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Elemental Composition Of Pulp And Seed Of Avocado Cultivars From Murang'a County

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Abstract
An estimated two billion individuals worldwide experience chronic micronutrient and mineral deficiencies as well as malnutrition. This represents 7% of the world's illness burden. Avocado is a widely consumed food that is rich in minerals and fats. The cultivar, climate, maturity level, and geographic growing region affect the quantity and makeup composition of lipids and nutrients. The ideal climate and well-drained soils of Murang'a County favour avocado production. Murang'a County has varied climatic conditions and farm management systems practices that affects the chemical composition of the fruits and hence require regular monitoring to ensure the required international market specifications are met. This study set out to analyse the elemental composition of pulp and seed from four distinct avocado cultivars grown in Murang'a County namely Fuerte, Golden, Pinkerton and Giant. The samples were collected from farms from in three geographical zones at an altitude of between 2200m and 1400m above sea level. Mineral element composition of the pulp and the seed were analysed by Atomic Absorption Spectroscopy AAS iCE 3000 series model. The data obtained was analysed using two-way ANOVA at p<0.05%. Elemental composition ranged as follows in the pulp; K 653.70-169.20, Na 0.028-0.096. Ca 1.41-32.20, Mg 0.0663-0.42, Zn 0.078-0.21, Fe 0.0037-0.01, Cu 0.0006-0.010 and as follows for the seed; K 264.70-848.60, Na 0.16-0.43, Ca 0.05-0.18, Mg 16.60-34.50, Zn 0.43-0.79, Fe 0.049-0.16 and Cu 0.0079-0.017 mg/100g. The findings inform producers, manufacturers and the consumers on the quality of the avocados and help determine applications of the pulp and the seed.

Keywords: *Avocado Fruit; Cultivars; pulp; seed; Elemental Composition*

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I. Introduction

An estimated two billion people globally suffer from malnutrition and chronic deficiency in micro-nutrients and minerals accounting for 7% global disease burden[1-5]. In Kenya, micro-nutrients, vitamins and minerals deficiency contributes to 53% child mortality and loss of 0.8% GDP annually[1]. One of the strategies employed to reduce micro-nutrient and mineral deficiency is dietary diversification [6] including taking fruits with high levels of phytochemicals, antioxidants, vitamins and minerals[7-10]. Plants have for long provided humanity with their basic necessities, including food, medicine and shelter [11-19]. Plants are the primary source of variety of vitamins, minerals, and other essential nutrients that enter the food chain. In addition, plants contain phytochemicals and antioxidants that help keep the body in balance and the immune system functioning properly and are harmful to infectious diseases [20-29]. In recent years, there has been an increase in the search for natural alternatives to synthetic chemicals used in the food, pharmaceutical, pesticides, and cosmetic industries [30-35]. Plant materials and extracts are recommended for food and infections control since they are safe for non-targeted organisms and the environment [36-47]. Furthermore, the risk that hazardous microorganisms may develop resistance to herbal treatments is exceedingly low.

Avocado, Percea Americana Mill, is a widely consumed food that is rich in minerals and fats [48, 49]. Avocado is a fruit with a characteristic good taste and aroma due to the presence of unsaturated fatty acids [50, 51]. Mineral found in avocado such as copper, zinc and iron are essential elements necessary for maintaining good health [52, 53]. Calcium, phosphorous and magnesium helps in maintaining the body's water balance, while potassium and sodium helps in the metabolism of fats and maintain better pH of the cells. Low levels of sodium make the avocado be recommended to patients who are hypersensitive [54]. Avocado is a "functional food'' and its inclusion in everyday diet also delivers other non-nutritive advantages that may enhance good health [55, 56].

Mineral composition determination is important in evaluating possible contribution of avocado in improving sustainability of food and pharmaceutical industries [57]. Most of the studies conducted focused on the fatty acids composition despite the avocado fruit being rich in minerals [52, 53]. In addition, most of the studies done focused on the avocado pulp while the seed that accounts for 13-18% of the fresh fruit by mass has scarcely been studied [56, 58]. The seed is generally discarded during processing and this contributes to environmental pollution [57, 59]. The elemental composition of the seed and the pulp vary greatly with geographical growing area and variety. Studies carried out in four commercial cultivars in Mexico (the highest producer of avocado in the world) showed that the amount of dry matter determines the amount of nutrients and not the size of the fruit or the amount of harvest [60]. The report concluded that growers should expect significant difference in nutrients in different avocado cultivars. The evaluation of these elements will shine more light into possible application of the seed there by reducing pollution and improve the economy. Ge and co-workers compared the minerals in two Chinese cultivars and reported that the seed contained more minerals than the pulp [61]. The study also reported a difference in mineralogical composition between the cultivars. Similar observations were made on heavy metal analysis on selected fruits in Ethiopia where fruits had different concentration of the elements depending on the area of origin [62].

II. Avocado Production In Kenya

Avocado farming has increasingly been adopted in recent years in over 57 countries, especially small-scale farmers who account to over 70 percent of the total production. In 2017 a total of 5,924,398 metric tonnes of avocados were produced globally representing a 5.5% increase from 2016. The high uptake of avocado by these farmers has been linked to the huge profitability especially from the international markets together with the global awareness of its health benefits [63]. Avocado is primarily grown for the fresh fruit market, either domestic or export. Avocados are also processed in industries for various products such as avocado oil for different applications including food market and cosmetic industry. Due to its nutritional value the production has increased drastically in the recent years (Figure 1). According to Food and Agricultural Organization Corporate Statistical Database, 2020, Kenya was ranked the 6th world largest exporter of the fruit and 2nd in Africa after South Africa. Kenya produced on average 115 000 metric tonnes of avocado and earned 5.2 billion in 2015 and 6.2 billion in 2016.

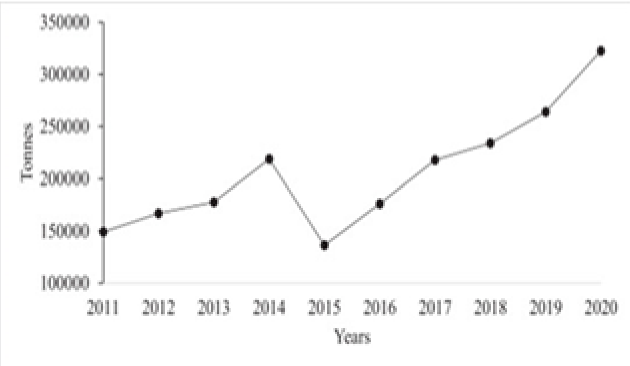

Figure 1. Production of avocado in Kenya since 2011 [64]

III. Avocado Varieties Grown In Murang'a County

In Murang'a County there are five main avocado cultivars grown. Hass and Fuerte are the main cultivars for commercial purposes. Golden, Giant and Pinkerton are the other cultivars grown in low quantities. Hass has better acceptance due to its excellent properties and it has higher resistance to post harvest processes that enable the fruit to reach the consumer at a higher price [65–67]. Murang'a County has varied climatic conditions and various soil types [57]. Chemical composition of avocado has been found to vary with season, cultivar, fruit part, geographical growing area, maturity, soil conditions and farm management practices [68]. This study investigated the variation in elemental composition of four different cultivars grown in three different geographical areas of Murang'a County.

IV. Materials And Methods

Study Site, Sampling and Sample Preparation

Avocado samples were collected from Murang'a County by clustered sampling. The county was divided into three zones depending on the climate (upper, middle and lower zone). The zones were assigned numbers as follows; 1-upper zone, 2-middle zone and 3- lower zone. Figure 2 below shows the distribution of avocado farms in Murang'a. To maximize the representation of farms in Murang'a, small avocado farms (less than 0.4 hectares) situated in different settlements were chosen. Four administrative wards were the focus of each vegetation productivity class. These are Kanyenya-Ini, Kangari, Kariara and Kinyona for zone1, Gatanga, Kihumbu-ini, Gaichanjiru and Muthithi for zone 2, Ichagaki, Makuyu, Nginda and Kamahuha for zone 3. Within each ward, four farms, spaced 0.5 to 9 km apart and situated in distinct villages, were chosen. But in wards where there were a few potential avocado farms or cultivars, at least two farms were chosen. A minimum of five trees under 30 years old on a farm were chosen for each cultivar. Mature fruits were identified and the samples labelled accordingly. The avocados collected were assigned random numbers according to variety and zone. A total of 10 fruits from each variety were collected and replication done.

The samples were kept at room temperature for 4-7 days until they ripened. The ripe fruits were thoroughly washed with water to remove mud and any other materials on its surface. The fresh fruit were weighed then cut longitudinally to remove the seed. The peel was then removed and the pulp and the seed were cut into small pieces and crushed in a mortar.

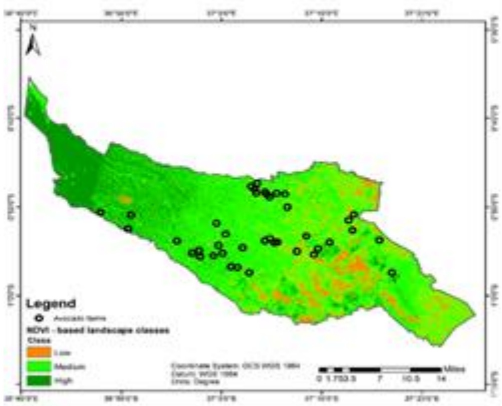

Figure 2: Distribution of avocado farms in Murang'a County, Kenya across three normalized difference vegetation index (NDVI)-based landscape classification [57]

Determination of Elemental Composition

The pulp and the seed were analysed separately by the method described by Ge et al with modification [66] . Five (5) g of the pulp and 5g of the seed were dried at 105ºC in an oven to a constant mass and ground into fine powder. The samples were ashed at 450ºC. 0.5g of the ash was then digested using 5 mL of 65% HNO_3 for 1 hour at 140ºC.The mixture was placed in a water bath to evaporate the acid. The digested sample was dissolved in 25mL distilled water and concentration of the essential elements determined by Atomic Absorption Spectrometer (AAS iCE 3000 series). Concentrated nitric acid was used as the blank control. Quantification was obtained from a calibration curve of certified reference materials ($R^2 \geq 0.995$). Elemental composition was expressed as mg/100 g on a fresh weight basis. Experiments were performed in triplicate.

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V. Results And Discussion

Pulp and seed of four avocado cultivars from three eco-logical zones in Murang'a County were analyzed to determine the elemental composition of some essential elements. The results are given in Tables 1 and 2 for pulp and seed respectively. The Giant variety pulp had the highest potassium content of 886.50mg/100g in zone 1 and the amount de-creased in zone 2 (582.18mg) and was lowest in zone 3 (442.76mg). The same trend was observed in Fuerte where the potassium composition decreased from 653.72, 479.13 and 264.78 mg/100g from zone 1, 2 and 3 respectively (Figure 3&4). Hass pulp had the lowest amount of potassium in zone 1 (232.84mg/100mg) and in zone 3 (169.22mg/100mg), for Pinkerton the lowest amount of potassium was in zone 2 (226.33mg). The results show significant differences in different cultivar grown in the same geographical area and same cultivar grown in different geographical areas. The values reported in this study are similar to those reported by [54] but higher than the ones reported by [58, 69]. This indicates that avocado cultivar and geographical growing location have an effect on the amount of potassium in avocado fruit. The highest potassium content was recorded in the seed of Fuerte grown in zone 3 (992.52mg/100g) and the lowest potassium content in the seed Fuerte grown in zone1 (335.09mg/100g). The potassium content in Fuerte seed increased with a decrease in altitude. Giant seed showed significantly higher potassium content ($P \leq 0.05$) among the four cultivars studied. A higher potassium content was reported in the seed than in the pulp[58]. According to WHO, healthy adults should aim to consume 3,500–4,700 mg of potassium daily from foods [70]. To increase this intake, incorporation of potassium-rich foods into the diet such as avocado is therefore recommended.

The level of sodium recorded in this study ranged from 0.0279 to 0.0961mg/100g in the pulp. The highest amount of sodium was reported in Hass in zone 1 (0.096mg/100mg) and the lowest in Pinkerton from zone 2 (0.027mg/100g). The concentration of sodium in Hass cultivar decreased from 0.96 to 0.67mg/100g and finally to 0.30mg/100g with decrease in altitude from zone 1 to zone 3. For Giant, sodium content was highest in zone 3 followed by zone 1 and lowest in zone 2. In Fuerte the concentration of sodium was highest in zone 3 followed by zone 2 and lowest in zone 1. Pinkerton the concentration of sodium was highest in zone 1 and lowest in zone 2.

Table 1: Elemental composition pulp of avocado cultivars from different zones (mg/100g)

Zone	Cultivar	K	Na	Ca	Mg	Zn	Fe	Cu
Zone 1	Fuerte	653.72 ^{i}	0.0418 ^{e}	27.4847 ^{k}	0.1433 ^{i}	0.1483 ^{d}	0.0357 ^{h}	0.0083 ^{i}
	Giant	886.50 ^{j}	0.0545 ^{h}	32.2034 ^{l}	0.1332 ^{h}	0.1433 ^{f}	0.0418 ^{j}	0.0080 ^{g}
	Hass	232.84 ^{de}	0.0961 ^{i}	18.0110 ^{h}	0.1118 ^{f}	0.1451 ^{h}	0.0362 ^{i}	0.0086 ^{k}
	Pinkerton	401.77 ^{c}	0.0672 ^{i}	1.7410 ^{c}	0.0663 ^{a}	0.1017 ^{b}	0.0091 ^{c}	0.0006 ^{a}
Zone 2	Fuerte	479.13 ^{g}	0.0462 ^{g}	27.0380 ^{j}	0.1700 ^{k}	0.1581 ^{j}	0.0037 ^{a}	0.0083 ^{j}
	Giant	582.18 ^{h}	0.0413 ^{d}	1.4127 ^{a}	0.1466 ^{j}	0.1701 ^{k}	0.0995 ^{l}	0.0077 ^{f}
	Hass	397.90 ^{d}	0.0676 ^{j}	25.8615 ^{i}	0.1222 ^{g}	0.2083 ^{l}	0.0313 ^{g}	0.0103 ^{l}
	Pinkerton	226.33 ^{b}	0.0279 ^{a}	3.4714 ^{e}	0.1037 ^{e}	0.0784 ^{a}	0.0268 ^{f}	0.0011 ^{b}
Zone 3	Fuerte	264.78 ^{c}	0.0459 ^{f}	4.2538 ^{f}	0.0778 ^{c}	0.1294 ^{d}	0.0037 ^{b}	0.0082 ^{h}
	Giant	442.76 ^{f}	0.0680 ^{k}	1.4178 ^{b}	0.4289 ^{l}	0.1442 ^{g}	0.0882 ^{k}	0.0075 ^{e}
	Hass	169.22 ^{a}	0.0310 ^{c}	3.0718 ^{d}	0.0774 ^{b}	0.1058 ^{c}	0.0241 ^{e}	0.0026 ^{c}
	Pinkerton	424.33 ^{ef}	0.0301 ^{b}	4.9957 ^{g}	0.0913 ^{d}	0.1431 ^{e}	0.0102 ^{d}	0.0028 ^{d}

Values are means of three replicated; Means followed by different letters down the column are statistically different at P ≤0.05 based on the Tukey's Honestly significant difference

Table 2: Elemental composition seed of avocado cultivars from different zones (mg/100g)

Zone	Cultivar	K	Na	Mg	Ca	Fe	Zn	Cu
Zone 1	Hass	335.09 ^{a}	0.23 ^{abc}	0.05 ^{a}	22.8 ^{d}	0.529 ^{c}	0.077 ^{c}	0.0087 ^{c}
	Fuerte	625.43 ^{c}	0.17 ^{ab}	0.08 ^{b}	31.6 ^{i}	0.43 ^{b}	0.049 ^{a}	0.0079 ^{a}
	Giant	721.03 ^{e}	0.16 ^{a}	0.11 ^{c}	22 ^{c}	0.548 ^{e}	0.065 ^{c}	0.0086 ^{c}
	Pinkerton	649.97 ^{c}	0.19 ^{ab}	0.133 ^{f}	16.6 ^{a}	0.596 ^{g}	0.0875 ^{f}	0.00817 ^{b}
Zone 2	Hass	778.75 ^{f}	0.2 ^{abc}	0.14 ^{h}	34.5 ^{l}	0.679 ^{i}	0.096 ^{g}	0.0118 ^{h}
	Fuerte	941.50 ^{i}	0.43 ^{d}	0.18 ^{k}	30.9 ^{h}	0.786 ^{l}	0.152 ^{i}	0.0165 ^{k}
	Giant	848.62 ^{h}	0.4 ^{d}	0.13 ^{g}	31.8 ^{j}	0.7849 ^{j}	0.161 ^{l}	0.014 ^{j}
	Pinkerton	823.81 ^{g}	0.22 ^{abc}	0.132 ^{f}	29.5 ^{f}	0.559 ^{f}	0.0758 ^{d}	0.00835 ^{c}
Zone 1	Hass	992.52 ^{j}	0.17 ^{ab}	0.111 ^{d}	17.9 ^{b}	0.429 ^{a}	0.062 ^{b}	0.0084 ^{d}
	Fuerte	926.11 ^{i}	0.25 ^{cd}	0.11 ^{e}	23.15 ^{e}	0.619 ^{h}	0.094 ^{h}	0.0107 ^{f}
	Giant	501.20 ^{b}	0.26 ^{abcd}	0.14 ^{i}	30.7 ^{g}	0.547 ^{d}	0.159 ^{k}	0.0138 ^{i}
	Pinkerton	690.31 ^{d}	0.21 ^{abc}	0.15 ^{j}	31.9 ^{k}	0.764 ^{k}	0.152 ^{j}	0.0109 ^{g}

Values are means of three replicates; Means followed by different letters down the column are statistically different at P ≤0.05 based on the Tukey's honestly significant difference.

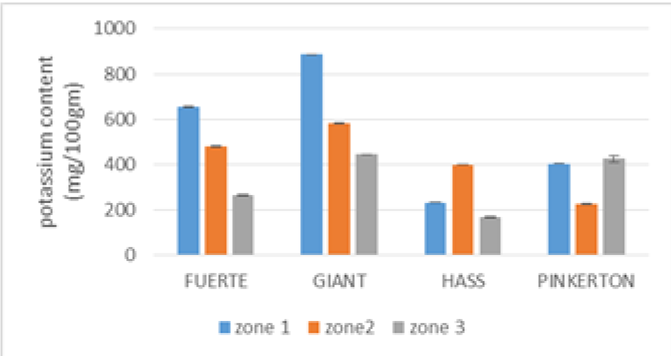

Figure 3: Influence of zone and cultivar on variation of potassium levels in the avocado pulp

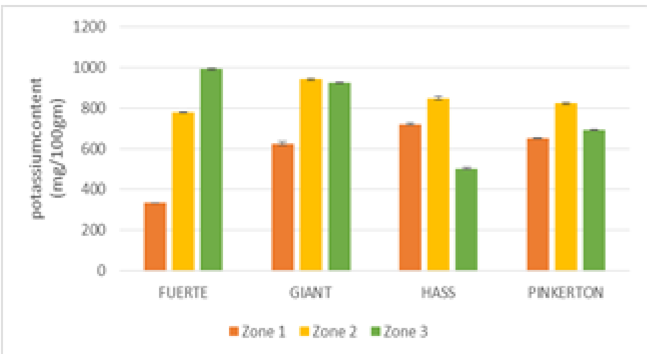

Figure 4: Influence of zone and cultivar on variation of potassium levels in the avocado seed.

The concentration of sodium ranged from 0.16mg/100g to 0.42mg/100gm in the seeds. The concentration of sodium in Hass avocado seed decreased from 0.23mg/100g to 0.20mg/100g and finally to 0.17mg/100g with decrease in altitude from zone 1 to zone 3. For Giant, Fuerte and Pinkerton the concentration of sodium was highest in zone 2 and lowest in zone 3. The concentration of sodium in avocado pulp reported in this study is similar to 0.23mg/100g reported in Nigeria [69], and within the range of 0.20mg/100g-0.80mg/100g reported by[54]. The concentration of sodium in avocado seed was lower than the value of 1.54mg/100g previously reported [71].

Calcium content was found to be the second most abundant mineral in avocado pulp and seed. The concentration of calcium in the pulp ranged from 14.12mg/100g to 49.95mg/100g while in the seed it ranged from 16.6mg/100g to 34.5mg/100g. The calcium content increased from zone 1 to zone 3 for Hass and Pinkerton. For the Giant cultivar, the calcium content was highest in zone 1 and lowest in zone 3 and Fuerte it was highest in zone 3 and lowest in zone 2 (Figure 4). Calcium content in avocado seeds was highest in Hass avocado seeds grown in zone 2 (34.5mg/100g) and lowest in Pinkerton grown in zone 1 (16.6mg/100g). Concentration decreased with decrease in altitude for Pinkerton but increased with decrease in altitude for Fuerte. For Giant and Hass the concentration was highest in zone 2 and lowest in zone 1. The value of Calcium observed are higher than those reported in other studies[54, 69]. For Hass pulp, the calcium concentration ranged (3.07-25.86) was lower than 26.35-54.67mg/100mg reported in Ecuador [72]. The Dietary allowance for calcium is 1,300 mg for adults and children aged 4 years and older. Avocado provides a higher (>20%) calcium content and therefore considered good for inclusion inhuman diet.[70, 73].

The concentration of magnesium reported in this study ranged from 0.07 to 0.17mg/100g for pulp and 0.05 to 0.18mg/100g for seed. The magnesium content in the seed and the pulp showed significant differences between the variety and geographical growing areas. The values were lower than those reported earlier of 1.40 & 1.41mg/100g for the pulp and seed in RN-7 respectively, 1.73 & 1.83mg/100g for the pulp and seed in RN-8 respectively [66]. However, magnesium content is similar to 0.15mg/100g reported in avocado seed and 0.103mg/100g for avocado pulp [69].

Iron concentration ranged between 0.01 to 0.09mg/100g for the pulp and 0.429 to 0.786mg/100g for the seed. There was significant difference between the iron content in the seed and the pulp. The concentration of iron decreased from zone 1 to zone 3 for Hass pulp while it increased for Fuerte pulp from zone 1 to zone 3. Pinkerton had the lowest iron concentration in all zones. The concentration of iron in avocado seeds was highest in zone 2 for Hass, Fuerte and Giant (0.679, 0.786 and 0.749mg/100g respectively). For Pinkerton seed, the iron concentration increased from zone 1 to zone 3. The values were lower than those reported in the pulp and the seed of RN-7 and RN-8 [61]. The values were also lower than 0.5, 0.58, 0.6 and 0.4mg/100g reported in Pollock, Kallar round, Hybrid purple and Fuerte cultivars respectively (Nair et al., 2018). However, the concentrations were similar to iron content of 0.069mg/100g reported in the avocado pulp in Nigeria [69]. Iron is an important dietary mineral that is involved in various bodily functions, including the transport of oxygen in the blood. The average person needs to absorb approximately 1mg for adult males and 1.5 mg females for good health [70].

The concentration of zinc in the pulp ranged from 0.078 to 0.2mg/100g while in the seed the range was 0.049 to 1.59mg/100gm. For zone 1 zinc content in avocado pulp was higher than in the seed. The concentration of zinc was highest in zone 2 and lowest in zone 1 for Hass, Fuerte and giant cultivar. For Pinkerton zinc content was highest in zone 3 and lowest in zone 2. In the seed the zinc content was highest in zone 3 (0.159mg/100g) and lowest in zone 2 (0.049mg/100g). For Giant, Hass and Fuerte zone 2 had the highest zinc content with zone 3 having the lowest. The results are comparable with 0.07 and 0.10mg/100g obtained from RN-7 and RN-8 avocado seeds [61] but lower than 0.18mg/100mg obtained in avocado seed [71]. The Recommended Dietary Allowance (RDA) for adults 19+ years is 11 mg a day for men and 8 mg for women [70, 73]. Copper is a trace element required in the human body. The study reported copper concentration in the range of between 0.0079mg/100g and 0.0165mg/100g in the seeds and 0.0006 to 0.0103mg/100g in the pulp. Pinkerton had the lowest concentration of 0.001, 0.0011 and 0.002mg/100g in zone 1, 2 and 3 respectively. Hass pulp had 0.086mg, 0.01mg and 0.002 mg/100g in zone 1, 2 and 3 respectively. There was significant difference between the copper content in the seed and the pulp. These values are lower than 0.47mg/100g reported for avocado from Ethiopia[62]. The range in copper concentration was 0.007 to 0.165mg/100g in avocado seed. Zone 1 had a copper concentration of about 0.008mg/100g all the cultivar. Among the zones, the concentration was highest in zone 2 and lowest in zone 1. In adults age 20 and older, average daily intakes of copper from food are 1,400 mcg for men and 1,100 mcg for women. Total intakes from supplements and foods are 900 to 1,100 mcg/day for children and 1,400 to 1,700 mcg/day for adults age 20 and over [70].

VI. Conclusion

The study investigated the influence of the cultivar and geographical growing environment on elemental composition of the pulp and the seed of four avocado cultivars grown in Murang'a County. The study found significant differences in elemental composition of the pulp and the seed between the zones and the cultivars. The elemental concentration of potassium, magnesium, calcium, iron and copper was higher in the seed than in the pulp while the concentration of sodium and zinc was higher in the pulp compared to the seed. Because of its rich nutrients make up, there is need to process avocado seed waste into value added products with extra value such as animal feed supplement. However, the safety and pharmacological proper-ties of particular molecules in avocado seed for use in animal feeds require a thorough examination not supported from the research.

The mineral elements found in avocado such as potassium, calcium, magnesium, Copper, Zinc and iron are essential for maintaining good health. The low levels of sodium make the avocado be recommended to patients who are hypertensive. Avocado is a "functional food'' and its inclusion in everyday diet also delivers other non-nutritive advantages that may enhance good health.

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