

# Chemical Analyses of *Parkia biglobosa* Fruit Husk Extract and Lateritic Soil Used in Ethnobotanical Preparation of Mud Wall Plaster in Some West African Countries

Samson Abah Abagale<sup>1, \*</sup>, Sylvester Kwadwo Twumasi<sup>2</sup>, Johannes Awudza<sup>3</sup>

<sup>1</sup>Department of Applied Chemistry and Biochemistry, CK Tadam University of Technology and Applied Sciences, Navrongo, Ghana

<sup>2</sup>Faculty of Public Health and Allied Sciences, Catholic University College of Ghana, Fiapre, Sunyani, Ghana

<sup>3</sup>Chemistry Department, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana

## Email address

sabagale@uds.edu.gh (S. A. Abagale)

\*Corresponding author

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**Abstract:** Mud wall plaster ethnobotanically produced from *Parkia biglobosa* husk extract and laterite soil in some rural communities of West Africa imparts resilience against adverse weather conditions to mud walls. Chemical analyses of the husk extract and soil was therefore carried out to determine the presence and levels of relevant elements that may be contributing to the chemical constitution of the plaster. Atomic absorption, Flame photometry, and X-ray analyses were carried out on the samples. In the soil, there were larger quantities of potassium (559.02±4.11 mg/Kg), magnesium (230.11±2.04 mg/Kg), iron (410.72±1.23 mg/Kg), calcium (318.04±16.97 mg/Kg) and Silicon (1409.83±0.51 mg/Kg). The husk also contained larger amounts of iron (107.24±2.99 mg/Kg), potassium (962.83±0.00 mg/Kg) and magnesium (245.02±0.99 mg/Kg). Sodium, nickel, lead and zinc were also present in the soil and husk at relatively lower levels. X-ray diffraction indicated presence of Silica in the soil. Clear parts of the diffraction compared well with standard diffraction data of pure silica. The X-ray mineral profile of the soil also agrees well with its mineralogy determined by Atomic Absorption.

**Keywords:** *Parkia biglobosa*, Husk, Laterite, Mud Wall, Plaster, Chemical Analysis

## 1. Introduction

Brick houses are more aesthetically attractive and provide a better satisfactory indoor climate [1]. According to the Ghana housing census 2002 report, brick houses constitute about 15% of total stock of houses in the country [2]. Also, well-constructed earth wall homes, according to international standards, have no damage in tremors, survive and are repairable in medium quakes and are damaged beyond repair but do not pose a threat to life in large quakes [3]. But extensive wetness, by volume over time, may eventually lead to the collapse of these building [4-5]. Therefore, calls have been made to take interest in reducing the rate of deterioration of these buildings so as to make them more durable and safe for habitation [6].

There are various building materials including cement,

cement based pozzolana and earth or mud. The chemical makeup of these building materials include minerals and tiny crystalline hydroxyl aluminium silicates from sources such as kaolinite and quartz, chlorite, goethite and hematite [7], while others are oxides of calcium and magnesium aluminates, ferrates, silicates and clay minerals. The ability of materials to be used for building depends mainly on their chemical make-up.

The use of earth or mud in construction is well-established as energy efficient. Earth is used to construct walls, floors, roofs and even furniture, fireplaces and ovens. These buildings are easier and cheaper to build though less durable [1, 5] compared to buildings from sand, stone and concrete. In some cultures, boiled linseed oil and turpentine brushed on several coats are used to provide a final finish [8]. Bitumen (or asphalt) emulsion and cutback have also been used to

improve impermeability of the plaster soil, and keep it from losing its strength when wet [9-10]. Many other natural material variables that have been used include psyllium husk extract, cactus juice, natural fibres (e.g., grass, straw, sisal, sawdust), sodium silicate (water-glass), resins, gypsum and cow dung. Finishes enhance durability of mud walls making them non-erodible. Laterite soils generally give very good results. The stability of wall finishes against environmental factors such as rain enables them to provide protection to the walls [11]. The stabilizing effect of finishes is reported to depend on the formation of cementitious compounds such as calcium silicates [6].

Ethnobotanically, mud wall plaster made from a mixture of laterite soil and aqueous parkia husk extract has been used in parts of West Africa to provide protection to mud or earth buildings [11-13]. According to [11] and [13], decoctions of the fruit husk of *Parkia biglobosa* extracted by boiling are used to impart water resiliency to floors, walls, and ceramic pots. The extract produced from steeping and boiling the husks is mixed with soil to plaster walls of mud houses. It is also used to paint tamped earthen floors and has been reported to act by binding the soil to render the surface impervious to water [11]. The extract has also been mixed with other components to make natural paintings or murals to decorate mud walls [12-14]. This product is commonly used by the people because it is cheap, available and also looks good. It should also be encouraged because this style of building is environmentally friendly [15].

Available local building materials are abundant but may not be durable enough to support sustainability of their architecture in terms of resistance to challenging factors [6]. Therefore studies of traditional building materials, architecture and indigenous technology such as the current study should contribute to improvement of the buildings [16]. In our earlier work [14] the aqueous *Parkia* husk extract was characterized. In the current study some chemical components of the extract and laterite soil which are usually exclusively mixed to produce the mud plaster have been characterized.

In the current study, absorption and flame photometric methods as well as X-ray diffraction procedures have been used to assess the levels of some elements in the soil and extract. Further work is expected to analyse the plaster in order to determine the chemical compounds that contribute to make the *Parkia* based mud wall plaster resilient against adverse conditions.

## 2. Materials

Materials used in this study were *Parkia biglobosa* fruit husk, laterite soil, reagents/chemicals, and distilled water.

Dried *Parkia biglobosa* fruit husk were purchased from the Navrongo central market in the Kassena-Nankana District of Ghana and dry laterite soil was also obtained from Balobia, a suburb also in the same district. The samples were brought to the laboratory for further processing.

Authentication of the soil was done at the Savannah

Agricultural Research Institute in Tamale, Ghana and the husk was identified and authenticated at the Horticulture Department of Kwame Nkrumah University of Science and Technology (KNUST) with confirmation at the KNUST Botanical Gardens.

All reagents/chemicals used were of analytical reagent grade from local agents of BDH Laboratory supplies Ltd, Poole, England. Distilled water was used for the preparation of all solutions.

## 3. Methods

### 3.1. Sample Preparation

To eliminate traces of water, the husk were further air-dried for seven days in the laboratory to a constant weight. To obtain a coarsely powdered sample, the moisture free husks were then pulverized using a mill at the Faculty of Agriculture, Kwame Nkrumah University Science and Technology.

The coarsely powdered husk was Soxhlet extracted using distilled water. Extraction was done repeatedly until the solvent in the column of the Soxhlet became colorless. The crude extract was concentrated under reduced pressure using the Büchi RotaVapor, R-114 (by Kontron Instruments), collected into clean empty beakers and dried in the oven to constant weight at 105°C.

The collected laterite soil was also air-dried for three days in the laboratory and sieved using a 76 micron diameter pore-space sieve to remove lumps, stones and other unwanted materials. The fine-grained soil obtained was ground further using porcelain mortar and pestle and used in chemical analyses.

### 3.2. Metal Analyses

Metal analyses were done by Absorption Spectrometry, Flame ionization and X-ray diffraction approaches.

#### 3.2.1. Absorption and Photometric Analyses

Metal analyses of the soil sample and dry aqueous husk-extract was done on acid digested samples using the UNICAM model 929 Atomic Absorption Spectrometer (AAS) with a slight modification of the procedure of Ababio et al. [17]. Spectronic 21, Multron Roy model Flame Photometer was used in this analysis.

Iron, zinc, silicon, lead and nickel were analysed using AAS while calcium, magnesium, sodium and potassium were analysed by Flame Photometry. Each metal was determined in triplicate and the mean concentration calculated from any two closely related values.

#### 3.2.2. Soil Mineralogy

Powder X-ray diffraction was used to further characterize the soil. X-ray analyses were conducted on the sieved and mortar-ground soil sample to confirm the minerals identified through absorption and photometric analyses [17].

### 4. Results

#### 4.1. Metal Constituents of the Samples

The calculated mean levels of some metals determined in

the soil sample and in the dried crude extract of the husk by spectrometry and photometry are presented with the respective electronegativities of the metals from literature [18].

Table 1. Mean levels of some metals in the soil and powdered husk.

Element	Electronegativity Index (X <sub>m</sub> )*	Mean Amount ± SD (mg/Kg)	
		Soil	Husk
Na	0.93	98.32±0.81	77.71±0.11
K	0.82	559.02±4.11	962.83±0.00
Ca	1.00	318.04±16.97	531.72±1.02
Mg	1.31	230.11±2.04	245.02±0.99
Fe	1.83	410.72±1.23	107.24±3.99
Si	1.90	1409.83±0.51	1.51±0.49
Ni	1.91	105.41±3.91	124.95±0.00
Pb	2.33	11.92±1.48	111.85±0.53
Zn	1.65	57.03±1.02	55.49±5.03

\*[18]

#### 4.2. X-ray Diffraction

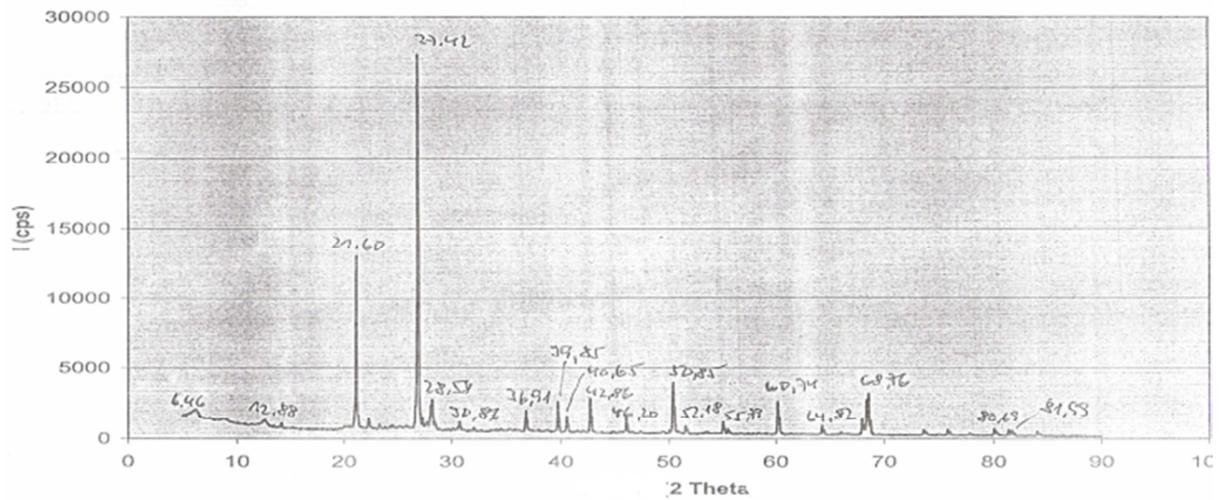


Figure 1. X-ray diffraction patterns of the laterite soil.

Table 2. X-ray diffraction of the laterite soil.

2 Theta (2θ)	Theta (θ)	Intensity (I)	Relative intensity (I/I <sub>0</sub> )	d-spacing
6.46	3.23	800	2.963	13.684
12.88	6.44	500	1.852	6.8739
21.6	10.8	13000	48.15	4.1146
27.42	13.71	27000	100	4.2531
28.58	14.29	2000	7.407	3.1236
30.86	15.43	200	0.741	2.8978
36.91	18.46	1800	6.667	2.4356
39.85	19.93	1300	4.815	2.2624
40.65	20.33	1500	5.556	2.2197
42.86	21.43	2400	8.889	2.1102
46.2	23.1	1500	5.556	1.9651
50.85	25.43	3800	14.07	1.7958
52.18	26.09	200	0.741	1.7531
55.79	27.9	750	2.778	1.648
60.74	30.37	2400	8.889	1.525
64.82	32.41	220	0.815	1.4385
68.76	34.38	2900	10.74	1.3654
80.69	40.35	300	1.111	1.1909
81.99	41	300	1.111	1.1753

Table 3. Comparison of d-spacing and relative intensities.

d-spacing		Relative intensity (I/I <sub>0</sub> )	
Sample	Pure silica*	Sample	Pure Silica*
4.1146	3.343	48.15	100
4.2531	4.55	100	20
2.4356	2.457	6.667	10
2.2197	2.281	5.556	10
2.1102	2.128	8.889	10
1.7958	1.818	14.07	10
1.525	1.541	8.889	10
1.3654	1.375	10.74	10

\*(A. S. T. M., 1996)

### 5. Discussion

Generally, only about 5% of the diffraction pattern of the soil (Figure 1) could be identified clearly. The amorphous component of the sample could not be identified. Also, there were many peaks with very small intensities that could not be assigned. The d spacing deduced from the x-ray diffraction

(Table 3) compared well with the standard diffraction data of pure silica (Table 3) [19] though not all the relative intensities were exact.

In the spectroscopic and flame analyses, the soil was found to have higher levels of Potassium, Magnesium, Iron, Calcium and Silicon ( $230.11 \pm 2.04$ - $1409.83 \pm 0.51$  range) as well as smaller amounts of Sodium, Nickel, Lead and Zinc ( $11.92 \pm 1.48$ - $105.41 \pm 3.91$  range). The husk generally had higher amounts of most of the analysed metals than the soil. Potassium, Calcium, Magnesium, Nickel, and Lead were found in higher quantities ( $111.85 \pm 0.53$ - $962.83 \pm 0.00$  range) in the husk than in the soil. Iron, Potassium, Calcium and Magnesium were relatively in higher quantities ( $107.24 \pm 3.99$ - $962.83 \pm 0.00$  range) in the husks (Table 1). Metals from the soil and husk could interact with organic components such as alkaloids, flavonoids and saponins that have been reported previously [14] in *Parkia* husk extract. These interactions could have potential for and form complexes with various metals of the soil.

The differences between the relative intensities of the soil and pure silica (Table 3) could be attributed to interference from signal overlaps with signals of other crystals present in the soil. However, the peak with the highest count per second (cps) (Figure 1) in the soil was identified as the peak for silica. The mineral profile exhibited by the soil in X-ray patterns (Figure 1 and Table 3) agree well with the mineralogy of the soil determined by AAS and flame (Table 1), as both revealed high concentration of silica based components. Mineralogy is a known key factor controlling physical and chemical properties [20].

Silica which is indicated herein is a known component of building materials [6-7]. Strong binding and reduced water penetration into bricks, concrete and buildings have can be enhanced by impregnation with silicon based complexes [21]. Additionally, dimethyl and phenylmethylpolysiloxanes have been used as paint additives to improve water repellent properties [22]. Stability of the *Parkia* husk based mud wall plaster to water could therefore be attributed to presence of water insoluble complexes formed between the metals found in laterite and organic compounds emanating from secondary metabolites in the *Parkia* husk.

The presence of organic moieties and metals together may result in formation of complexes [23]. Electronegative ligands such as flavonoids and other unsaturated C-C groups in the organic natural product could offer  $\pi$  electrons to the transition metal electron sinks leading to bond formation of binders [21]. Most alkoxy infrared bands shift to higher values when the organic component increases in size.

From literature [14], the husk contains a number of secondary metabolites. The carboxylic and phenolic functional groups of tannins are able to form complexes and also chelate with metals. The tannins could form stable water-insoluble co-polymers with alkaloids and proteins. Tannin that hydrolyse into tannic acid are able to combine with iron and other such metals (Table 1) largely present in the soil to form iron-tannate or other complexes. Electronegative ligands and unsaturated C-C groups could

offer  $\pi$  electrons to the transition metal electron sinks leading to bond formation. Thus, conjugated aromatic systems in flavonoids could provide electrons into metal sinks such as contained in zinc (and cobalt) present in the laterite soil (Table 1). Terpenes would also easily bind to metal sites in the form of resin. This can be facilitated by saponins which increase and accelerate calcium and silicon complexing processes. Similar reactions have been cited in paint dryers to confer stability in coatings [24]

Bond polarity ( $C-M^+$ ) increases as the metal electronegativity index ( $X_m$ ) decreases. The trend of  $X_m$  in the metals of the soil is  $Ni (1.91) > Si (1.90) > Zn (1.65) > Mg (1.31)$  (Table 1). Therefore organometallic compounds of Ni, Si, Zn, and Mg respectively have increasing polarity. Lower polarities support the stability of mud wall plaster to rain because of the presence of water insoluble complexes of the metals.

Ca, Mg, Na and K found in both husk and soil (Table 1) have various useful properties for bonding and bond stability. The very electronegative elements easily form stable bonds with carbon compounds that are generally electropositive.  $Mg^{2+}$  has high affinity for nitrogen bases and some dye stuffs due to its high charge density (Table 1) and thus ability to polarize.  $Mg^{2+}$  is bound preferentially (in the series  $Mg^{2+} > Ca^{2+} > Na^+ > K^+$ ) to nitrogen bases such as alkaloids. Also,  $Ca^{2+}$  preferentially binds to multidentate anions and strong acid anions;  $K^+$  binds to large centres composed of neutral donors alone or neutral donors with a singly-charged strong-acid donor;  $Na^+$  to smaller centres of neutral donors and/or neutral donors plus one singly-charged donor which may be of a weak acid [26-28].

The large availability of silicon in the soil could result in formation of organosilanes and other such coordinated compounds. Silicon considered as a metal with dampened traits forms bonds with carbon that are less polar than those formed by Groups I-III metals. Although silicon has no available 3s-or 3p-orbitals and hence organosilanes form no coordination compounds, highly electronegative ligands permit the attainment of higher coordination numbers, apparently by  $3sp^3d^2$  hybridization.

The stability conferred on the carbon-metal (R-M) bond in organometallic compounds depends on unsaturation of R and its location. Carbon-carbon unsaturation at  $\alpha$ ,  $\beta$ -and  $\beta$ ,  $\gamma$  with respect to carbon-metal (C-M) linkage can cause an increase or decrease of chemical stability in R-M depending on the nature of the metal. Many C-M bonds are highly polar ( $C-M^+$ ) and so the mutual alignment of such polar linkages in individual metal alkyl units might be pictured as the driving force. For  $\alpha$ ,  $\beta$ -unsaturation the stability of the potential carbanion in R-M parallels the assumed hybridization of the  $\alpha$ -carbon atom [29]. Donation of  $\pi$ -electrons by unsaturated groups attached to a given metal could then result in  $p_\pi-p_\pi$  or  $d_\pi-p_\pi$  bonding, depending on availability and energy of metal orbitals. Higher valence states of Fe, Ni, Zn and Pb found in the soil are able to participate in  $p_\pi-p_\pi$  bonding. Also,  $d_\pi-p_\pi$  bonding in transition metal alkyls and aryls (such as alkoxides of Mn, Fe, Co and Zn) with unsaturated groups could also form stable C-M bonds.

## 6. Conclusion

The soil was found to contain larger quantities of potassium (556.351 mg/Kg), magnesium (230.054 mg/Kg), iron (419.499 mg/Kg), calcium (336.315 mg/Kg) and Silicon (1400.564 mg/Kg), while sodium, nickel, lead and zinc were in relatively smaller amounts. The husk also contained larger amounts of iron (144.248 mg/Kg), potassium (962.832 mg/Kg) and magnesium (246.018 mg/Kg).

From the spectrophotometric and flame analyses silicon was identified as the largest component in the laterite soil and this was corroborated by the results of the X-ray diffraction in which silica was the major component. Identified metals in the soil were largely made of silicon and this provides opportunity for possible interactions and formation of organometallic compounds/complexes through  $3sp^3d^2$  hybridization to contribute to water resistant properties.

## 7. Recommendations

A formulated plaster of *Parkia biglobosa* fruit husk extract and laterite soil should be analysed. Also, samples from field applications of aqueous extract of *Parkia biglobosa* fruit husk on existing mud buildings should be analysed.

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