



Investigation and Determination of Mineral Nutrient of Composition of Cassava, at Selected Woreda's of Jimma Zone, Ethiopia

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Abstract: Cassava (*Manihot esculenta Crantz*) is one of the oldest root and tuber crops, used by humans to produce food, feed and beverages. It can be produced adequately in drought conditions making it the ideal food security crop in marginal environments. Although cassava can tolerate drought stress, it can be genetically improved to enhance productivity in such harsh environments. Currently, cassava is produced in more than 100 countries and fulfills the daily caloric demands of millions of people living in tropical America, Africa, and Asia. In this study the nutritional composition, toxic heavy metal and cyanide content of cassava root grown in Jimma Zone, Ethiopia were investigated. Cassava samples were collected from five selected Woredas (Districts) of the Zone, where the plant usually grows. The concentration of the mineral elements; calcium, magnesium iron and copper analyzed ranged from 153-436 mg/kg, 65-207 mg/kg, 54.23-127.03 mg/kg, and 0.09-0.36 mg/kg respectively. In addition to the above parameters, the recovery of the mineral and toxic heavy metals determined was between 81-120%. Wet sample digestion method was used for mineral and toxic heavy metal determination purpose. The results of mineral composition of analyzed cassava root samples were rich in mineral contents. The composition of cassava depends on the specific tissue (root or leaf) and on several factors, such as geographic location, variety, age of the plant, and environmental conditions.

Keywords: Cassava, Root, Nutritional Compositions, Minerals, Nutrient

1. Introduction

1.1. Background of the Study

Cassava (*Manihotesculenta Crantz*) is a woody shrub native to South America [1]. The plant is known by its edible starchy tuberous root. It is a drought tolerant, staple food crop grown in tropical and subtropical areas where many people are afflicted to under nutrition, making it a potentially valuable food for developing countries [1].

It is widely used in food security because; its mature edible root can be stored in the ground for up to three years. As a result, it represents a household food bank that can be drawn upon when adverse climatic condition limits the production of other foods. Because of its capability in producing efficient food energy, availability throughout the year,

tolerance to extreme stress conditions, and suitability to present farming and food systems in Africa, cassava plays a role to alleviate the African food crisis [2].

Cassava is a dicotyledonous plant belonging to the botanical family Euphorbiaceae and has some inherent characteristics which make it attractive to the smallholder farmers [6]. Although its introduction period is not yet known, it is widely grown in south, south west and western part of Ethiopia [7]. Its use as a potential food crop in Ethiopia has been appreciated since 1984 famine [7]. In Ethiopia, cassava is usually consumed by boiling the tuber. Cassava is the third most important source of calories in the tropics and the sixth most important food crop after sugar cane, maize, rice, wheat and potato, in terms of global annual

production [9]. Because of its versatile nature, cassava is referred as the drought, war and famine crop to several developing countries. Thus, it is the important crop to improve food security in a time of climate change [10, 11, 12]. There are several indigenous cultivated or semi-cultivated root and tuber crops in Ethiopia. These crops have an important place in the diet of the population. Tuberous roots of the plant which can be retrieved from the soil up to three years after maturity. Cassava root is the main consumable part as food product allowing crops to be abandoned during periods of agricultural and social instability. This provides an important form of insurance against social disruption, prolonged droughts, or other periods of stress and unrest. Beside, its production also could not need to use of large amounts of agricultural inputs such as fertilizers, water and pesticides. Cassava is known in Jimma in different names and called as "MukaFurno". For Ethiopians, the consumption of cassava as food is of immense importance and regarded as the food security crop for millions of people. But the nutrient content of cassava roots, which are cultivated in Ethiopia, has not been addressed so far. Currently, some cassava collection, introduction and evaluation productivity works have been initiated by the Ethiopian Institute of Agricultural Research (EIAR) [13]. However, the nutritional composition, mineral and heavy metal as well as cyanide content of the collected and introduced accessions have not been properly evaluated and remain unknown to both consumers and producers. Since the nutritional value of cassava root from different districts of Jimma Zone in location and variety didn't considered; it is necessary to analyze their mineral composition values. The present study was, therefore, planned to assess the nutritional composition and level of some selected mineral and heavy metals of cassava in Jimma Zone

In tropical regions, cassava is the most important root crop as a source of energy for human consumption. It is a major source of carbohydrate for an estimated 500 million people in tropical Africa. Cassava is a major staple food in the developing world, providing a basic diet for over half a billion [14, 15]. It is produced at relatively low cost and more frequently than other staples for sale. It is the third largest source of food carbohydrates in the tropics, after rice and maize [16]. Cassava is referred to as a food security crop which can stay for long period of time. Its roots are very rich in starch and contain significant amounts of calcium and phosphorus (40 mg/100g) [17].

Cassava was introduced to Africa by Portuguese traders from Brazil in the 16th century. Maize and cassava are now important staple foods, replacing native African crops [18]. It is attractive as nutrition source in certain ecosystems because cassava is one of the most drought-tolerant crops, can be successfully grown on marginal soils, and gives reasonable yields where many other crops do not grow well.

Cassava plant is hardy and better able to tolerate drought and poor soil conditions than most other food plants. It can grow in extremely poor, acidic soils because it forms a symbiotic association with soil fungi (mycorrhizae). It is also

one of the most productive food plants in terms of carbohydrate production per unit of land, and unequalled in its ability to recover when foliage is lost or damaged by diseases or pests.

1.2. Nutritional Value of Cassava Roots

There is much variation in the nutrient quality of the cassava root [19]. Cassava is an important root crop, is a source of energy in tropical regions and has high calorific value compared to most starchy crops [18]. The starch content of the fresh cassava root is about 30%, and gives the highest yield of starch per unit area of land. Tubers are underground plant stems or shoot bearing tiny leaves whose buds are the eye of the tuber. They are valued for their highly nutritious starch content [20].

Levels of minerals in cassava root are appreciable and useful in the human diet. Cassava contains appreciable amounts of iron, phosphorus and calcium, and is relatively rich in vitamin C [21]. The composition of cassava depends on the specific tissue and on several factors, such as geographic location, variety, age of the plant, and environmental conditions. The nutritional value of cassava root is important because they are the main part of the plant consumed in developing countries [22].

Figure 1 shows cassava plant and its roots.



Figure 1. Cassava plant and its roots (Captured during sampling).

1.3. Minerals

Cassava roots have valuable minerals like calcium, iron, potassium, magnesium, copper, zinc, and manganese contents comparable to those of many legumes, with the exception of soybeans. The calcium content of cassava is

high compared to that of other staple root crops and ranges between 15 and 35 mg/100 g edible portion [23].

The mineral contents are lower in cassava roots than in sorghum and maize [23]. These minerals are necessary for proper development, growth and function of human body's tissues. For example, calcium is necessary for strong bones and teeth; iron helps in the formation of two proteins hemoglobin and myoglobin which carry oxygen to your body; and manganese helps in the formation of bones, connective tissue and sex hormones. Potassium is necessary for synthesis of proteins and helps in the breakdown of carbohydrates

2. Materials and Methods

2.1. Sample Collection Site

Cassava samples were collected from five Woredas of Jimma zone; Mana with altitude of (1786 m), Sakachekorsa (2107 m), Dedo (2096 m), Sokoru (1620 m), Gomma (1805 m) and JARC (1753 m) above sea level were selected purposively. Two varieties were collected from Gomma Woreda (white and red), but only the white variety was collected from the other four Woredas. Map of Jimma zone and the areas of sampling sites were displayed in Figure 3 below.

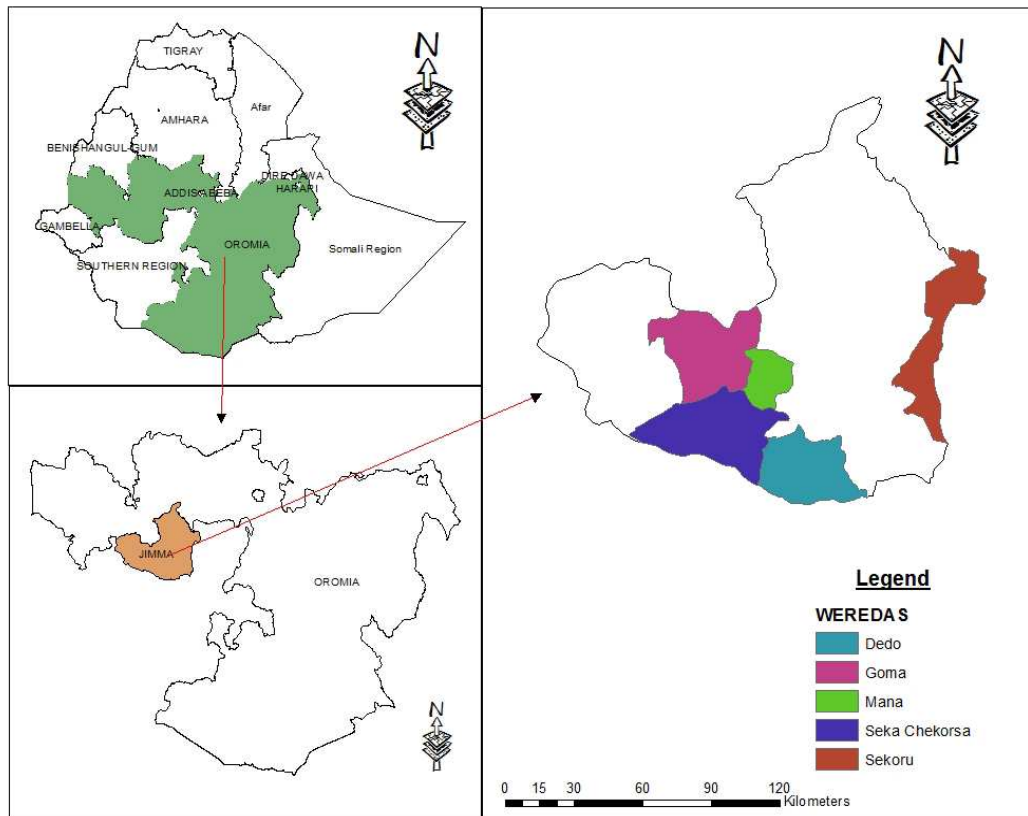


Figure 2. Map of the sampling area.

2.2. Sampling and Sample Pretreatment

Locally grown representative cassava root samples were collected randomly from five selected Woredas of Jimma Zone to determine their nutritional value, to investigate the level of some heavy metals and anti-nutrients. The analysis was conducted by categorizing into two sub- categories; which were collected from the farmer's farm land of different Woredas and the second category was collected from Jimma Agricultural Research Center (JARC). All the analyses were conducted in triplicate on cassava root. After collection, the samples were washed with tap water to remove soil and the outer parts of the root were mechanically removed using knife and transported to the laboratory soaked overnight in plastic pot [24] and then, dried at room temperature. The dried samples ground using mortar and pestle. The samples were made ready for analysis in triplicate.

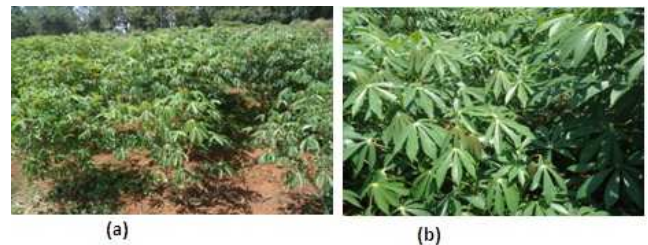


Figure 3. Figures of cassava varieties: (a) Red cassava and (b) White cassava (Captured during sampling).

2.3. Sample Digestion Procedure by Wet Method

One (1 g) of powdered sample was weighed into the digestion tube and 2 mL of nitric acid HNO_3 (69%), 2 mL of perchloric acid HClO_4 (70%) and 3 mL of hydrogen peroxide, H_2O_2 was added using a pipette to each sample.

The spiked and unspiked sample was digested for 3 hours on digestion block, colorless aliquot was obtained and the digest was filtered to 50 mL volumetric flask, and then filled to the mark with distilled water [25]. The blank sample was digested in the same way like the sample.

2.4. Instruments and Apparatus

Different equipment's such as analytical balance (Crystal), digestion tube, Atomic Absorption spectroscopy (Agilent 240 Series AA), furnace (Karl Kolb), drying oven (Memmert), fume hood.

2.5. Reagents

Analytical and reagent grade chemicals used during the analysis of the sample, were; sulphuric acid, H₂SO₄ (98%, INDIAN), perchloric acid, HClO₄ (70%), hydrogen peroxide, H₂O₂ (30%), nitric acid, HNO₃ (69%), sodium hydroxide NaOH (INDIAN), boric acid, H₃BO₃ and methyl orange.

2.6. Validation of Method

Validation of an analytical procedure is the process by which it is established, by laboratory studies, that the performance characteristics of the procedure meet the requirements for the intended analytical applications. The power of detection of any atomic spectrometric method of analysis is conveniently expressed as the lower limit of detection (LOD) of the element of interest. The detection limits were obtained by the mean reagent blank signal (X_{blank}) plus three times the standard deviations of the mean reagent blank signal (S_{blank}). Analyses of ten blank samples for all metals of interest were performed and the standard deviation of the seven blank reagents was calculated

$$\text{LOD} = X_{\text{blank}} + 3S_{\text{blank}}$$

The lowest concentration level at which the measurement is quantitatively meaningful is called the limit of quantification. In this study, LOQ was obtained from analysis of ten reagent blanks which were digested in the same digestion procedure as the actual samples. It was calculated by multiplying standard deviation of the blank (S_{blank}) by ten plus the mean of the reagent blank (X_{blank}).

$$\text{LOQ} = X_{\text{blank}} + 10S_{\text{blank}}$$

2.7. Statistical Analysis

The mean, SD, LOD and LOQ was determined (calculated). The mineral, cyanide and toxic heavy metal concentration of each sample was analyzed by using AAS. The result calculated statistically by using SAS software (Version 9.0).

3. Results and Discussion

3.1. Limits Detection and Quantification

Limit of detection is the lowest concentration of analyte that can be detected confidently. Limit of quantification is lowest concentration level at which the measurement is quantitatively detected. In this study, LOQ was obtained from analysis of ten reagent blanks which were digested in the same digestion procedure as the actual samples.

Table 1. Instrumental detection limits, LOD and LOQ.

Element	ILD mg/L	LOD, mg/L	LOQ, mg/L
Ca	0.001	2.275	4.746
Mg	0.003	0.755	1.521
Cd	0.002	0.017	0.046
Cu	0.003	0.004	0.011
Cr	0.006	0.007	0.019
Fe	0.006	0.910	2.521
Mn	0.002	0.085	0.122

3.2. Recovery Studies

The recovery (%R) for the mineral and heavy metals was done as follows

$$\% R = ((C_{\text{ss}} - C_{\text{us}})/C_{\text{s}}) \times 100$$

The obtained recovery values are presented in Table 2.

Table 2. Recoveries of the studied metals.

Cassava variety	%R					
	Cr	Cu	Fe	Mn	Ca	Mg
SK	84	96	87	82	108	95
DD	96	97	87	82	100	101
HS	97	84	108	107	87	89
GMW	102	108	94	88	119	112
QL	103	102	106	100	104	94
SQ	116	109	81	94	84	82
MN	106	103	101	105	84	90
GMR	99	107	115	104	96	86
CH	120	99	83	97	107	115
KL	114	83	106	85	84	87

Table 3. Concentration (mg/kg) of minerals and toxic heavy metals.

Woreda	Parameters (mg/kg)						
	Ca	Mg	Cr	Cd	Cu	Fe	Mn
GMR	157.78 ± 3.32	204.82 ± 5.82	0.33±0.06	ND	0.16 ± 0.03	97.55 ± 1.48	0.93 ± 0.07
SK	327.13 ± 1.93	195.29 ± 8.70	0.92±0.08	ND	0.34 ± 0.03	81.16 ± 2.73	0.59±0.06
DD	436.03 ± 3.74	136.99 ± 5.23	0.87±0.12	ND	0.27 ± 0.04	91.90 ± 1.04	1.06 ± 0.07
SQ	153.51 ± 6.69	97.20 ± 4.41	0.43 ± 0.02	ND	0.24 ± 0.04	75.23 ± 4.89	0.78 ± 0.14
GMW	316.68 ± 4.96	92.62 ± 1.65	0.90 ± 0.06	ND	0.31 ± 0.04	84.61 ± 3.21	0.83±0.06
MN	373.88 ± 3.74	61.27 ± 1.46	0.25 ± 0.02	ND	0.09 ± 0.03	54.23 ± 1.45	0.26 ± 0.04
CH	161.94 ± 3.90	130.20 ± 3.90	0.48 ± 0.03	ND	0.21 ± 0.05	86.60 ± 3.47	0.70 ± 0.12
KL	157.18 ± 3.86	65.85 ± 4.13	0.39 ± 0.04	ND	0.20 ± 0.05	69.78 ± 4.00	0.53 ± 0.07

Woreda	Parameters (mg/kg)						
	Ca	Mg	Cr	Cd	Cu	Fe	Mn
QL	372.04 ± 7.32	207.94 ± 3.58	1.20 ± 0.11	ND	0.31 ± 0.02	127.03 ± 3.71	1.06 ± 0.07
HS	425.39 ± 6.08	102.34 ± 4.41	1.18 ± 0.09	ND	0.36 ± 0.07	75.26 ± 3.35	0.76 ± 0.14
LSD	12.65	7.99	0.09		0.05	8.28	0.04

Where; GMW- Gomma white, SK- Sokoru, DD- Dedo, SQ- Sakachekorsa, MN- Mana, CH- Chichu, KL- kello, QL- Qulle, HS-Hawassa

Where; LSD- Least Significance Difference; GMW- Gomma white, SK- Sokoru, DD- Dedo, SQ- Sakachekorsa, MN- Mana, CH- Chichu, KL- kello, QL- Qulle, HS-Hawassa 1. Values are mean ± SD of three individually analyzed triplicates, (n=3) ($p < 0.05$).

Heavy metals and mineral composition of foods is an immense interest because of its considerable essential or toxic nature. Uptake of heavy metals in staple food could be from soil, atmosphere or water. Unlike organic wastes, heavy metals are non-biodegradable and can stay for long period of time in living tissues, causing various diseases and disorders. Metals like cadmium and copper are cumulative poisons, which cause environmental hazards and are reported to be exceptionally toxic [26]. The evaluation of minerals in cassava is an important exercise from nutritional to the toxicological point of view. This is because some metals have long term effects on human health when accumulated in target organs. The higher Ca, Mg, Cr, Cu, Fe and Mn contents in the cassava varieties was comparable with the study of [26]. Metal deficiency syndrome like rickets and calcification of bones is caused by calcium deficiency. Magnesium deficiency in man is responsible for severe diarrhea, migranes, hypertension, cardiomyopathy, arteriosclerosis and stroke. According to Reddy and Love, copper is needed for growth, production of bones, teeth, hair, blood, nerves, skin, vitamins and hormones. In this study the mineral, essential and toxic heavy metal concentration were determined by atomic absorption spectroscopy in mg/L.

Calcium: From the results obtained for Ca in this study, the cassava varieties of Chichu and Kello sample are not significantly different ($p < 0.05$). But the results of Ca concentration in Qulle, Hawassa 1 and Kello were significantly different ($p < 0.05$) as obtained from the Table 3, HS has high concentration of Ca than any other varieties included in this study. Concentration of Ca in the selected varieties is in the order of $425.39 > 372.04 > 161.94 > 157.18$ mg/kg for HS, QL, CH and KL respectively. The concentration of calcium in cassava root collected from different Woredas were in the order of $436.03 > 373.88 > 327.13 > 316.68 > 157.78 > 153.51$ mg/kg for DD, MN, SK, GMW, GMR and SQ respectively. From the given values of Woreda sample, there was significance difference.

Magnesium: The levels of Magnesium for samples obtained from Woreda and the varieties of present study were 204.82-61.27 and 207.94-130.20 mg/kg respectively. The levels of Mg concentration in varieties in present study were significantly different ($p < 0.05$) as indicated in Table 3 above. Similarly, the results obtained from the Woreda data were also significantly different ($p < 0.05$) as calculated by SAS software (Version 9.0).

Chromium: Chromium is used in the leather tanning industry, the manufacturing of catalyst, pigment and paints, fungicides, the ceramics and glass industries. As shown in Table 3, the level of Cr concentration in Woreda sample varied

from 0.25-0.92 mg/kg was observed in MN and SK Woreda respectively. The levels of Cr concentration in present study were ranged from 0.39-1.20 mg/kg in the varieties of KL and QL respectively. The concentration of Cr was found at higher level in the released varieties (1.20 mg/kg) than the Woreda samples (0.92 mg/kg), the difference appeared could be because of many daily activities that are done in the center (JARC). The Cr concentration content of cassava root samples greatly varied among the different Woreda's in the study area.

Cadmium: Cadmium occurs naturally in Zn, Pb, Cu and other ores which act as source to ground and surface waters. In this study Cd was not detected, because it was below the detection limit of the instrument.

Copper: High concentration of Cu causes metal fumes fever, hair and skin discolorations, dermatitis, respiratory tract diseases, and some other fatal diseases in human beings. The level of copper concentration in Woreda's was ranged from 0.09-0.34 mg/kg in MN and SK Woreda respectively. While the copper concentration in the released varieties varied from 0.20-0.36 mg/kg KL and HS variety's respectively. The Cu concentration is relatively high (0.36mg/kg) in the sample collected from JARC than the Woreda samples (0.34mg/kg), the variation could be due to the routine activities made daily in the center. As indicated in the Table 3 above, the mean values with the same column followed by the same letters are not significantly different ($p < 0.05$). The copper concentration from Woreda's result was higher than the concentration of copper from the varieties in this study. As reported by [27], the concentration of copper in the cassava root was 3.84 mg/kg, but in this study the maximum concentration of copper in cassava root from Woreda (0.34mg/kg) and the released varieties (0.36mg/kg) was lower than the reported value. Cu is essential element and is required for hemoglobin synthesis and in the catalysis of metabolic growth. The highest concentration of Cu determined in all the cassava root samples was 0.36 mg/Kg which is far below the 40 mg/Kg limit that has been set by WHO (WHO 1982) as limit of Cu in foods [28]. Statistically, there was significant differences in the concentration of Cu in cassava root which are grown in selected Woreda of Jimma Zone

Iron: Fe is essential in the body and its benefit is carrying oxygen to human blood cells. About two-thirds of the body iron is found in hemoglobin. The benefit of iron corresponds to proper growth of human body and maintaining robust health, also to produce red blood cells. But in very high amount, it causes vomiting, abdominal pain and liver enlargement. The distributions of Fe concentration in cassava root obtained from Woreda's sample ranged from 54.23-97.55mg/kg in MN and GMR respectively. While the concentrations of Fe in the

JARC varieties study ranged from 69.78-127.03mg/kg in the varieties of KL and QL respectively. According to [50], the availability of iron in cassava is (29.908 mg/kg), lower than the results found in this study. As showed in Table 3 above, the mean values of the iron concentration between the sampling site from Woreda's and varieties study were significantly different ($p < 0.05$). Fe is also essential metal for the body but excess intake may lead to colorectal cancer [29]. The concentration of Fe determined in cassava root was above the 15 mg/Kg limit set by World Health Organization as limit of Fe in Foods (WHO 1982). All the cassava root samples analyzed for iron were found to exceed acceptable limit at very high concentrations for samples from each location. The benefit of iron correspond to proper growth of human body and maintaining robust health also to produce red blood cells but in very high amount causes vomiting, abdominal pain and liver enlargement.

Manganese: The levels of Manganese element for samples obtained from Woreda and different varieties collected from JARC. In this study Mn ranged 0.26-1.06mg/kg in MN and DD Woreda's and 0.53-1.06 mg/kg in KL and QL variety's respectively. Results showed that the levels of this metal in cassava root found to be relatively similar when compared with values obtained from the Woreda's results. Similarly the results obtained from the Woreda data were also significantly different ($p < 0.05$) as calculated by SAS software. The prolonged consumption of unsafe concentrations of heavy metals through foodstuffs may lead to the chronic accumulation of heavy metals in the kidney and liver of humans causing disruption of numerous biochemical processes, leading to cardiovascular, nervous, kidney and bone diseases (WHO, 1992). The analysis of cassava root has revealed that the presence of poisonous metals such as chromium and manganese. Excessive intake of metals like iron could result in complications ranging from gastro-intestine irritation, vomiting to tissue damages and skin pigmentation while the excessive intake of manganese can cause diseases of brain and nervous system, muscular rigidity and slow, imprecise movement [30]. Metals and other elements can be naturally present in food or can enter food as a result of human activities such as industrial and agricultural processes. The metals of particular concern in relation to harmful effects on health are manganese, chromium and cadmium. The toxicity of these metals is in part due to the fact that they accumulate in biological tissues, a process known as bioaccumulation. This process of bioaccumulation of metals occurs in all living organisms as a result of exposure to metals in food and the environment. So the presence of these heavy metals in cassava root could be due to the absorbance of the metals through their root from the soil, water and agricultural activities that are done daily and human being can uptake these metals while consuming the plant.

4. Conclusion and Recommendations

4.1. Conclusion

Cassava root has a major potential as a substitute for other

types of flour or it can be used by mixing it with other flours. Its unique adaptivity to different ecological conditions gave it the most important famine crop reserve. Cassava flour has considerable values in terms of its proximate composition and mineral elements which are related to human health and food. From the selected cassava samples used in this study it is possible to conclude the following:

- a) The mean concentration of metals like iron and chromium were below WHO and consumers can consume it. These heavy metals sometimes are accumulated in the cassava through the soil.
- b) Cassava root contains some essential minerals for our body like Ca, Mg and Fe. The presence of Fe in low concentration plays a vital role in body.

4.2. Recommendations

Cassava roots are widely used for food security and it represents a basic diet of about 500 million people in the World. But in Ethiopia, till now there was no enough information regarding its mineral content and heavy metal level. Since Jimma agricultural research center has been performing research on the productivity of these varieties than the nutrient composition, it is advisable to concentrate on the quality beside the productivity of these varieties. Since this study was performed on the cassava root and the result was obtained without incorporating the soil result, it is better to analyze this plant by including the soil result to see its effect at the same time. In addition, as the government has given a great concern to this crop it is better to work further investigation on cassava to sustain food scarcity.

References

- [1] Burrell, M. M. Starch: the need for improved quality or quantity An overview. *Journal of experimental Botany* 2003, 218, 451-456.
- [2] Hahn, S. K.; Keyser, J. Cassava: a basic food of Africa. *Outlook on Agriculture* 1985, 4, 95-100.
- [3] Julie, A. M.; Christopher, R. D.; Sherry, A. T. Nutritional Value of Cassava for Use as a Staple Food and Recent Advances for Improvement. *Compressive reviews in food science and safety* 2009, 8, 181-194.
- [4] EL-Sharkawy, M. A. Nutritional Value of Cassava for Use as a Staple Food and Recent Advances for Improvement. 2003, 8, 181-194.
- [5] Montagnac, J. A.; Davis, C. R.; Tanumihardjo, S. A. Processing Techniques to Reduce Toxicity and Anti-nutrients of Cassava for use as a Staple Food. *Comprehensive Reviews. Food Science and Technology* 2009, 8, 17-27.
- [6] Bokanga, M. Cassava Fermentation and Industrialization of Cassava Food Production. *Proceedings of the Fourth Symposium, Int. Symposium for Trop. Root Crops African Bulletin* 1992, 197-201.
- [7] Amsalu, A. Caring for the Land Best Practices in Soil and Water conservation in Beressa Watershed, Highland of Ethiopia. *Trop. Resource Management* 2006, 76.

- [8] Teshome, S.; Demel, T.; Sebsebe, D. Ecological study of the vegetation in GamoGofa zone, southern Ethiopia. *Journal of Tropical Ecology* 2004, 45, 209-221.
- [9] Anna, B.; Roslyn, G.; Julie, C.; 2, Anabela, Z.; Timothy, C. Cassava: The Drought, War and Famine Crop in a Changing World. *Sustainability*, 2010, 2, 3572-3607.
- [10] Nassar, N. M. A.; Ortiz, R. Cassava improvement: Challenges and impacts. *Journal Agricultural Science* 2007, 145, 163-171.
- [11] Pearce, F. Cassava comeback. *New Scientist* 2007, 38-39.
- [12] Lebot, V. Tropical Root and Tuber Crops: Cassava, Sweet Potato, Yams and Aroids; CABI: Wallingford, UK, 2009.
- [13] Tewodros Mulualem and YaredDagne. Nature of gene action in elite cassava genotypes (*Manihotesculenta* Crantz) in South Ethiopia. *Sky Journal of Agricultural Research* 2014, 3, 67-73.
- [14] Hillocks R. J.; Thresh, J. M.; Tomas, J.; Botao, M.; Macia, R.; Zavier, R. Cassava brown streak disease in northern Mozambique. *International journal of pest management* 2001, 48, 179-182.
- [15] Yeoh, H. H.; Tatsuma, T.; Oyama, N. Monitoring the cyanogenic potential of cassava: the trend towards biosensor development. *Trends Analytical Chemistry* 1998, 17, 234-240.
- [16] Fauquet, C.; Fargette, D. African Cassava Mosaic Virus: Etiology, Epidemiology, and Control". *Plant Disease* 1990, 74, 404-411.
- [17] Food and Agriculture Organization of the United Nations (95): 111-125. *FAO animal production and health paper. Rome, Italy: Retrieved* 2010, 08-13.
- [18] Okigbo, B. N. Nutritional implications of projects giving high priority to the production of staples of low nutritive quality. In the case for cassava (*Manihotesculenta*, Crantz) in the humid tropics of West Africa. *Food Nut. Bull.* 1980, 2, 1-10.
- [19] Charles, AL.; Sriroth, K.; Huang, T. C. Proximate composition, mineral contents, hydrogen cyanide and phytic acid of 5 cassava genotypes. *Food Chemistry* 2005, 92, 615-616.
- [20] Welch, R. M.; Graham, R. D. Breeding for micronutrients in staple foods crops from a human nutrition perspective. *Journal Experimental Botany* 2004, 55, 353-364.
- [21] Enidiok, S. E.; Attah, L. E.; Otuechere, C. A. Evaluation of Moisture, Total Cyanide and Fiber Contents of Garri Produced from Cassava (*Manihotutilissima*) Varieties Obtained from Awassa in Southern Ethiopia. *Pakistan Journal of Nutrition* 2008, 7, 625-629.
- [22] Bradbury, J. H.; Holloway, W. D. Cassava, *M. esculenta*. Chemistry of tropical root crops: significance for nutrition and agriculture in the pacific. Australian Centre for Int. Agr. Research, monograph no. 6, Canberra, Australia 1988, 76-104.
- [23] Gil, J. L.; Buitrago, A. J. A. La yugaen la alimentacion animal. In: Osopina B, Ceballos H, (Eds). La yugaen el tercer milenio: sistemas modernos de produccion, procesamiento, utilizacion y comercializacion. *Cali, Colombia* 2002, 527-569.
- [24] Amsalu Nebiyu, Esubalew Getachew. Soaking and Drying of Cassava Roots Reduced Cyanogenic Potential of Three Cassava Varieties at Jimma, Southwest Ethiopia. *World Journal of Agricultural Sciences* 2011, 4, 439-443.
- [25] Novozamsky, I. V. J. G.; Houba, J. J.; van der Lee. A convenient method of digestion for elemental analysis of soil and plant material. *Comm. Soil Science and Plant Analysis* 1993, 24, 2595-2605.
- [26] J. Apau, A.; Acheampong, J. A.; Appiah, E.; Ansong. Levels and Health Risk Assessment of Heavy Metals in Tubers from Markets in the Kumasi Metropolis, Ghana. *International Journal of Science and Technology* 2014, 3, 534-539.
- [27] Obueh, H. O.; Kolawole, S. E. Comparative Study on the Nutritional and Anti-Nutritional Compositions of Sweet and Bitter Cassava Varieties for Garri Production. *Journal of Nutrition and Health Sciences* 2016, 3, 3-7.
- [28] Hayford, O.; Charles, T.; Paa, T. A.; Jonathan, A. Trace metal and aflatoxin concentrations in some processed cereal and root and tuber flour *International Journal of Food Contamination* 2016, 3, 2-6.
- [29] Senesse, P, Meance S, Cottet V, Faivre J, Boutron-Ruault MC. High dietary iron and copper and risk of colorectal cancer: a case control study in Burgundy. *France. Nutrition Cancer* 2004, 49, 66-71.
- [30] A. A. Audu, M. Waziri, T. T. Olasinde. Proximate Analysis and Levels Of Some Heavy Metals In Cassava Flour Processed By Roadside Drying Along Abuja-Lokoja Highway, Nigeria. *Indian Journal of Fundamental and Applied Life Sciences* 2012, 2, 55-58.