambu counties differed significantly. The recommended WHO 2020 and KEBS 2022 values for manganese range between 1.8-2.3mg/g but in this study the levels of Manganese ranged from 0.08±0.02mg/g to 0.09±0.05mg/g.

Table 11 Shows the Calculated F-Value for Manganese in Fuerte Avocado Waste.

P-Value	F-value	F critical
0.9	0.09	9.55

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➢ *Phosphorus Levels in Fuerte Avocado Peels Waste from Gikomba and Githurai Markets*

The levels of Phosphorus in the Fuerte avocado waste peels are shown in the table 12. From the data given the calculated F value is greater than the critical F-Value, the null hypothesis was rejected. The levels of Phosphorus mineral between the avocado peels waste from Nairobi and Kiambu counties differed significantly. The recommended WHO 2020 and KEBS 2022 values for manganese range between 4.0-7.0mg/g but in this study the levels of Phosphorus ranged from 0.400±0.003mg/g to 0.7±0.02mg/g**.**

➢ *Iron Levels in Fuerte Avocado Peel Waste from Gikomba and Githurai Markets*

Iron levels in Fuerte avocado ranged from 1.08±0.09mg/g -1.60±0.04mg/g as shown in table 12. Gikomba market had the highest levels of Iron than Githurai. From the data the calculated F value is greater than the critical value hence the null hypothesis was rejected, the levels of Iron mineral in avocado waste from Nairobi and Kiambu counties differed significantly. The recommended levels for Iron by WHO 2020 and KEBS 2022 is between 8.0-11.0mg/day respectively ,but the levels of Iron in avocado were within the stipulated values of 8.0 by WHO and 11mg/g by KEBS as shown in table.

Table 12 Shows the Calculated F-Value for Iron in Fuerte Avocado Waste

P-Value	F-value	F critical
0.86	0.038	18.55

➢ *Calcium Levels in Fuerte Avocado Peel Waste from Gikomba and Githurai Markets*

The levels of Calcium essential element in Fuerte avocado waste peels are shown in table 13. From the table the average Calcium levels from Gikomba was 0.010±0.002 while the levels of calcium from the avocado waste from Githurai was below the detection limit. The levels in the avocado waste peels samples were below the recommended levels of 8.0 mg/g by WHO 2020 and 18.0mg/g by KEBS 2022.

Table 13 Hass and Fuerte Essential Elements Levels in Avocado Peels Githurai Compared to WHO and KEBS Recommended Values

Element/variety	Zn	Fe	Mn	Mg	Ca	K	Na	p
Hass	0.06±0.02	1.70±0.03	0.90±0.02	0.060±0.007	0.040±0.002	3.04±0.60	0.13±0.50	0.400±0.007
Fuerte	0.08±0.01	1.60±0.04	0.80±0.12	0.04±0.12	ND	3.10±0.31	0.40±0.02	0.70±0.02
LOD	0.04	0.06	0.02	0.04	0.01	0.04	0.05	0.02
RECOMMENDED LEVELS								
WHO (mg/g)	8.0-11.0	8.0-18.0	1.8-2.3	8.0-18.0	8.0-18.0	8.0-18.0	8.0-18.0	4.0-7.0
KEBS(mg/g)	8.0-11.0	8.0-18.0	1.8-2.3	8.0-18.0	8.0-18.0	8.0-18.0	8.0-18.0	4.0-7.0

V. RECOMMENDATION

The Following recommendations were made from the current study

The avocado peels waste should be reused and reintegrated into useful by products can be used in manufacture of fertilizers, hence reduction to landfill overflow and emission of greenhouse gas.

The public should be educated on the importance and the valuable minerals that avocado peels waste contains hence proper disposal of the waste reducing environmental pollution.

Further studies should be done to determine how the locality of farming affects the levels of minerals in avocados.

More other varieties of avocado should be analyzed for essential elements and other contaminants like pesticides.

VI. CONCLUSION

The study found out that avocado peels waste samples contained valuable nutrients which can be converted into useful by products. From the study we conclude that Hass avocado peels waste samples from Kiambu county was rich in valuable essential elements than those from Nairobi County.

From the study Fuerte avocado peels waste samples from Nairobi is rich in valuable essential elements than from Kiambu.

The essential elements levels in the avocado peels waste ranged K > Fe >Na > Mn > Zn > P > Mg > Ca

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