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The biomedical significance of the phytochemical, proximate and mineral compositions of the leaf, stem bark and root of *Jatropha curcas*

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ABSTRACT

Objective: To analyse the phytochemical contents of leaf, stem bark and root of *Jatropha curcas* (*J. curcas*) in four solvent extracts and their proximate and mineral compositions.

Methods: Standard analytical procedures were used for the determination of phytochemicals, proximate and mineral compositions of the leaf, stem bark and root extracts of *J. curcas*.

Results: Results of the analysis showed the presence of polyphenols, flavonoids, alkaloids, cardiac glycosides, coumarins, saponins, terpenoids, steroids, triterpenoid saponins, carotenoids, phlobatannins and tannins in the leaf, stem bark and root of all the solvent extracts. Flavonoids were present in the highest amount in the ethyl acetate extracts of the leaf (7.35% ± 0.02%), stem bark (4.12% ± 0.01%) and root (3.35% ± 0.02%) followed by polyphenols in the methanol extracts of leaf (4.62% ± 0.02%), stem bark (2.77% ± 0.05%) and root (2.49% ± 0.02%). Poly-acetylated compounds were absent in all the solvent extracts of the leaf, stem bark and root. However, some anti-nutritional agents such as oxalates, phytates and cyanates were present in all the solvent extracts of the leaf, stem bark and root except the ethyl acetate. Phytates were high in the aqueous solvent of the leaf (6.12% ± 0.00%) but low in the stem bark (1.00% ± 0.05%) and root (0.89% ± 0.03%). Proximate composition showed appreciable amounts of total carbohydrate (36.33% ± 0.72%), crude protein (26.00% ± 0.47%) and reducing sugars (5.87% ± 0.14%) in the leaf, while crude fat was more in the stem bark (16.70% ± 0.30%). There was corresponding substantial energy in the leaf [(1514.77 ± 20.87) kJ/100 g] and stem bark [(907.00 ± 8.52) kJ/100 g]. Moisture and ash contents of the leaf, stem bark and root were within acceptable limits for the use in drugs formulation. The mineral composition showed substantial amounts of important elements such as Fe, Ca, Na, Mg and Zn. Others were P, K and Se.

Conclusions: The outcome of this study suggests that the leaf, stem bark and root of *J. curcas* have very good medicinal potentials, meet the standard requirements for drug formulation and serve as good sources of energy and nutrients except for the presence of some anti-nutritional elements predominant in the leaf.

1. Introduction

Jatropha curcas (*J. curcas*) or physic nut is a non-edible multipurpose shrub [1]. It is a medicinal herb that is a member of the plant family Euphorbiaceae, and an uncultivated non-food wild species with branched and erect parts growing up to 6 m in height and predominantly found in tropical and sub-tropical regions of the world [2,3].

The Greek root (jatros) from which the genus name *Jatropha* was derived means "doctor" implying ancient medical uses of the plant in its centre of origin in Latin America [4]. Different parts of the plant have been used as ethno-medicine in different countries for centuries [5].

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Many studies have been done to demonstrate the efficacy of *J. curcas* against a wide array of bacteria and fungi [3]. Results of several studies also revealed that *J. curcas* had anticancer and antitumour properties [6,7]. Other medicinal plants have been studied using modern scientific approaches. However, only few drugs of plant origin could reach clinical uses; for this reason, a special effort is needed for the development of herbal drugs having therapeutic ability [8]. Medicinal plants have a long tradition of use outside of conventional medicine. It is becoming more main stream as improvement in clinical research shows the value of herbal medicine in the treatment and prevention of disease [9].

Medicinal plants have continued to play important roles in the development of new drugs and effective health care systems in many countries, developed and less-developed countries alike. In a review of plant contribution to drug development, Newman *et al.* observed that at least 119 chemical substances of plant origin can be considered as important drugs that are used in one or more countries [10]. Of the 119 drugs, 74% were discovered as a result of chemical studies directed at the isolation of the active substances from plants used in traditional medicine. Numerous plant products in the form of decoction, tincture, tablets and capsules have been clinically used for the treatment of different ailments and diseases including cancer. Synthetic analogues in some cases have also been prepared to improve the efficacy and decrease the side effects of parent compounds. Traditional medicine using plant extracts continues to provide health coverage for over 80% of the world's population, especially in the developing world [11].

Indeed, traditional medicine is a potential source of new drugs and a source of cheap starting products for the synthesis of known drugs. Some examples include reserpine from *Rauvolfia* species, vinblastine from *Catharanthus roseus* or the discovery of a contraceptive in the zoapatle (*Montanoa tomentosa*) [12].

Plant chemicals from carbohydrates, fats, protein, vitamins and minerals, are parts of our body composition and chemistry. Plant medicine remains indispensible to modern pharmacology and clinical practice. Many of the current drug discovery and development process are plant-based and new medicines derived from plants are inevitable.

The increasing population of the world (especially the third world countries) requires that the search to accommodate this increase be broadened in the use of various plants so as to ensure easy reach and minimization of certain health care problems through meeting up with the nutritional and medicinal needs. Paucity therefore demands the evaluation of the medicinal and nutritional values of the leaf, stem bark and root of *J. curcas* through determination of phytochemical, proximate and mineral constituents of *J. curcas*.

2. Materials and methods

2.1. Equipment, chemicals and reagents

Materials used in laboratory included beaker, measuring cylinder, porcelain dish, test tubes, spatula, conical flasks and retort stands. Filter paper (Whatman No. 1), mortar and pestle, analytical and mechanical weighing balance were also used.

All chemicals and reagents used in this work were of analytical grade and they included ferric chloride solution, Fehling's solution A and B, hydrochloric acid (concentrated and dilute), sodium bicarbonate, sodium hydroxide and dilute ammonia solution. Tetraoxosulphate (VI) acid, glacial acetic acid, lead acetate, 10% alcoholic solution of naphthol, Mayer's reagent, Dragendorff's reagent, picric acid solution (Hager's reagent), Wagner's reagent, ethanol, methanol, ethyl acetate and distilled water were also included among others.

2.2. Collection and preparation of the plant materials

The leaf, stem bark and root of *J. curcas* were collected from Bedia farm in Obudu, Obudu Local Government Area, Cross River of Nigeria. Identification and authentication (identification no: 67) was done by Frank I. Apejoye of Botany Department, University of Calabar.

2.2.1. Processing of the plant materials

The leaf, stem bark and root of *J. curcas* were collected and air dried at room temperature in Medical Biochemistry Laboratory, Cross River University of Technology Okuku Campus, Nigeria for 14 days for use in the determination of phytochemicals, anti-nutrients investigation, proximate composition and mineral elements. The samples were ground into powder using a pulverizer and stored in an air tight bottle prior to use for analysis. The ground samples were used for the analysis of proximate composition and minerals content. After weighing 200 g, each of the ground sample of the leaf, stem bark and root was dissolved in 1000 mL each of deionised water, ethanol, methanol and ethyl acetate and was kept in the refrigerator for 72 h. The extract was filtered using a chess cloth and Whatman filter paper No. 1 (24 cm), to obtain filtrates of the respective solvents of water, ethanol, methanol and ethyl acetate which were then used for phytochemicals estimation spectrophotometrically.

2.3. Proximate analysis

The analysis of the proximate composition of *J. curcas* leaf, stem bark and root was carried out using the official methods of analysis of the Association of Official Analytical Chemists [13,14].

2.3.1. Energy value

This was calculated (kJ/100 g) using the equation:

$$\text{Energy value} = (37 \times \text{fat}) + (17 \times \text{carbohydrate}) + (17 \times \text{protein})$$

2.4. Phytochemical analysis

Phytochemical analysis for tannins, phenolics, flavonoids, saponins, carotenoids, sesquiterpenoids, cardiac glycosides and alkaloids were carried out according to known and standard methods. Tannins and phlobatannins were estimated using the Folin-Denis spectrophotometric method [15]. Saponin and triterpenoid saponin content were determined using the method of Liener [16], and modified by Hudson and El-Difrawi [17]. Flavonoids, alkaloids and sesquiterpene lactones were determined by ethyl acetate extraction and gravimetric measurement, the alkaline precipitation and gravimetric method and the double extraction and gravimetric measurement, respectively as described by Harborne [18]. Total oxalate was determined according to the procedure of Day and Underwood [19]. Phytate content was determined using the method

described by Reddy and Love [20]. Hydrocyanic acid content was determined using the alkaline titration method of Association of Official Analytical Chemists [21].

2.5. Mineral analysis

Minerals were determined after the dried powdered samples were first digested with nitric acid and perchloric acid and the filtered aliquots were used for the determination of Na, K, Ca, Mg, P, Fe, Cu, Zn, Se, Cr, Co and Mn content. K and Na were determined by the flame photometric method. Fe, Cu, Zn, Mn, Cr, Co, Se, Ca and Mn were determined by atomic absorption spectrophotometric method described by James [22], and Association of Official Analytical Chemists [21].

2.6. Statistical analysis

All determinations were done in triplicates and data were expressed as mean ± SEM. These data were subjected to ANOVA using SPSS 16.0 and statistical significance was obtained at $P < 0.05$.

3. Results

3.1. Phytochemical composition of the leaf, stem bark and root of J. curcas

The results of the phytochemical composition of the leaf of *J. curcas* in four solvent extracts were given in Table 1. The results of phytochemicals of aqueous extract showed the presence of polyphenols, flavonoids, alkaloids, cardiac glycosides, coumarins, saponins, terpenoids, steroids, triterpenoid saponins, carotenoids, phlobatannins, tannins, oxalates, phytates and cyanates. Polyacetylated compounds and volatile organic compounds (VOCs) were absent in the aqueous extract of the leaf of *J. curcas*. Results of phytochemicals of ethanol extract showed the presence of polyphenols, flavonoids, alkaloids, cardiac glycosides, coumarins, saponins, terpenoids, steroids, triterpenoid saponins, carotenoids, phlobatannins, tannins, oxalates, phytates, cyanates and VOCs. Polyacetylated compounds were absent in the ethanol extract of the leaf of *J. curcas*. Results of phytochemicals of methanol extract showed the presence of polyphenols, flavonoids, alkaloids, cardiac glycosides, coumarins, saponins, terpenoids, steroids, triterpenoid saponins, carotenoids, phlobatannins, tannins, oxalates, phytates, cyanates and VOCs. Polyacetylated compounds were absent in the methanol extract of the leaf of *J. curcas*. Results of phytochemicals of ethyl acetate extract showed the presence of polyphenols, flavonoids, alkaloid, cardiac glycosides, coumarins, saponins, terpenoids, steroids, triterpenoid saponins, carotenoids, phlobatannins, and tannins. Polyacetylated compounds, oxalates, phytates, cyanates and VOCs were absent in the ethyl acetate extract of the leaf of *J. curcas*.

The results of the phytochemical composition of the stem bark of *J. curcas* in four solvent extracts were given in Table 2. The results of phytochemicals of aqueous extract showed the presence of polyphenols, flavonoids, alkaloids, cardiac glycosides, coumarins, saponins, terpenoids, steroids, triterpenoid saponins, carotenoids, phlobatannins, tannins, oxalates, phytates, cyanates and polyacetylated compounds and VOCs were absent in the aqueous extract of the stem bark of *J. curcas*.

Results of phytochemicals of ethanol extract showed the presence of polyphenols, flavonoids, alkaloids, cardiac glycosides, coumarins, saponins, terpenoids, steroids, triterpenoid saponins, carotenoids, phlobatannins, tannins, oxalates, phytates, cyanates and VOCs. Polyacetylated compounds were absent in the ethanol extract of the stem bark of *J. curcas*.

Results of phytochemicals of methanol extract showed the presence of polyphenols, flavonoids, alkaloids, cardiac glycosides, coumarins, saponins, terpenoids, steroids, triterpenoid saponins, carotenoids, phlobatannins, tannins, oxalates, phytates, cyanates and VOCs. Polyacetylated compounds were absent in the methanol extract of the stem bark of *J. curcas*.

Results of phytochemicals of ethyl acetate extract showed the presence of polyphenols, flavonoids, alkaloids, cardiac glycosides, coumarins, saponins, terpenoids, steroids, triterpenoid saponins, carotenoids, phlobatannins and tannins. Polyacetylated compounds, oxalates, phylates, cyanates and VOCs were absent in the ethyl acetate extract of the stem bark of *J. curcas*.

Table 1

Phytochemical composition of different solvent extracts of the leaf of *J. curcas* [w/w, dry mass basis (%)].

Phytochemicals	Aqueous extract	Ethanol extract	Methanol extract	Ethyl acetate extract
Polyphenols	3.37 ± 0.01	4.45 ± 0.01[a]	4.62 ± 0.02[a,b]	4.44 ± 0.00[a]
Flavonoids	4.42 ± 0.02	6.67 ± 0.00[a]	7.22 ± 0.01[a,b]	7.35 ± 0.02[a,b]
Alkaloids	0.65 ± 0.05	1.55 ± 0.05[a]	1.58 ± 0.01[a]	1.62 ± 0.00[a]
Cardiac glycosides	0.21 ± 0.04	0.46 ± 0.05[a]	0.51 ± 0.01[a]	0.54 ± 0.00[a]
Coumarins	0.11 ± 0.01	0.44 ± 0.05[a]	0.54 ± 0.00[a]	0.41 ± 0.00[a]
Saponins	0.25 ± 0.01	2.31 ± 0.00[a]	2.35 ± 0.01[a]	2.41 ± 0.01[a,b]
Terpenoids	0.72 ± 0.01	1.81 ± 0.01[a]	2.44 ± 0.00[a,b]	2.78 ± 0.01[a,b]
Steroids	1.46 ± 0.04	3.55 ± 0.00[a]	3.88 ± 0.05[a,b]	3.71 ± 0.01[a]
Triterpenoid saponins	0.21 ± 0.01	0.22 ± 0.00	0.24 ± 0.00[a]	0.27 ± 0.01[a,b]
Polyacetylated compounds	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Carotenoids	1.09 ± 0.00	0.94 ± 0.01[a]	1.12 ± 0.00[a,b]	1.66 ± 0.01[a,b]
Phlobatannins	0.34 ± 0.00	0.38 ± 0.05	0.47 ± 0.01[a]	0.48 ± 0.02[a]
Tannins	0.06 ± 0.01	0.04 ± 0.00	0.15 ± 0.00[a,b]	0.02 ± 0.00[a]
Oxalates	1.15 ± 0.00	1.09 ± 0.01[a]	1.02 ± 0.00[a,b]	0.00 ± 0.00[a,b]
Phytates	6.12 ± 0.00	5.93 ± 0.03	5.88 ± 0.05	0.00 ± 0.00[a,b]
Cyanates	0.10 ± 0.00	0.02 ± 0.00	0.10 ± 0.05	0.00 ± 0.00[a]
VOCs	0.00 ± 0.00	0.14 ± 0.00[a]	0.56 ± 0.05[a,b]	0.00 ± 0.00[b]

Values are expressed as mean ± SEM ($n = 3$). [a]Values are significant at $P < 0.05$ compared with aqueous extract. [b]Values are significant at $P < 0.05$ compared with ethanol extract.

Table 2
Phytochemical composition of different solvent extracts of the stem bark of *J. curcas* [w/w, dry mass basis (%)].

Phytochemicals	Aqueous extract	Ethanol extract	Methanol extract	Ethyl acetate extract
Polyphenols	2.45 ± 0.04	2.54 ± 0.00	2.77 ± 0.05[a,b]	2.62 ± 0.01[a]
Flavonoids	3.61 ± 0.04	3.70 ± 0.05	3.95 ± 0.01[a,b]	4.12 ± 0.01[a,b]
Alkaloids	0.48 ± 0.01	1.54 ± 0.05[a]	1.57 ± 0.00[a]	1.59 ± 0.01[a]
Cardiac glycosides	0.15 ± 0.01	0.44 ± 0.01[a]	0.52 ± 0.00[a,b]	0.55 ± 0.02[a,b]
Coumarins	0.17 ± 0.00	0.41 ± 0.01[a]	0.42 ± 0.01[a]	0.37 ± 0.02[a]
Saponins	0.22 ± 0.02	2.27 ± 0.03[a]	2.31 ± 0.00[a]	2.35 ± 0.00[a,b]
Terpenoids	0.64 ± 0.00	1.65 ± 0.02[a]	2.25 ± 0.01[a,b]	2.42 ± 0.00[a,b]
Steroids	1.27 ± 0.01	3.23 ± 0.05[a]	3.55 ± 0.02[a,b]	3.67 ± 0.01[a,b]
Triterpenoid saponins	0.15 ± 0.00	0.19 ± 0.00[a]	2.21 ± 0.00[a]	0.23 ± 0.01[a,b]
Polyacetylated compounds	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Carotenoids	0.60 ± 0.00	0.68 ± 0.01[a]	1.07 ± 0.01[a,b]	1.42 ± 0.01[a,b]
Phlobatannins	0.29 ± 0.01	0.34 ± 0.00[a]	0.42 ± 0.01[a,b]	0.45 ± 0.00[a,b]
Tannins	0.05 ± 0.01	0.03 ± 0.00	0.14 ± 0.01[a,b]	0.01 ± 0.00[a]
Oxalates	1.11 ± 0.01	1.04 ± 0.00	0.81 ± 0.01[a,b]	0.00 ± 0.00[a,b]
Phytates	1.00 ± 0.05	0.75 ± 0.01[a]	0.53 ± 0.01[a,b]	0.00 ± 0.00[a,b]
Cyanates	0.11 ± 0.00	0.02 ± 0.01[a]	0.11 ± 0.00[b]	0.00 ± 0.00[a]
VOCs	0.00 ± 0.00	0.17 ± 0.01[a]	0.65 ± 0.01[a,b]	0.00 ± 0.00[b]

Values are expressed as mean ± SEM (n = 3). [a]Values are significant at $P < 0.05$ compared with aqueous extract. [b]Values are significant at $P < 0.05$ compared with ethanol extract.

The results of the phytochemical composition of the root of *J. curcas* in four solvent extracts were given in Table 3. The results of phytochemicals of aqueous extract showed the presence of polyphenols, flavonoids, alkaloids, cardiac glycosides, coumarins, saponins, terpenoids, steroids, triterpenoid saponins, carotenoids, phlobatannins, tannins, oxalates, phytates and cyanates. Polyacetylated compounds and VOCs were absent in the aqueous extract of the root of *J. curcas*.

Results of phytochemicals of ethanol extract showed the presence of polyphenols, flavonoids, alkaloids, cardiac glycosides, coumarins, saponins, terpenoids, steroids, triterpenoid saponins, carotenoids, phlobatannins, tannins, oxalates, phytates, cyanates and VOCs. Polyacetylated compounds were absent in the ethanol extract of the root of *J. curcas*.

Results of phytochemicals of methanol extract showed the presence of polyphenols, flavonoids, alkaloids, cardiac glycosides, coumarins, saponins, terpenoids, steroids, triterpenoid saponins, carotenoids, phlobatannins, tannins, oxalates, phytates, cyanates and VOCs. Polyacetylated compounds were absent in the methanol extract of the root of *J. curcas*.

Results of phytochemicals of ethyl acetate extract showed the presence of polyphenols, flavonoids, alkaloids, cardiac glycosides, coumarins, saponins, terpenoids, steroids, triterpenoid saponins, carotenoids and phlobatannins. Polyacetylated compounds, tannins, oxalates, phytates, cyanates and VOCs were absent in the ethyl acetate extract of the root of *J. curcas*.

3.2. Proximate composition of the leaf, stem bark and root of J. curcas

Table 4 shows the proximate compositions of the leaf, stem bark and root samples. The carbohydrate, protein and moisture content occurred in appreciable amounts. The fibre and ash content were also high and suggested the high nutritive value of *J. curcas.*

The results of the proximate composition of the leaf of *J. curcas* showed the presence of moisture, crude fat, crude

Table 3
Phytochemical composition of different extracts of the root of *J. curcas* [w/w, dry mass basis (%)].

Pytochemicals	Aqueous extract	Ethanol extract	Methanol extract	Ethyl acetate extract
Polyphenols	2.23 ± 0.01	2.32 ± 0.00[a]	2.49 ± 0.02[a]	2.35 ± 0.01[a,b]
Flavonoids	2.92 ± 0.04	2.95 ± 0.01	3.11 ± 0.01[a]	3.35 ± 0.02[a]
Alkaloids	0.38 ± 0.00	1.60 ± 0.05[a]	1.57 ± 0.05[a]	1.57 ± 0.02[a]
Cardiac glycosides	0.12 ± 0.03	0.41 ± 0.05[a]	0.48 ± 0.00[a]	0.48 ± 0.05[a]
Coumarins	0.15 ± 0.00	0.29 ± 0.01[a]	0.33 ± 0.01[a]	0.26 ± 0.01[a]
Saponins	0.22 ± 0.01	2.26 ± 0.05[a]	2.29 ± 0.01[a]	2.31 ± 0.00[a]
Terpenoids	0.56 ± 0.01	1.44 ± 0.00[a]	1.76 ± 0.00[a,b]	2.11 ± 0.00[a,b]
Steroids	0.94 ± 0.03	3.12 ± 0.01[a]	3.22 ± 0.01[a,b]	3.42 ± 0.01[a,b]
Triterpenoid saponins	0.14 ± 0.02	0.20 ± 0.00[a]	0.21 ± 0.01[a]	0.22 ± 0.00[a]
Polyacetylated compounds	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Carotenoids	0.35 ± 0.03	0.41 ± 0.00	0.87 ± 0.05[a,b]	1.14 ± 0.05[a,b]
Phlobatannins	0.25 ± 0.01	0.31 ± 0.01[a]	0.38 ± 0.02[a]	0.35 ± 0.01[a]
Tannins	0.04 ± 0.00	0.01 ± 0.00[a]	0.09 ± 0.01[a,b]	0.00 ± 0.00[a]
Oxalates	1.07 ± 0.01	0.96 ± 0.05	0.77 ± 0.01[a,b]	0.00 ± 0.00[a,b]
Phytates	0.89 ± 0.03	0.44 ± 0.03[a]	0.32 ± 0.00[a]	0.00 ± 0.00[a,b]
Cyanates	0.12 ± 0.01	0.01 ± 0.00[a]	0.12 ± 0.00[b]	0.00 ± 0.00[a]
VOCs	0.00 ± 0.00	0.12 ± 0.00[a]	0.33 ± 0.01[a,b]	0.00 ± 0.00[b]

Values are expressed as mean ± SEM (n = 3). [a]Values are significant at $P < 0.05$ compared with aqueous extract. [b]Values are significant at $P < 0.05$ compared with ethanol extract.

Table 4
Proximate analysis of the leaf, stem bark, and root of *J. curcas* (%).

Parameters	Leaf	Stem bark	Root
Moisture	11.90 ± 0.17	5.77 ± 0.07^{*,a}	9.77 ± 0.06*
Crude fat	12.30 ± 0.29	16.70 ± 0.30^{*,a}	6.80 ± 0.16*
Crude protein	26.00 ± 0.47	4.70 ± 0.20*	5.66 ± 0.21*
Total carbohydrate	36.33 ± 0.72	12.23 ± 0.32^{*,a}	15.00 ± 0.47*
Total reducing sugar	5.87 ± 0.14	0.52 ± 0.03^{*,a}	1.27 ± 0.05*
Ash content	14.10 ± 0.12	11.83 ± 0.07^{*,a}	7.93 ± 0.12*
Crude fibre	17.67 ± 0.27	50.53 ± 0.64^{*,a}	43.33 ± 0.54*
Energy value (kJ/100 g)	1514.77 ± 20.87	907.00 ± 8.52^{*,a}	602.93 ± 4.19*

Values are expressed as mean ± SEM (n = 3). *Values are significant at $P < 0.05$ compared with the leaf. ^{a}Values are significant at $P < 0.05$ for stem bark compared with the root.

protein, total carbohydrate and reducing sugar, ash content, crude fibre and energy value.

The results of the proximate composition of the stem bark of *J. curcas* showed the presence of moisture, crude fat, crude protein, crude carbohydrate, total reducing sugar, ash content, crude fibre and energy value.

The results of the proximate composition of the root of *J. curcas* showed the presence of moisture, crude fat, crude protein, crude carbohydrate, total reducing sugar, ash content, crude fibre and energy value.

3.3. Mineral profile

The mineral compositions of the plant samples were presented in Table 5. Fe, Ca, Mg, Na and Zn were presented in appreciable quantities. The results of the mineral composition of the leaf of *J. curcas* showed the presence of Fe, Ca, Na, Mg, K, Al, Zn, P and Se. The results of the mineral composition of the stem bark of *J. curcas* showed the presence of Fe, Ca, Na, Mg, P, Al, Zn, P and Se. The results of the mineral composition of the root of *J. curcas* showed the presence of Fe, Ca, Na, Mg, P, Al, Zn, P and Se.

3.3.1. Heavy metals

The heavy metals compositions of the plant samples were presented in Table 6. The results of Pb and Cr compositions of the leaf, stem bark and root of *J. curcas* showed no significant

Table 5
Mineral compositions of leaf, stem bark and root of *J. curcas* [mg/100 g, dry mass basis (%)].

Parameters	Leaf	Stem bark	Root
Fe	70.33 ± 3.66	61.33 ± 1.96	62.00 ± 1.89
Ca	65.00 ± 1.41	56.67 ± 1.19^{*,a}	50.00 ± 0.47*
Na	47.00 ± 1.24	24.67 ± 1.19^{*,a}	31.33 ± 1.18*
Mg	127.30 ± 2.37	43.00 ± 2.16^{*,a}	80.67 ± 1.19*
K	1.95 ± 0.11	0.67 ± 0.12*	0.40 ± 0.05*
Al	11.40 ± 0.17	4.04 ± 0.14^{*,a}	3.00 ± 0.17*
Zn	50.67 ± 1.96	14.33 ± 1.66^{*,a}	26.67 ± 2.13*
P	4.47 ± 0.23	0.70 ± 0.09*	1.33 ± 0.12*
Se	0.46 ± 0.02	0.30 ± 0.05	0.20 ± 0.05*

Values are expressed as mean ± SEM (n = 3). *Values are significant at $P < 0.05$ compared with the leaf. ^{a}Values are significant at $P < 0.05$ for stem bark compared with the root.

Table 6
Heavy metals compositions of leaf, stem bark and root of *J. curcas* (%).

Parameters	Leaf	Stem bark	Root
Pb	0.030 ± 0.000	0.030 ± 0.010	0.040 ± 0.000
Ar	0.000 ± 0.000	0.000 ± 0.000^{a}	0.010 ± 0.000*
Cd	0.020 ± 0.000	0.010 ± 0.000^{a}	0.030 ± 0.000
Cr	0.010 ± 0.000	0.010 ± 0.000	0.020 ± 0.000
Hg	0.002 ± 0.000	0.001 ± 0.000^{*,a}	0.002 ± 0.000

Values are expressed as mean ± SEM (n = 3). *Values are significant at $P < 0.05$ compared with the leaf. ^{a}Values are significant at $P < 0.05$ for stem bark compared with the root.

($P \geq 0.05$) difference among them, while Cd and Hg recorded a significant ($P < 0.05$) difference only between the stem back and root. That of Ar showed a significant ($P < 0.05$) difference between the leaf and the stem bark compared with the root.

4. Discussion

The medicinal and nutritional potentials of the leaf, stem back and root of *J. curcas* were assessed in this study through quantitative determination of the relative distribution of phytochemicals in four different solvents and the proximate composition and minerals content. Plants are known to play prominent roles in the treatment of diseases as some species especially the *Euphorbia* have been reported to possess antitumour and anticancer activities [23,24]. They are also known to express antiproliferative, antimicrobial and inhibition of HIV-1 infection [25–27]. *J. curcas* belongs to *Euphorbia* family and has strong potentials for use both medicinally and nutritionally. The results obtained from this study show that there is relative distribution of phytochemicals in solvents. The determination of their presence is a factor of the solvent used as their presence was the highest when methanol and ethyl acetate solvents were used and the lowest when aqueous solvent was used comparatively. For example, aqueous, ethanol, methanol and ethyl acetate extracts of flavonoids of the leaf were 4.42% ± 0.02%, 6.67% ± 0.00%, 7.22% ± 0.01%, 7.35% ± 0.02% respectively; aqueous, ethanol, methanol and ethyl acetate extracts of flavonoids of stem bark were 3.61% ± 0.04%, 3.70% ± 0.05%, 3.95% ± 0.01%, 4.12% ± 0.01% respectively and aqueous, ethanol, methanol and ethyl acetate extracts of flavonoids of root were 2.92% ± 0.04%, 2.95% ± 0.01%, 3.11% ± 0.01%, 3.35% ± 0.02% respectively. However, the use of ethyl acetate recorded the absence of anti-nutritional agents such as oxalates, phytates and cyanates as well as VOCs, but this was not the case with other solvents.

There is relative increase in the phytochemicals content as one moves from the root to the leaf. In other words, the phytochemicals content of the *J. curcas* plant is the highest in the leaf and the lowest in the roots irrespective of the solvents used. This would also mean that the leaf should have a higher potential to express the benefits of phytochemicals than other parts of the plant.

The presence of flavonoids in appreciable amount was found in the leaf [(4.42 ± 0.02)% − (7.35 ± 0.02)%]. Polyphenols and flavonoids are known to exercise anti-oxidative activities, protection against allergies, inflammation, platelet aggregation, microbes, ulcers, hepatic toxicity, viruses and tumour [28–30]. This therefore means that all the plant parts of *J. curcas*

especially the leaf, strongly exhibit the potentials mentioned above including that of an anti-carcinogenic and anti-ulcerative agent [28].

Saponins and steroids are also present in appreciable but safe amounts in the leaf, stem bark and root, meaning that they have great potentials as fertility agents. Levels <10% are considered safe and non-toxic as high saponin levels have been associated with gastroenteritis, manifested by diarrhoea and dysentery [31].

There is a significant amount of alkaloids in the ethanol, methanol and ethyl acetate extracts of leaf (1.55% ± 0.05%, 1.58% ± 0.01%, 1.62% ± 0.00% respectively), stem bark (1.54% ± 0.05%, 1.57% ± 0.00%, 1.59% ± 0.01% respectively) and root (1.60% ± 0.05%, 1.57% ± 0.05%, 1.57% ± 0.02% respectively) compared with the aqueous extract. Alkaloids are one of the most efficient therapeutically significant bioactive substances in plants. Pure isolated alkaloids and the synthetic derivatives are used as basic medicinal agents because of their analgesic, antispasmodic and bactericidal properties [32].

The results of the phytochemicals taken together show that indeed the leaf, stem bark and root of *J. curcas* possess strong potentials for medicinal use and would also serve as agents for the treatment of a wide range of diseases and infections.

The results obtained from proximate analysis of leaf, stem bark and root of *J. curcas* establish the fact that they can be used as rich carbohydrate sources. The carbohydrate content in the leaf is significantly higher than in the stem and root. Carbohydrates serve as a source of energy and aid digestion and the assimilation of other nutrients. Moreover, some carbohydrates in these plants have medicinal value. The proximate analysis revealed moisture contents for the leaf (11.9% ± 0.17%), stem bark (5.77% ± 0.07%) and root (9.77% ± 0.06%) fell within the acceptable limits of about 6%–15% for most vegetable drugs [33].

Total ash value recorded for the leaf, stem bark and root belongs to the range given for some official drugs such as *Citrus* leaf (7.0%), neem leaf (11.6%) and *Atropa* leaf (16%) [33]. However, there are higher values of the total ash of the leaf and stem bark than the root of *J. curcas*. This would also mean that the mineral content of the leaf and stem bark are higher than in the root. The total ash value is a diagnostic purity index. It represents both physiological and non-physiological ash. Physiological ash is the ash inherent in the plant due to biochemical processes and the non-physiological ash contaminants from the environment. These may be carbonates, phosphates, nitrates, sulphates, chlorides and silicates of various metals which were taken up from the soil [33]. The non-physiological ash component of the total ash could be reduced by rinsing the fresh plant material several times in clean water before drying and processing for medicinal uses.

Crude fibre content of the stem bark is higher than that of the root and leaf. This has nutritional implications that fibre prevents diverticulosis and aids absorption of trace elements in the gut as well as helps in the elimination of undigested food materials through the bowel [34,35]. The energy values for the leaf [(1514.77 ± 20.87) kJ/100 g], stem bark [(907.00 ± 8.52) kJ/100 g] and root [(602.93 ± 4.19) kJ/100 g] were high thus making them good nutritional sources of energy.

There were abundance of Fe, Ca, Na, Mg, Zn and Al in the leaf, stem bark and root of *J. curcas*. Fe is important in immune function, cognitive development, temperature regulation and energy metabolism [36]. It is also required for the synthesis of haemoglobin and myoglobin while its deficiency causes anaemia. It is therefore an important diet in pregnant and nursing women, infants and elderly people to prevent anaemia and other related diseases [37]. Ca along with P is required for formation and maintenance of bones and teeth. It is also required in blood clothing and muscle contraction [36]. Mg is needed in over 300 enzymes that utilize adenosine triphosphate. It contributes to DNA and RNA synthesis during cell proliferation. It is important for nerve and heart function as well as release of insulin and ultimate insulin action on cells and it decreases blood pressure by dilating arteries and preventing abnormal heart rhythm [36]. Deficiencies in animals lead to irritability, convulsion and even death. Zn and Se are components of antioxidative enzymes, superoxide dismutase, catalase and glutathione peroxidase. Zn also is required for the function of over 200 enzymes and is important in growth and sexual development in man [38]. Al has no nutritional benefits but is present in foods, drugs and cosmetics and in most parts of the body. It is also not toxic except in high concentrations, but the presence of high levels of Mg protects against such an outcome [39].

Na is the major element of the extracellular fluid and is a key factor in retaining body fluid. In conjunction with K, through creation of electrical potential, nerve impulses are conducted and the contraction of muscles is enabled. It participates in facilitating the absorption of nutrients such as glucose and amino acids in the small intestine. However, high levels of Na are associated with hypertension and high blood pressure. The presence of Ca, Mg and K collectively are known to reduce hypertension and blood pressure as well as used in the prevention and treatment of high blood pressure [36]. Therefore, their presence in the leaf, stem bark and root gives a positive weight to the nutritional importance of the *J. curcas* plant.

The heavy metals assayed are in highly insignificant amounts and therefore do not exhibit any toxic effect. High levels of anti-nutritional agents such as oxalates, phytates and cyanates were more in the leaf than in the stem bark and root and their levels appeared increased in polar solvents than in non-polar. Oxalates tend to render Ca unavailable by binding to plasma Ca ion to form complexes [40,41]. Phytates binds with Fe, Mg and Ca as well as proteins, decreasing their bioavailability [42]. The levels of cyanates were low and non-toxic in all the plant parts and high levels of cyanates are considered deleterious as it inhibits cytochrome oxidase which leads to energy deprivation and consequently death. However, if the problem of anti-nutrients persist, solvents like ethyl acetate can be used for the extraction of the plant parts of *J. curcas* as their presence is excluded using this solvent.

Plant medicine is considered safer and better for human health than synthetic drugs. This is because human beings have co-evolved with plants over the past decades. We eat plant, drink their juices, ferment and distil libations from them and consume them in a thousand forms. The present study has shown the phytochemical, proximate and mineral compositions of the leaf, stem bark and root of *J. curcas*. The phytochemical assay in different solvent extracts has demonstrated the relative absorption of these phytochemicals and their gradual increased presence from the root to leaf. The rich array of phytochemicals in all the plant parts in this study presents *J. curcas* as a plant with very good potential for medicinal use and in the possible treatment of diabetes, malaria, cardiovascular, hepatic infections and myriad of other diseases. The proximate and mineral contents with low moisture content and good ash value (all falling within standards) have also added to their usefulness in drugs

formulation. These plant parts present good nutritional sources with high energy values and rich sources of macronutrients and micronutrients, however this is dominant in the leaf. The presence of relatively high levels of some anti-nutrients especially in the leaf is the main set back in the plant which can be remedied either through the selective use of the extraction solvent or by adopting some separation approaches.

Conflict of interest statement

We declare that we have no conflict of interest.

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