An Investigation on Possible Leachability of Impurities from the Three-Legged Aluminum Pot Material from Rural Foundries as Cassava Leaves are Being Cooked: Feasibility and Kinetics Studies

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***Abstract*—**Three legged aluminium pots are widely used, sold and produced in the Southern African rural communities. These pots are greensand cast from molten aluminium scraps of diverse origins. In some pots, there amounts of harmful impurities are usually found and since these pots are used for cooking, these impurities find their way into the food that is cooked. When these pots are used for cooking, due to cooking heat, the amount of impurities inside them may find its way into the food that is cooked using these aluminium pots. Cassava leaves and roots are consumed in Many African countries like DRC, Mozambique, Zimbabwe, Nigeria, Cameroon, etc. Many households in the Southern African rural areas employ the artisanal casted three-legged aluminum pots. Cassava leaves have cyanogenic glycosides which form cyanide as the leaves are pounded or boiled. As these pots are manufactured from aluminum scrap without any controlled chemistry nor specific chemical composition, the presence of heavy metals lie Pb my pose some health threat to the user of the pots if due to the heat such an impurity diffuses away from the pot material. This papers discusses the empirical leaching feasibility of the aluminum material into the food in a controlled environment.. The cyanide present in cassava leaves was the lixiviant that triggered aluminum to diffuse into the solution. Aluminum was detected in the cassava leaves laboratory Bunsen boiled in the pot found. The value of aluminum 4325000mg attained was higher than the value permitted by WHO 0-95mg . It was noticed silicon and iron exceeded the amount that is permitted to be in food by the WHO. The concentration of cyanide in the solution was attained using UV-Vis and the results compared to the WHO threshold. The value of cyanide that the student got was higher than the one that is permitted by WHO which is 200mg. Temperature improves the leaching kinetics overtime. Aluminum migrate into cassava leaves and solution in the presence of hydrogen cyanide at a lower concentration. .

***Keywords*—**Cassava leaves, aluminum materials, rural foundry.

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I. Introduction and background

Artisanal pots, simply known as three legged pots are widely used in local communities due to their light weight, and low cost. These pots can be made of recycled car engine and bike parts, soft drink cans, cast aluminium, old rolled aluminium, aluminium turnings, clean aluminium, iron aluminium, and construction materials. The reason behind this recycling being aluminium is easy to recycle since it is a light nonferrous metal with a relatively lower melting temperature of 660 ºC and does not degrade during the recycling process.

In some instances, the raw material used to cast these pots may contain heavy metals as impurities such as lead which as a results of the cooking and high temperature. As a result, during the cooking process as the pots go through heating, this might cause the lethal impurities to diffuse through the pot material, get exposed and migrate into the food. This becomes a health issue since these impurities, for example, lead are hazardous to human. Cassava leaves have cyanide which is acidic and poisonous. Cyanogenic glucosides found in cassava leaves are major drawbacks that might limit its consumption by humans. When aluminum pot is used several times, it wears out through mechanical and erosive leaching. As noticed by [1] when acidic food, lemon juice like tomato, or reactive reagents like table salt or different spices is left raw but in contact with the aluminum material the aluminium materials is affected. When the surface of aluminium pot is in in contact with acidic food it will dissolve and make aluminum to diffuse into food "[3] . While in the literature the reactivity of the alumnium metal has been studied even the possible food contamination [4] , the leaching process has not systematically studied.

Cassava leaves are consumed in at least 60% of countries in the world [5]. According to South African languages cassava leaves in IsiZulu is called unjumbulu or amaqabunga omdumbulu, in Xitsonga are called nstumbulu, in TshiVenda are called mutumbulu and in Sesotho are called makhasi a cassava

Cassava leaves are a crop that can supply food security to places or countries that have low rain fall and poor or marginal soil. Cassava leaves is the world's fourth important crop and is eaten by over billion people [6]. The plantation of cassava leaves does not require excessive resources in terms of labor, money and time. It is important to know how cassava leaves are processed before consumption because the leaves contain cyanogenic glucosides. Many methods have been developed to process cassava leaves and not every method is I00% efficient. Some methods were used to remove the toxic cyanide but end up destroying the food nutrients.

II. MATERIALS AND METHODS

A size 3 three-legged aluminum pot was used in this work. The chemical analysis on the pot materials was done using a Spectro photograph Bruker Q4 TASMAN machines

A 20 mm x 20 mm piece was resin mounted before being subjected to the XRF . The micrograph on the material was collected using the scanning electro microscope (SEM) . A 110 ^{0}C over night dried cassava leave was studied with SEM. A second piece was studied with FTIR. Cassava leaves were pounded using a ceramjc conical mortar and ceramic pestle. The pounded cassava leaves were placed in a conical flask that have tap water. The cassava leaves were left inside a conical flask with tap water overnight for cyanide in the leaves to go into the solution. The next day morning color changed and the solution was dark brown. The solution was filtered and taken to UV-Vis spectrophotometer for analysis. Another set of cassava leaves was pounded before being boiled and 4 solutions were collected after each 30 minutes and taken to UV-Vis spectrophotometer for analysis. 70g of pounded cassava leaves were placed inside the artisanal cast aluminum pot. 1600 ml of tap water was added to the pot. Bunsen burner was used to cook cassava leaves. Cassava leaves were boiled for 2 hours. Solution and pounded cassava leaves were collected after 15 minutes. In a period of 2 hours the solution was collected 8 times.

(a). Cassava leaves

(b) three legged aluminum pots

(c)Pounding of the leaves

(d) Bunsen cooking of the pounded cassava leaves

Fig. 1. (a), (b), (c) and (d) Cassava leaves, pot, pounding and cooking of cassava leaves.

III. FINDINGS AND DISCUSSION

Two different pots were used to do spectrograph analysis. Even if the pots were manufactured from the same place they do no have the same concentrations. The chemical analysis assisted to identify or know the concentration of different elements present in the artisanal pot. Pot A have high silicon concentration compared to pot B. Pot B only have high concentration when it comes to titanium and zinc. When studying the feasibility and kinetics of leaching, silicon and iron also went dissolved and must be taken into consideration.. Silicon required for a better fluidity during the casting, was also found in the material studied.

Table 1. Chemical composition of the studied material.

Sipho's pot	**Si%**	Fe%	Mn %	Mg %	Cr%	**Ni %**	Zn%	Ti%	Ag %	Cu%
Test I	5.01	0.99	0.18	0.07	0.06	0.21	3.86	0.04	0.03	2.20
Test 2	7.02	1.51	0.23	0.17	0.09	0.30	4.54	0.05	0.03	2.71
Test 3	7.914	>2.64	0.28	0.07	0.09	0.32	3.94	0.02	0.01	1.85
Average	6.65	1.71	0.23	0.1	0.08	0.28	4.11	0.04	0.02	2.25

Tobias pot										
Test I	4.39	0.51	0.13	0.5	0.04	0.14	4.10	0.04	0.02	1.51
Test 2	6.51	0.73	0.19	0.08	0.05	0.22	5.97	0.05	0.02	2.12
Average	5.45	0.62	0.16	0.06	0.04	0.18	5.03	0.04	0.02	1.83
TotaJ average of pot A and **B**	6.05	1.17	0.20	0.08	0.06	0.23	4.57	0.04	0.02	2.04

The EDS data of the cassava leaves showed presence of potassium is high in percentage, calcium and iron. Carbon was also seen but this could be due to the coating used for the SEM testing.

The ICP testing of the solution of from the cassava leaves cooking showed presence of Al, Si and Fe in the solution..

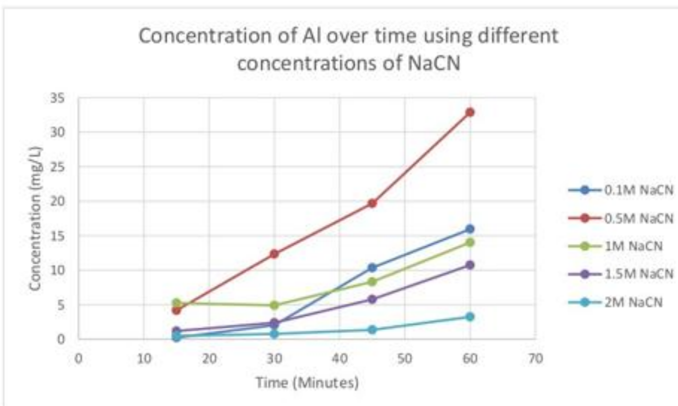

Fig 2. Dissolution of aluminum as impacted by different concentrations of the aqueous NaCN.

As per the Fig 2 the loner the contact time, the higher dissolution amount was observed.

The Si dissolution was also observed. It i increased with the cyanide concentration. It was also noticed that co dissolution of SI and Fe occurred. Fig. 3 shows Fe dissolution at different concentration. The Higher the concentration , the more Fe went into solution.

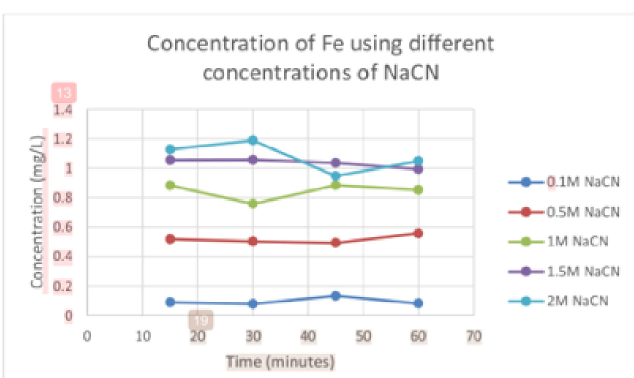

Fig 3. Fe dissolution with increase on cyanide solution concentration.

Optimization of the co-dissolution was studied using the response surface methodology, (RSM) with central composite design (CCD)

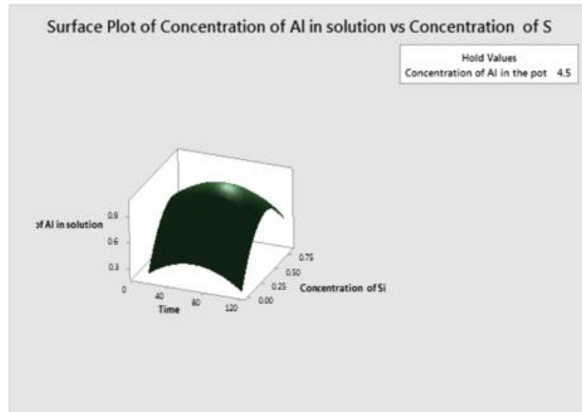

Fig. 4. Co dissolution of Fe and Si was modelled using the response surface methodology.

IV. Conclusion

Cooking cassava leaves in aluminum pots produced by greensand casting of aluminium scrap showed a co dissolution of the aluminum from the material as well as Si and Fe due to the presence of cyanide in the leaves. This was exacerbated by the cooking heat. o anl as well as

Contribution of authors

Antoine F. Mulaba - Bafubiandi initiated, conceptualized and supervised the research project. Sipho Bob Ngema studied the possible dissolution during cassava leaves coouking under the suervison of Antoine F. Mulaba-Bafubiand and Kulani Mageza..

Declaration of interest

The authors have no financial nor personal interest in the content of the work here presented.

References

[1] Bergkvist, C., Klipper, M., Hamadani, M. and Tofail, F. (2010). Assesment of early- life lead exposure in rural Bangladesh. Environ Res; I 10:7 I8-24 https://doi.org/10.1016/j.envres.2010.07.004

[2] Verissimo, M. and Oliveira, J. (2006). Leaching of Aluminum from cookjng pans and food containers. Sensors and Actuators B, I I8 (1-2) (2006), pp. 192-197. https://doi.org/10.1016/j.snb.2006.04.061

[3] Joshi, S. R. B., Toma, N. and Medora. B. (2003). Detection of Aluminum in sauces packaged in Aluminum pouches. Food Chemistry, 83 (2003), pp. 383-386. https://doi.org/10.1016/S0308-8146(03)00099-2

Available at: https://www.sciencedirect.com/science/article/abs/pii/S03088 I 4603000992

[4] Neelam B. M. and Kaladhar, M. (2000). Risk of increased Aluminum burden in the Indian population: contribution from Aluminum cookware. Food Chemistry, 70 (2000), pp. 57-61. https://doi.org/10.1016/S0308-8146(00)00068-6 Available at: https://www.scopus.com/record/display.uri?eid=2-s2.0-0034002l 3&origin=inward&txGid=637cc27b8f2df46ce7fed8276a5dle83

[5] Ranau, R., Oehlensclager, J. and Steinhart, H. (200 I). Aluminum levels of fish fillet baked and grilled in Alumjnum foil. Food Chemistry, 73 (200 I), pp. 1-6. https://doi.org/10.1016/S0308-8146(00)00318-6 Available at: https://www.sciencedirect.com/science/article/abs/pii/S03088l 4600003 l 86