

Analysis of Some Selected Major, Minor-Essential and Toxic Metals from Jackfruit (*Artocarpus heterophyllus* Lam) With Their Supporting Soil Samples Cultivated in Teppi, Southwest Ethiopia

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Abstract

The study was conducted in Teppa town, SNNPR Regional State, Ethiopia. Samples of jackfruit as well as its supporting soils, were gathered from three kebeles. Jackfruit was chosen for the estimation of some important, essential and toxic metals that can be used as mineral nutrients. The objective of this research work is to estimate and evaluate the concentrations of some major, minor-essential and toxic metals and also some physical properties of jackfruit. A random sampling method was used for this experiment. Samples of jackfruit and soils were analyzed for their major elements by using the microwave digestion system of Berghof with some modifications. Values of pH and EC of samples were measured through a pH-EC Meter. Calcium, Magnesium, Manganese, Zinc, Copper, Lead, and Cadmium were quantified using the Flame Atomic Absorption Spectroscopy method. According to the results, moisture content in the sample is between 57.95% – 58.56% in fruits and 72.05% – 73.66% in soil samples. Organic matters are between 21.09% – 22.05% in fruits and 79.65% – 81.67% in soil samples. The electrical conductivity in the sample is between 0.07ms/cm to 0.09ms/cm in fruits and 0.61ms/cm – 0.69ms/cm in soil samples. The pH value in the sample is between 5.35–5.38 in fruits and 6.79–6.99 in soil samples. The results indicated that jackfruit contains an adequate amount of Calcium (152 ± 0.15) mg/kg, Magnesium (120 ± 0.50) mg/kg, Manganese (16 ± 0.56) mg/kg, Zinc (13.5 ± 0.35) mg/kg, and Copper (6.9 ± 0.45) mg/kg, and that it is safe for copper (6.9 ± 0.45) mg/kg. The transfer factor of all metals under the study was < 1 . All values obtained within the normal range were in good agreement with values reported by different international guidelines.

1. INTRODUCTION

The jackfruit tree (*Artocarpus heterophyllus* Lam) belongs to the genus *Artocarpus* in the Moraceae family. The fruit originated from India but is primarily cultivated in some Middle Eastern countries and several African countries (Albi Abraham and J Jayamuthunagai, 2014). This tree is an evergreen tree that has a medium-sized stature and is 9 to 12 meters tall, with dark green and glossy leaves. Jackfruit forms minute flowers, which aggregate themselves in a crowded inflorescence (Abedin S *et al.* 2012 and Eke Ejiofor. J, Owuno, F. 2013). Jackfruit (*Artocarpus heterophyllus* Lam) is known to be the 'biggest tree-borne fruit', which consists of edible flakes and inedible material that can be used for making value-added products. Edible flakes can be converted into items such as juices, jams, dried flakes, fruit leather, and wines, whereas the inedible part can be used for producing pectin (Abedin S *et al.*, 2012).

According to the fruit morphology, 8–15% of the fruit weight corresponds to the seeds, which are covered with brown spermoderm, which surrounds the white cotyledon containing starch and protein. The fruit weight for the majority of jackfruit varieties is 10–30 kg. In terms of fruit quality, the fruit is mainly classified into two major types. The first type is strongly aromatic, has a soft pulp, which is highly sweet with a thin fibrous consistency, while the second one is tough pulp, sometimes crisp with less aroma. Jackfruit is composed of 54% of the rind, 29% of the pulp, and 12% of the seed. Inside the ripe fruit is a huge sweet yellow bulb, surrounded by narrow bands and a central core made up of 25–30% of the whole fruit (Seleim M.A.A and Manal A.M. Hassan, 2019).

In Ethiopia, various wild and domesticated plants have served as a food resource. The selected mechanism represents a process of gradual reduction that proceeds from broad efforts to minimize risks over time, culminating in the implementation of measures intended to minimize damages associated with the emergence of a crisis. Various plant parts have been used as food, including leaves, stems, fruits, and roots. This phenomenon occurs throughout all rural areas of the country. These plants are critical for use as additional food resources and as an aid for surviving droughts and famines. These plants are sources of vitamins, minerals, trace elements, and proteins. Consequently, wild and domesticated food plants improve food security and local incomes (Tilahun Teklehaymanot and Mirutse Giday, 2010; Ermias Lulekal et al., 2011; Debela Hunde et al., 2011).

The southern parts of Ethiopia, particularly the southwest, are quite biodiverse, and thus, in this regard, various indigenous and domesticated plant species have been utilized in the past as sources of food by the local communities. Tepi is one such biodiverse place, where numerous fruits abound in abundance. Out of all the fruits, the jackfruit was chosen to be studied for its mineral content, especially when it comes to major, minor-essential, and toxic metals in Tepi, Southern Nations Nationalities and Peoples Region (SNNPR), which is the study area. It is known that this particular fruit serves as the main diet of people in the area, and it provides minerals. Consequently, there is a need to evaluate both the quality and quantity of the major, minor-essential, and toxic metals present in the fruit.

2. MATERIALS AND METHODS

2.1. Description of the study area

This research was carried out in Teppi town, which lies in the southwestern part of Ethiopia. Tepi town is found in Sheka Zone, Southern Nations Nationalities and Peoples' Region (SNNPR), with coordinates 7°12'N latitude and 35°27'E longitude, with an average elevation of 1,097 meters above sea level (Tsion, D. and Serawit, D., 2014).

2.2. Sample collection

Fruit and soil representative samples were collected from three areas. In the case of this study, samples were collected from Hibret, Andnet, and Selam kebeles, in which the production of jackfruit is high. In this regard, 10 jackfruit trees were randomly collected from each location, while collecting two fruit samples from each tree. Soil samples were collected from the point where the jackfruit plant was sampled. Thus, the number of fruit samples collected totaled 60. Moreover, a new methodology for soil sample collection was introduced. Following this methodology, the formation of a circular area with a one-meter radius around the jackfruit plant was done. The circle was cut into eight segments, soil samples were collected twice from every segment by use of the auger at 30cm, and all the soils were combined to form ¼ kg soil sample from each jackfruit plant, followed by combination of all ¼ kg soil samples from all the jackfruit plants to obtain 2kg soil samples from all the jackfruit plants at every study site. The jackfruit plant samples and the soil samples were kept in a polythene bag. The sampled jackfruits and soil samples were tagged and brought to the laboratory (Mizan -Tepi University).

2.3. Sample preparation

The jackfruit samples were stored in polyethylene bags for 3 days. The fruit samples that were classified were washed thoroughly using tap water and detergent solutions before being rinsed using distilled water to remove any external contaminants. The fruit mass was weighed using an electronic balance to determine the portion with moisture. The fruit samples were peeled using a stainless-steel knife, while the pulp samples were blended using a mixer. The fruit juices obtained after the blending process were dried at 90°C for 72 hours using the oven (PIF 60, Sheffield, s 30, 2RR England). The dried fruit samples were powdered using the pestle and mortar, and the well-powdered samples were blended manually and preserved in polyethylene bags before digestion. The soil samples were stirred gently and dried under natural conditions in the open air until a constant weight of soil was attained. The dried soil samples were powdered using a pestle and mortar, and the well-blended soil samples were stored in polyethylene bags until digestion.

2.4. Sample digestion

The Berghof Microwave Digestion Application (2011) process was adopted with little modification. The 0.3 grams of dried and powdered fruits were weighed (Analytical digital balance, ADAM®) and carefully introduced into digestion vessels, after which 7 mL of 68% concentrated HNO_3 and 3 mL of 30% H_2O_2 were added to each digestion vessel and shaken. All samples were left under the fume hood for 15 minutes before digestion to ensure that no foaming occurred. The mixture of pre-digested samples and reagents in the digestion vessel was sealed and subjected to microwave digestion in the BMS-1 microwave oven. Fruit sample digestion using this technique involved three stages; in stage one, the temperature was set at 170°C for 10 minutes by setting the magnetron to 80%-watt power, in stage two, the temperature was increased linearly to 190°C for 15 minutes with magnetron rotated to 90% watt, finally the temperature was decreased linearly to 50°C for 10 minutes by turning off magnetron.

After digestion of the fruit samples, to prevent loss of sample during spraying, the digestion was allowed to cool down to room temperature within a period of 20 minutes. The cooled fruit sample solutions were then transferred to 10mL volumetric flasks, and the volumes were made up to the mark using double distilled deionized water.

0.5 g of dried and homogenized soil samples were precisely weighed using an analytical digital balance (ADAM®) and transferred quantitatively into digestion vessels where 2.5 mL of concentrated HNO_3 (68%) and 7.5 mL of concentrated HCl (38%) were introduced, and all the mixed samples were left in a fume hood for 15 minutes before digestion to prevent any foam formation. The pre-digested soil samples were then sealed and subjected to digestion by a microwave oven (BMS-1). This digestion procedure was done in two steps; first, the digestion process involved maintaining the temperature at 190°C for 25 minutes by adjusting the magnetron to 90%-watt power. Secondly, the temperature was reduced linearly to 100°C for 10 minutes at a fixed power of 90%. The resulting soil samples were allowed to cool to room temperature within 20 minutes in a fume hood. However, since the digested and

cooled soil samples contained precipitates, they were filtered through a Whatman filter paper (110 mm) and transferred to a 25 mL volumetric flask, filling their volumes with double-distilled deionized water up to the mark.

Optimization plays an important role in ensuring that practical analysis activities are conducted using minimum amounts of reagents, time, temperature, and in an environmentally safe manner. Optimization of sample digestion in both fruits and soils was carried out using varying amounts of sample weight, reagent volume, temperature, and time. Digestions were done in triplicate.

2.5. Determination of major, minor, essential, and toxic metals

Calibration curves for major metals, minor essential metals, and toxic metals were obtained using the above instrument (FAAS) with five working standard solutions per metal. Working standards were made by diluting the intermediate standard solutions with double-distilled deionized water. An intermediate standard solution is obtained from the standard stock solution, which is 1000 mg/l for all metals. Parameters of the flame atomic absorption spectrophotometer, such as the burner position, lamp position, slit width, and wavelength, were adjusted to obtain maximum intensity of the above instrument. The acetylene and air flow rates were adjusted as per the flame condition requirement. Hollow cathode lamps for metal interest were adjusted to their source. Metal ions (Ca, Mg, Mn, Zn, Cu, Pb, and Cd) were analyzed with FAAS (Buck Science Atomic Absorption Spectrophotometer Model 210 VGP) with a Deuterium Arc Background Corrector with standard air-acetylene flame assembly.

2.6. Recovery analysis

The efficiency and accuracy of the optimal technique used to analyze jackfruit and soil samples for their major, minor, and essential metals, and toxicity were evaluated using the spiking method. Herein, the efficiency of the optimal technique was measured by adding known concentrations of each metal to be analyzed to 0.3 grams of jackfruit and 0.5 grams of soil samples. For spiking jackfruit and soil samples, 0.1 mg/L of zinc, copper, and manganese metals were added to the digesters containing 0.3 grams of the fruit samples altogether in one reaction flask. 0.05 mg/L of lead and cadmium metals were added to the reaction flasks containing 0.3 grams of the same fruit sample, while calcium and magnesium metals were spiked with 1 mg/L in another flask with 0.3 grams of the same fruit sample. Each sample was subjected to analysis in the same way as described before for jackfruit and soil samples, respectively. Spiking experiments were carried out in triplicate. Analysis was done using a flame atomic absorption spectrophotometer (Buck Scientific absorption spectrophotometer model 210 VGP).

2.7. Method detection limit

The method detection limits of the research for both fruit and soil samples were determined based on the mean and standard deviation of the blanks. The blanks of the jackfruit samples were subjected to digestion procedures along with those of the soil samples, as explained above in respect to the digestion of the fruits and soil. Each blank was analyzed for each of the target elements, which included calcium

(Ca), magnesium (Mg), manganese (Mn), copper (Cu), zinc (Zn), lead (Pb), and cadmium (Cd), using the flame atomic absorption spectrophotometer (Buck Scientific Absorption Spectrophotometer model 210 VGP).

2.8. Sample Physical Analysis

pH and EC values of fruit and soil samples (solid: deionized water = 1:5) were measured by a pH meter and an EC meter by PH-EC Meter; Model 1615. Organic matter and moisture content were determined for both samples. Organic matter was determined based on the mass loss principles in a muffle furnace after ashing the fruit and soil samples at 500°C for 4 hr. (Danielle V *et al.*, 2014).

$$\%OM = Ms/Mb \times 100$$

Where, Ms = Mass of the sample after ashing (g)

Mb = Mass of the sample before ashing (g)

OM = Organic matter, %

Moisture content was determined based on the mass loss after drying it in an oven at 105°C for 24 hr. (Nouri E. *et al.*, 2009).

$$\%M = Ms/Mb \times 100$$

Where, Ms = Mass of the sample after oven drying (g)

Mb = Mass of the sample before oven drying (g)

M = Moisture content, %

2.9. Transfer Factor (TF)

The transfer factor is the ratio of the concentration of specific metals to the total metal concentration in the respective soil sample (Opaluwa *et al.*, 2012).

$$TF = \text{metal concentration in fruit} / \text{metal concentration in soil}$$

2.10. Statistical Analysis of Data

Statistical analysis was made to check whether there was a significant difference in metal concentration between jackfruits that grow in different areas using one-way ANOVA. A t-test was used to check the difference in the metal concentration between the fruit and soil samples. The calculation was made using Origin 8 software.

3. RESULTS AND DISCUSSION

3.1. Physicochemical Parameters Analysis

Moisture Content

For moisture content, the interval is from 57.95%-58.56% for fruit and 72.05%-73.66% for soil samples. For both types of samples, the order of the moisture content is Hibret > Andnet > Selam Kebeles, showing that the soil moisture content is positively correlated with the fruit moisture content.

Organic Matter (OM)%

The percentage composition of organic matter is between 21.09%-22.05% for fruit samples and 79.65%-81.67% for soil samples. The percentage composition of organic matter indicates that there is a high ability or capacity of the soils to hold metal ions. Based on these analyses, we have Selam > Andnet > Hibret. From the results, the presence of high amounts of metals in soils compared to fruits can be attributed to organic matter composition.

Electrical Conductivity (EC)

Electrical conductivities of samples were indicated to vary from 0.07ms/cm to 0.09ms/cm in fruit samples, while varying from 0.61ms/cm to 0.69ms/cm in soil samples. Electrical conductivity in Jackfruit samples showed that Andnet > Hibret > Selam, while electrical conductivity in soil samples showed that Andnet soil > Selam soil > Hibret soil. Electrical conductivity in samples gives an insight into the amount of ionic concentration. Electrical conductivity values in soil samples were found to be higher than those in fruit samples.

pH

Values were found to range between 5.35 and 5.38 in fruit samples, while the soil samples were between 6.79 and 6.99. As for both fruit and soil samples, the pH in Andnet > Hibret > Selam, which means that the degree of acidity in the soil is related to the degree of acidity in the fruit sample. This indicates results from weak basicness to neutrality and clearly indicates that this fruit can be consumed based on the pH value. Additionally, soil pH values are greater than 6.79, indicating metal mobility and transfer from soil to plant or plant, which is suitable for plant growth (Seyed E. and Somashekar R., 2008).

Table 1
Determination of physicochemical parameters

Sample	Moisture (%)	OM (%)	EC (ms/cm)	pH
Jackfruit 1	58.56 ± 0.32	21.09 ± 0.13	0.08 ± 0.006	5.37 ± 0.05
Jackfruit 2	58.25 ± 0.25	21.11 ± 0.07	0.09 ± 0.005	5.38 ± 0.04
Jackfruit 3	57.95 ± 0.50	22.05 ± 0.04	0.07 ± 0.005	5.35 ± 0.05
Soil 1	73.66 ± 0.54	79.65 ± 0.21	0.61 ± 0.003	6.97 ± 0.07
Soil 2	72.35 ± 0.25	81.32 ± 0.14	0.69 ± 0.003	6.99 ± 0.09
Soil 3	72.05 ± 0.15	81.67 ± 0.20	0.65 ± 0.002	6.79 ± 0.03
NB; Jackfruit 1& Soil 1 = Sampled from Hibret, Jackfruit 2& Soil 2 = Sampled from Andnet, Jackfruit 3& Soil 3 = Sampled from Selem kebeles respectively				

3.2. Determination of major, minor-essential, and toxic metals

The concentrations of the selected eight metals in the digested and diluted solutions of fruit and soil samples are shown in Table 2.

Table 2
Metals mean concentration in fruit and soil samples

Sample	Concentration of metal(mg/kg) mean ± SD						
	Ca	Mg	Cu	Zn	Mn	Cd	Pb
Jackfruit 1	112 ± 0.12	101 ± 0.30	6.5 ± 0.45	12.9 ± 0.35	16 ± 0.56	ND	ND
Jackfruit 2	136 ± 0.20	99 ± 0.45	4.0 ± 0.25	12.6 ± 0.20	12 ± 0.25	ND	ND
Jackfruit 3	152 ± 0.15	120 ± 0.50	6.9 ± 0.45	13.5 ± 0.35	13 ± 0.38	ND	ND
Soil 1	1230 ± 0.52	1350 ± 0.68	160 ± 0.20	178 ± 0.45	110 ± 0.33	65 ± 0.35	87 ± 0.24
Soil 2	1480 ± 0.58	1290 ± 0.56	197 ± 0.56	177 ± 0.55	125 ± 0.25	59 ± 0.25	89 ± 0.50
Soil 3	1560 ± 0.55	1430 ± 0.55	189 ± 0.55	172 ± 0.62	109 ± 0.45	61 ± 0.32	86 ± 0.26
NB; Jackfruit 1& Soil 1 = Sampled from Hibret, Jackfruit 2& Soil 2 = Sampled from Andnet, Jackfruit 3& Soil 3 = Sampled from Selem kebeles respectively							

It has been demonstrated through the current research that the jackfruit contains considerable amounts of important metals. The high levels of Ca and Mg in fruit samples are due to the highly mobile nature of these metals within the plant. They can easily move from old plant parts to the fruit part of the plant. The presence of metal in the plant and its movement is related to its mobility, soil nature, and plant type.

Levels of metals in fruit and soil samples

The analysis revealed that the concentration of Ca, Mg, Cu, Zn, and Mn was found to be in all samples. In contrast, Cd and Pb concentrations were observed in all soil samples, whereas there was no observation of Cd and Pb concentrations in fruit samples. The results revealed that jackfruit can be a good source for the concentration of calcium (152 ± 0.15) mg/kg, magnesium (120 ± 0.50) mg/kg, manganese (16 ± 0.56) mg/kg, zinc (13.5 ± 0.35) mg/kg, and copper (6.9 ± 0.45) mg/kg and that it is within the safe limit of copper (6.9 ± 0.45) mg/kg.

Soil pH and Organic Matter in relation to the availability of the above metals are very crucial. The most important one is the soil pH since it affects the chemical structure of the mineral. Manganese (Mn), Zinc (Zn), and Copper (Cu): In Acidic soils ($\text{pH} < 7.0$), the availability of the above elements increases since with a reduction in the soil pH, these elements get dissolved in the soil solution, hence increasing their absorption by the root. That is why Manganese always shows high translocation in acidic soils. Calcium (Ca) and Magnesium (Mg). These are Base Cations. These base cations are usually more accessible in neutral to alkaline soils. In strongly acidic soils, calcium and magnesium may even leach out. This may require extra effort from the tree to maintain the high structural concentrations. The soil organic matter functions as a sponge and magnet for the nutrients in the soil. It prevents nutrient leaching because of heavy tropical rains, but also affects their extraction by the tree. Soil organic matter enhances the capacity of the soil for cation exchange. As such, since the elements like calcium, magnesium, zinc, manganese, and copper have positive charges, they are readily available in soils with high organic content (Adina Berbecea et al., 2011 and Ali Sungur et al., 2014).

Based on the above discussion, jackfruit is a good provider of major and minor essential metals and is relatively safe concerning the level of heavy metals. Several organizations around the globe have developed guidelines for regulating the level of metals in foods. As jackfruit is consumed in its natural state, it will make sense to calculate the amount of metal intake from this fruit. The interviews were carried out during the sampling; hence, a person should take 0.25 kg/day of dried jackfruit, and accordingly, the intake of metals through jackfruit is estimated.

Daily intake of metals (mg/day) = daily fruit consumption (kg/day, dry weight) X average metals concentration in fruit (mg/kg) (M. A. Elbagermi et al., 2012).

Table 3
Comparison of the present study with different international guidelines

Metal	Name of organization	AI (mg/day)	UL (mg/day)	Present study (mg/day)
Mg	IOM, 1999	Adults Women, 320 Men, 420	-----	30
Ca	IOM, 1999	Age 19–50, 1000 > 50, 1200	2500	38
Cu	IOM, 2001	Adults, 0.9	10	1.73
Zn	IOM, 2001	Women, 8 Men, 11	40	3.38
Mn	IOM, 2001	Women, 1.8 Men, 2.3	11	4

According to WHO (2012), the recommended dietary allowance (RDA) of Mg and Ca is 320–420 and 1000–1200 mg/day, respectively. Therefore, the concentrations of Mg and Ca fall under permissible limits. The tolerable limit (TOL) for Cu, Zn, and Mn is 10, 40, and 11 ppm, respectively. Daily intake of these metals through fruit consumption is lower than their tolerable limit, hence jackfruit was not affected by fate due to the high content of these metals.

3.3. Transfer factor of metals

Table 4
Transfer factor of metals

No	Metal	Concentration of metal in sample (mg/kg) mean $\pm$ SD								
		Jackfruit 1	Soil 1	TF	Jackfruit 2	Soil 2	TF	Jackfruit 3	Soil 3	TF
1	Ca	112 $\pm$ 0.12	1230 $\pm$ 0.52	0.09	136 $\pm$ 0.20	1480 $\pm$ 0.58	0.09	152 $\pm$ 0.15	1560 $\pm$ 0.55	0.10
2	Mg	101 $\pm$ 0.30	1350 $\pm$ 0.68	0.07	99 $\pm$ 0.45	1290 $\pm$ 0.56	0.08	120 $\pm$ 0.50	1430 $\pm$ 0.55	0.08
3	Cu	6.5 $\pm$ 0.45	160 $\pm$ 0.20	0.04	4.0 $\pm$ 0.25	197 $\pm$ 0.56	0.02	6.9 $\pm$ 0.45	189 $\pm$ 0.55	0.04
4	Zn	12.9 $\pm$ 0.35	178 $\pm$ 0.45	0.07	12.6 $\pm$ 0.20	177 $\pm$ 0.55	0.07	13.5 $\pm$ 0.35	172 $\pm$ 0.62	0.08
5	Mn	16 $\pm$ 0.56	110 $\pm$ 0.33	0.15	12 $\pm$ 0.25	125 $\pm$ 0.25	0.10	13 $\pm$ 0.38	109 $\pm$ 0.45	0.12
6	Cd	ND	65 $\pm$ 0.35	---	ND	59 $\pm$ 0.25	---	ND	61 $\pm$ 0.32	---
6	Pb	ND	87 $\pm$ 0.24	---	ND	89 $\pm$ 0.50	---	ND	86 $\pm$ 0.26	---
NB; Jackfruit 1& Soil 1 = Sampled from Hibret, Jackfruit 2& Soil 2 = Sampled from Andnet, Jackfruit 3& Soil 3 = Sampled from Selem kebeles respectively										

The Transfer Factor (TF) for metals from soil to plants is essential data concerning the complex process involved in metal uptake/accumulation by the plants. The most critical aspect concerning the estimation of the dynamics of metal transfer is the TF, which is the index that reveals the ratio of the metal concentration in the plant relative to its concentration in the soil. If the TF is high, then the metal concentration in the plant is also high, indicating inefficiency of metal retention in the soil or poor metal uptake by the plant. However, when the TF is low, the metal concentration in the plant is low compared to the concentration in the soil, indicating that the metal concentration in the soil colloid is high (Mbong, E. O. et al., 2014, and Lamiaa Belasri et al., 2024). Transfer Factor of the Metal is the quotient of the amount of the specific metal in the fruit component to the total amount of the respective soil (Opaluwa O. et al, 2012). Quotients of the Transfer Factor > 1 denote the absorption of metal by the plant, quotients ~ 1 imply that the impact is negligible, and quotients < 1 denote the exclusion of the metal in the plant, providing important insights. For this research, the Transfer Factor of Manganese (Mn) is higher in all the samples. The Transfer Factor of Manganese in jackfruit reflects the efficiency of the plant at transporting this nutrient from the soil to its consumable components. Jackfruit trees have an extensive root system.

Under acidic and tropical conditions, Manganese exists as a highly soluble Mn^{2+} form in soil. Jackfruit trees have developed transport proteins within their roots that work effectively to acquire the available manganese from the soil. The Transfer Factor of Copper is low in all cases. The reason behind the low Transfer Factor of Copper is that Copper (Cu) is usually slower compared to the other elements discussed. Copper is the most tenacious micronutrient in tropical soils. Copper has a high binding capacity to soil organic matter. Copper will easily form complexes in the soils that lock it up. This makes it difficult for plants' roots to absorb it. Copper is also easily attracted to Fe and Al Oxides common in acidic soils such as those of jackfruits. High concentrations of copper are very toxic to plants as they lead to oxidative stress. However, the jackfruit tree has a defense mechanism against copper by which it stores the element in the cell wall of the roots. Upon absorption of the copper by the roots, the plant usually sequesters the metal inside the vacuoles or binds it to the proteins to prevent it from entering the xylem, leading to the formation of a low translocation bottleneck (Jean B. Diatta 2018, and Guilherme Wilbert *et al.*, 2025).

CONCLUSION

The results obtained in the current study indicate that none of the soil samples contained any traces of Cd and Pb metals. The concentration of the detected metals was found to be relatively high in soil samples compared to the fruit samples. The findings indicated the presence of Ca, Mg, Cu, Zn, and Mn metals in all the samples, while Cd and Pb metals were found in all soil samples but not in fruit samples. It could be inferred from the findings that jackfruit is an excellent source of Calcium (152 ± 0.15) mg/kg, Magnesium (120 ± 0.50) mg/kg, Manganese (16 ± 0.56) mg/kg, Zinc (13.5 ± 0.35) mg/kg, and Copper (6.9 ± 0.45) mg/kg. The order of elements in all samples in terms of percentage was $Ca > Mg > Mn > Zn > Cu$. The percent moisture content in fruit and soil samples ranged between 57.95% and 58.56%, while the organic matter range was 21.09%- 22.05%. The electrical conductivities of the fruit and soil samples were 0.07 ms/cm to 0.09 ms /cm and 0.61 ms /cm to 0.69 ms/cm, respectively. The concentration levels of all the metals are below the RDA value in all the fruit samples. The levels found for all the metals within the normal range showed significant agreement with those cited in other international guides. The transfer factor of all the metals was less than one, which implies a lesser transfer level of the metals in question from the soil to the fruit. This is attributed to the presence of organic matter accumulation. The transfer factor of Manganese (Mn) metal is relatively high in all samples, which implies that Manganese is highly soluble in the Mn^{2+} state. Copper (Cu) metal has low transfer factor values in all samples. This is attributed to the fact that copper is quite sluggish, thus having low Transfer Factors. Copper has a high affinity to the organic matter present in the soil. It tends to form stable complexes that bind the copper in the soil, thus limiting their uptake by the roots.

Declarations

Author Contribution

Berhe Akele (Corresponding Author); wrote the whole manuscript, did the sample collection, sample preparation, data analysis, and interpretation. Shisho Haile (Co-author); Did the sample collection, and figure preparation.

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References

1. Adina Berbecea, Isidora Radulov, F. Sala, F. Crista, and Alina Lato. 2011. Interrelation between metal availability, soil pH, and mineral fertilization, *Research Journal of Agricultural Science*, 43 (3): 19–22.
2. Albi Abraham and J Jayamuthunagai. 2014. An Analytical Study on Jackfruit Seed Flour and Its Incorporation in Pasta. *Research Journal of Pharmaceutical, Biological and Chemical Sciences*, 5(2): 1597–1610.
3. Ali Sungur, Mustafa Soylak, and Hasan Ozcan. 2014. Investigation of heavy metal mobility and Availability by the BCR sequential extraction procedure: relationship between soil properties and heavy metal availability, *Chemical Speciation and Bioavailability*, 26(4): 219–230.
4. Danielle V., Guimarães, Maria I., S. Gonzaga and José de O. Melo Neto. 2013. Management of soil organic matter and carbon storage in tropical fruit crops. *Revista Brasileira de Engenharia Agrícola e Ambiental*, 18(3): 301–306.
5. Debela Hunde, Jesse T. Njoka, M.M. Nyanjito, Zemedu Asfaw, 2011, Nutraceutical wild plants of semiarid east shewa, Ethiopia: contributions to food and healthcare security of the semiarid people, *Research Journal of Forestry*, 5(1): 1–16.
6. Devi Swasti Prabasiwi, Sukirno, Sri Murniasih and Kharistya Rozana. 2020. Transfer factor as indicator of heavy metal content in plants around adipala steam power plant. *Journal of Physics Conference Series*, 8(2):1–11.
7. Eke- Ejiofor. J., Owuno. F. 2013. The physico-chemical and sensory properties of jackfruit (*artocarpus heterophilus* Lam). *International Journal of Nutrition and Food Sciences*, 2(3): 149–152.
8. Ermias Lulekal, Zemedu Asfaw, Ensermu Kelbessa, Patrick Van Damme, 2011, Wild edible plants in Ethiopia: a review on their potential to combat food insecurity, *Afrika Focus*, 24(2): 71–121.
9. Guilherme Wilbert Ferreira, Samya Uchoa Bordallo, Lucas Dupont Giumbelli, Zayne Valéria Santos Duarte, Gustavo Brunetto, George Wellington Bastos de Melo, Deborah Pinheiro Dick, Tadeu Luis Tiecher, Tales Tiecher, and Cledimar Rogério Lourenzi. 2025. Chemical Fractions of Soil Organic Matter and Their Interactions with Cu, Zn, and Mn in Vineyards in Southern Brazil, *Agronomy*, 15: 1–28.
10. Jean B. Diatta. 2018. Mutual Cu, Fe, and Mn solubility control under differentiated soil moisture status, *J. Elemental*, 13(4): 473–489.

11. Lamiaa Belasri, Mourad Arabi, Safaa Sabri, Fouzia Hmimid and Samah Ait Benichou. 2024. Transfer of Metals from the Soil to Medicago sativa Irrigated with Municipal Landfill Leachate. *Journal of Ecological Engineering*, 25(8): 336–346.
12. M. A. Elbagermi, H. G. M. Edwards and A. I. Alajtal, 2012. Monitoring of heavy metal content in fruits and vegetables collected from production and market sites in the Misurata area of Libya, *International Scholarly Research Network*, 10: 1–5.
13. M. S. Abedin, M. M. Nuruddin, K. U. Ahmed and A. Hossain. 2012. Nutritive compositions of locally available jackfruit seeds (*Artocarpus heterophyllus*) in Bangladesh. *International Journal of Biosciences*, 2(8): 1–7.
14. Mbong, E. O., Akpan, E. E and Osu, S. R. 2014. Soil-plant heavy metal relations and transfer factor index of habitats densely distributed with *Citrus reticulata* (tangerine). *Journal of Research in Environmental Science and Toxicology*, 3(4): 61–65.
15. Olowoyo, J. O., Matodzi, N., Aina, O. E. and Agboola, O. O. 2024. Assessing differences in the concentrations of trace metals from different tomato varieties harvested from soils treated with municipal waste sludge. *Applied ecology and environmental research*, 22(1): 917–931.
16. Opaluwa, O. Da., Aremu, M. Oa., Ogbo, L. Ob, Abiola, K. Ab., Odiba, I. Ec., Abubakar, M. Ma. and Nweze, N.Od. 2012. Heavy metal concentrations in soils, plant leaves and crops grown around dump sites in Lafia Metropolis, Nasarawa State, Nigeria. *Advances in Applied Science Research*, 3 (2):780–784.
17. Seleim M.A. A and Manal.A.M.Hassan. 2019. Physicochemical Properties and Nutritional Evaluation of Jackfruits (*Artocarpus Heterophyllus* L.). *International Advanced Research Journal in Science, Engineering and Technology*, 6(10): 75–84.
18. Seyed E. and Somashekar R. 2008. Heavy metals and safety of fresh fruits in bangalore city. India, kathmandu university journal of science. *Engineering and technology*, 1(5):17–27.
19. Tilahun Teklehaymanot, Mirutse Giday, 2010, Ethnobotanical study of wild edible plants of Kara and Kwego semi-pastoralist people in Lower Omo River Valley, Debub Omo Zone, SNNPR, Ethiopia, *Journal of Ethnobiology and Ethnomedicine*, 6(23): 1–8.
20. Tsion, D. and Serawit, D., 2014. Rate and Predictors of Adherence to Antiretroviral Therapy among Clients on Antiretroviral Therapy at Tepi Health Center, South-west Ethiopia. *Journal science, Technology and Arts Research*, 3(3):2305–2311.