Available online at www.elixirpublishers.com (Elixir International Journal)

Applied Chemistry

Elixir Appl. Chem. 47 (2012) 8961-8968

ISSN: 2229-712X

Characterization and phytochemical screening of coconut (*Cocos nucifera L.*) Coir dust as a low cost adsorbent for waste water treatment

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ARTICLE INFO

Article history:
Received: 20 April 2012;
Received in revised form:
2 June 2012;
Accepted: 16 June 2012;

Keywords
Coconut coir dust,
Extraction,
Phytochemical screening,
Acetone solvent.

ABSTRACT

Characterization and phytochemical screening of coconut (*Cocos nucifera L.*) coir dust was carried out. Studies were carried out on the extraction and characterization of unmodified coconut *(Cocos nucifera L.)* coir using water, acetone, acetone/water (70/30), (50/50) respectively. The percentage extract decreased in the following order: acetone/water (70/30) > water > acetone > acetone/water (50/50). Amount of extract obtained from a fixed mass of coir dust increased with decreased particle sizes: 150µm > 300µm > 600µm for all solvent systems. The amount of extract obtained using water as extractant increased with increase in volume in the order of: 400mL > 200 mL > 100 mL of water. Characterization of unmodified coir dust reveal the moisture, ash, lignin, cellulose contents and pH of aqueous solution as 25.20%, 9.0%, 53.5%, 35.99% and 6.4 respectively. Phytochemical screening of acetone coir extract for the presence of active ingredients such as tannins, flavonoids, polyphenols, phlobatannins, and also reveals the absence of saponins, anthraquinones.

Introduction

Over the years, enhanced industrial activities have led to the discharge of unprecedented volumes of waste waters and effluents into the environment. The various activities associated with environmental pollution are mining operations, ore-processing and smelting, urbanization, metal-plating, tanneries and agriculture-related processes [38]. These metal contaminants are not biodegradable but accumulate in living organisms becoming a permanent burden on the ecosystem [6]. Their presence in the environment even at low concentration has therefore the potential of becoming a cause of toxicity to humans and other forms of life [21]. Industrial effluents and drinking water loaded with metals is thus a serious public health problem [13]. Over-abundance of the essential trace elements and particularly their substitution by non-essential ones, such as Cd, Ni, Ag can also cause toxicity symptoms.

Biosorbents are adsorbents derived from agricultural byproducts such as maize cob [37] onion skin [32] cassava waste [3], banana pith [33], coconut fibre [23], and sugarcane baggage [31]. Studies reveal that various agricultural waste materials such as rice bran, rice husk, wheat bran, wheat husk, saw dust of various plants, bark of the trees, groundnut shells, coconut shells, black gram husk, hazelnut shells, walnut shells, cotton seed hulls, waste tea leaves, *Cassia fistula* leaves, maize corn cob, jatropa deoiled cakes, sugarcane bagasse, apple, banana, orange peels, soyabean hulls, grapes stalks, water hyacinth, sugar beet pulp, sunflower stalks, coffee beans, arjun nuts, cotton stalks etc has been tried [14, 35, 38]. These promising agricultural waste materials are used in the removal of metal ions either in their natural form of after some physical or chemical modification.

These lignocellulosic materials have been used to remove metal ions from solutions. The search for an economical all-efficient adsorbent to cushion the high rise in metal toxicity and its environmental effect is of technological and scientific concern. There are different types of adsorbents-organic (polymers/ polymeric resins), inorganic (sand, zeolites, alumina etc) used in adsorption. The efficiency of any adsorbent depends on its selectivity. Selectivity is the preference of a particular adsorbate to the surface of adsorbent. Adsorbent selectivity is influenced by many factors such as nature of adsorbate, particle size, adsorbate concentration contact time, pH of solution and temperature. The adsorbents are used different applications; although the specific application of these adsorbents depends on their selectivity-the difference in the affinity of the surface for the different components.

Among several agricultural wastes studied as biosorbents for water treatment, coconut has been of great importance as various parts of this tree (e.g, coir, shell etc.) have been extensively studied as biosorbents for the removal of diverse type of pollutants from water. Coconut palm (*Cocos nucifera)* is a member of the family *Arecaceae* (palm family). The coconut palm is grown throughout the tropical world. It sustains the livelihood of millions of people in coastal regions of tropics. Coconut palms have been called the “tree of life” because of the vast variety of uses.

Fig. 1 (a) Coconut *(Cocos nucifera L.)* tree with fruits; (b) A Cross-sectional area of a Coconut fruit (An annotated diagram showing the mesocarp where the coir dust is generated)

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It ranks seventh most important vegetable oil crop in the world. Coconut trees are grown mainly for high oil content of the endosperm (copra), which is utilized in food as well as in other purposes also. From 1980 to the present year, total world coconut productivity has increased significantly from 35 to 50 million tones [47]. India, the third largest producer of coconut in the world, produces Ca. 9 million tones of coconut trees in a vast area of 2 million hectares in the year 2003 [47]. Besides the valuable contents of the nuts, coconut palm is of significant importance as the husks, shells, leaves and the stem of this tree find many applications. The husk of the tree which surrounds the coconut is the source of coir fibers. Copra production gives rise to coir as the by-product, whereas the husks are considered as waste and left behind as mulch, or sometimes used as fertilizer due to its high potash content.

Pith, the by-product of coir fiber extraction, has been accumulating in large quantities at production sites for years. The ratio of fiber production to coir pith is 1:2, it is estimated that the production of coir pith in India is about 7.5 million tones per year. Raw coir pith consists of 35.0% cellulose, 25.2% lignin, 7.5% pentosans, 1.8% fats and resins, 8.7% ash content, 11.9% moisture content and 10.6% other substances [16]. Coconut husk is the mesocarp of coconut and coconut consists of 33-35% of husk. Husks are composed of 70% pith and 30% fiber on a dry weight basis.

The world production of coir fibers ranges between 5 to 6 million tones per year. However, less than 10% of this yield enters for commercial trade [47]. In 1996, the continuous intensifying production of the brown fiber reached up to 216,000 tonnes (70%, India, 27%, Sri Lanka) [47]. Coconuts shells could be utilized more efficiently in the production of activated carbon. Carbonization of one tones of coconut shells produces of the order 300 kg of charcoal, which can be converted into 120 kg of activated carbon. Different optimizing conditions by various methods have been reported by several researchers to prepare activated carbon utilizing coconut wastes [50]. In all the foregoing extract, from coconut coir dust has not been modified into cation exchange resin/adsorbent used for removal of metal ions from solution. This is the objective of the present research. The present work also deals with the utilization of agricultural waste materials as biosorbents for removal of toxic heavy metal ions from aqueous solution.

MATERIALS AND METHODS

Coconut (*Cocos nucifera L.*) coir dust was procured from a local coconut processing mill in Uyo, Nigeria. It was air dried for 24 hours and in oven at $60^\circ C$ to constant weight. The dried coir dust was separated into different particle sizes ranging from 50 – 800 μm and stored in air-tight lid containers.

Extraction of Coconut Coir Dust

The solvent systems used were water, acetone, acetone/water (V/V) $\left(\frac{70}{30}\right)$ and $\left(\frac{50}{50}\right)$ respectively. The modified procedure of Pansera *et al.*, (2004) in the extraction of tannins from Acacia mearnsii (black wattle) was adopted.

Extraction of Coir Dust in Water

Coir dust $(1\ g)$ was added to $100 mL$ of deionised water in a beaker on hot plate and stirred for 60 minutes at the boiling point of the solvent. At the end of 60 minutes, the mixture was filtered and the filtrate was evaporated to dryness. The weight of the extract was obtained. The above procedure was repeated for different volumes of water ranging from $100 - 400\ mL$ for the various particles sizes $(63 - 800\ \mu m)$. The weight of extracts and residues were determined in all the experiments.

Extraction of Coir Dust with Acetone and Acetone/Water Mixtures

Coir dust $(1\ g)$ was placed in the thimble set in the soxhlet extractor fitted into a round bottomed flask with solvent $(80\ mL)$ while $20\ mL$ was added to soak the sample in the thimble. The whole set up was placed in a water bath at constant temperature of $60^\circ C$. The solvent was heated to reflux and the extraction completed in 60 minutes. The filtrate was distilled to remove the solvent and the extract dried to constant weight at $60^\circ C$. The same procedure was used for the different solvent systems water, acetone, acetone/water $\left(\frac{70}{30}\right)$ and $\left(\frac{50}{50}\right)$ for each particle size.

Characterization of Coir Dust

The coir dust was characterized for moisture, ash, lignin, cellulose contents, pH, cation exchange capacity, degree of swelling and solubility in some solvents according to standard methods.

Determination of Moisture Content

The unmodified coir dust $(1g)$ was measured into a pre-weighed porcelain dish with cover and weighed. The coir dust and the container with the lid open was placed in an oven at $55 - 60^\circ C$ for 5 hours. Further drying was carried out at $80^\circ C$ for 3 hours. The container with the lid was allowed to cool and reweighed with minimum exposure to atmosphere. The last drying was repeated for another 3 hours till a constant weight was obtained [44]. Moisture content determined according to the formula:

$$Moisture\ content(\%) = \frac{W_1 - W_2}{W_1} \times 100 \qquad (1)$$

where, W_1 is the initial weight of coir dust before drying and W_2 is the final weight of coir dust after drying.

Alkali Solubles

1% NaOH solubility- $2.0g$ of coir dust meal was placed in a conical flask and $100\ ml$ of 1% NaOH was added. The mixture was placed in water bath maintained at $100 \pm 5^\circ C$ for 1 hour after which the solution was filtered, washed and dried; then, 18% NaOH solubility $2.0g$ of crushed coir dust was placed in a conical flask and $100\ ml$ of 18% NaOH was added. The mixture was allowed to stand for 1 hour at the end of which it was filtered, washed with deionised water and dried to constant weight. In each case, the loss in weight was determined as percentage solubility in alkali *(Tappi Standard T 212 OS 76)*.

$$\%Solubility = \frac{Weight\ of\ sample\ residue}{Weight\ of\ sample\ before\ use} \qquad (2)$$

Solubility in Water

Cold water – $2.0g$ of sample was placed in a beaker and $100\ ml$ of deionsed water added. The mixture was kept in the open at the laboratory temperature of $32 \pm 2^\circ C$ for 2 days (48 hours) after which it was filtered and dried; then hot water – $2.0g$ of sample was placed in a flask and $100\ ml$ of hot deionsed water was added. The flask was placed in a boiling bath and allowed to digest for 3 hours after which it was filtered and dried. The percentage solubility in water is expressed as

$$\%Solubility = \frac{W_Y - W_o}{W_Y} \qquad (3)$$

Where W_Y is the initial weight of oven dried sample and W_2 is the final weight of residue after solubility test (Tappi Standard T 20771).

Determination of Lignin Content

$2.0g$ of extractive free sample was shaken in 72% H_2SO_4 and allowed to stand overnight. The acid was prepared by diluting 734.7ml of 98% conc. H_2SO_4 to the $1000\ ml$ mark in a volumetric flask. The mixture was transferred to a beaker, rinsed with water until the solution reached about 3% acid content. It was then heated for few minutes (20 minutes) and allowed to stand. The lignin settled out and was filtered using filter paper. It was then dried to a constant weight at $100℃$ and weighed. The amount of lignin was determined as (Tappi Standard T 222 OS-74).

$$\%\ Lignin = \frac{Weight\ of\ oven-dried\ lignin}{Weight\ of\ extractive-free\ ovendried\ sample} \times 100 \qquad (4)$$

Cellulose Content

$4g$ of sample in a conical flask, $10cm^3$ parazon (bleach) was added in $90\ cm^3$ of deionised water into conical flask. The mixture was boiled until sample is bleached. It was filtered, washed and dried at $80℃$. To the bleached sample, $100\ cm^3$ of 24% aqueous NaOH was added, and boiled for 1 hour to remove the hemicelluloses. The residue was filtered, washed and dried at $80℃$.

$$\%\ Content = \frac{Weight\ of\ final\ sample}{Weight\ of\ sample\ before\ bleaching} \times 100 \qquad (5)$$

Acid Extractives Determination

Unmodified coir dust $(1\ g)$ was weighed into conical flask and $100\ ml$ of $0.2M$ HCl and heated on a Bunsen burner for 1 hour. The content was filtered and the residue air dried and then in oven at $80℃$ and reweighed.

$$\%Acid\ extractive\ = \frac{W_f - W_i}{W_f} \times 100 \qquad (6)$$

where W_1 is the weight of extracted coir dust and W_2 is the weight of un-extracted coir dust.

Percentage Swelling

Percentage swelling (α_m) was determined gravimetrically by swelling a sample in deionized water and determining the weight of the swollen sample (M_w) and the weight of the corresponding dry sample (M_d). Coir dust $(1g)$ was swelled in $100\ ml$ of deionised water in a conical flask for 1,5,10 and 24 hours. The weight of swollen sample (M_w) was determined and the dried sample M_d determined [48].

$$\%\ Swelling = \frac{W_w}{W_d} \times 100 \qquad (7)$$

where W_w is the weight of swollen sample and W_d is the weight of dry sample.

Swelling in some Solvents

Coir dust $(1g)$ was soaked in $100ml$ acetone and dilute HCl, respectively. The same procedure carried out for swelling in deionised water was repeated here. This was to deduce the solvent that causes the highest swelling of the sample.

Results and discussion

The coir dust was characterized by standard methods [1, 2, 9] and the results are presented in Table 1. The moisture, cellulose, lignin, ash contents, water and dilute acid extractives, expressed in percentages were $25.20, 35.99, 53.50,$ $9.0, 28.20\ and\ 41.30$ respectively.

The solubility in aqueous NaOH solutions $(1\%) and\ (18\%)$ were $27.5\%\ and\ 41.0\%$ while solubility in cold and hot water were $25.0\%\ and\ 31\%.$ The pH of the coir filtrate and cation exchange capacity were $6.40\ and\ 2.39\ mmolg^{-1}$ respectively.

Table 1: Characterization of Coir Dust

	Assay Parameter	% Content in Coir Dust
	% Moisture content	25.2
i	% Ash content	9.0
ii	% Water extractables	28.2
v	% Acid (Dil HCI) extractables	41.3
	% Swelling in H_2O	
	1 hour	65.7
	5 hours	70.8
	10 hours	77.7
	24 hours	85.7
i	Acetone	0.934
ii	Dil. HCI	3.229
iii	pH of coir dust in H_2O	6.4
x	Cellulose	35.99
	Lignin	53.5
i	Alkali soluble (1% NaOH solution)	27.5
ii	Alkali soluble (18% NaOH solution)	41.3
iii	Cation exchange capacity ($mmolg^{-1}$)	2.39

The coir (Coconut mesocarp pith)is the fibrous material that constitutes the thick mesocarp (middle layer) of the coconut fruit (*Cocos nucifera L*). The high lignin cellulose contents $(53.5\%$ and $35.99\%)$ of this and low ash content are characteristic of agricultural hyproducts generally referred to as lignincellulosic materials.

The values of lignin and cellulose of the coir in this study is in comparism to those earlier reports of [2, 11, 18, 45]. These authors reported values of cellulose to vary between 23-43%, lignin 35-54%, ash content 8.25% while the rests were extractive components. These values however depend on the age, source, period extraction and extraction method. [2, 45]. The lignin and cellulose content of coir dust were higher than those of other agricultural byproducts such as corn cob, rice straw, sugarcane bagasse and cotton stalk. The cellulose content of rice straw is: 37.2% , bagasse: $46.2\%,$ cotton stalk: 42.8% while their lignin contents is $12.2\%,$ $20.2\%\ and\ 27.3\%$ respectively [36]. The high lignin and cellulose contents of the coir dust contribute to its physical stability which does not change markedly with moisture content. Also coir resists bacterial or chemical decomposition and breakdown due to uncommonly high protective lignin content. Piles of coir dust have been found to last as long as 100 years without breaking down at coir processing centres [17, 34].

Lignin and cellulose are biopolymers bearing multiple phenolic hydroxyls, carboxylic, amino, sulphonate groups admittedly associated with the responsibility for the removal of metal ions and other contaminants from wastewater/effluents [19, 43, 49].

The water extractable (28.2%) were less than that acid extractable (41.3%) (Table 1) which may be attributed to the fact that in water the component of coir dust is only hydrosolubilized while in acid the components are both hydrolyzed and hydrosolubilized. The alkaline solubility of coir dust increases with increasing concentration of the alkali. With 1% NaOH solution, 27.5% of the extractives are removed against 41.3% with 18% NaOH solution. This is very useful when the coir dust is subjected to pulping and bleaching for paper production. Another research [36] obtained similar increase for treating sugarcane bagasse with different sodium hydroxide concentrations ranging from 0.5 – 5.0% before phosphoxylation of the product. Treatment of agricultural byproducts causes depolymerization of the lignin matrix, partial degradation of the bonds between lignin and cellulose and dissolution of waxes and resins. It has been reported that non-woody agricultural byproducts exhibit high solubility in dilute alkali and free the hydroxyl groups attached to lignin and cellulose [46].

The solubility in cold water-25%, hot – 31% shown in (Table 1) gives an indication of the level of extractives and water soluble constituents of the coir dust. The extractives, waxes and resins are the undesirable components of pulp and paper of lignocellulosic materials; hence their removal improves the quality of coir as pulp and paper raw materials [12].

This will hinder the penetration of adsorbates (contaminants) to these sites, hence, low sorption. Most agricultural byproducts are poor adsorbent/ion exchanger in the unmodified forms [4]. The degree of swelling of the coir dust in water was greater than that in dilute HCl while swelling in acetone-non polar solvent had the least (0.934%). The swelling of the coir in water increases slightly with increase in contact time. Table 1 shows that at 60 mins, the degree of swelling was 65.7% while for 24 hours it rose to 85.7%. The degree of swelling of saw dust-based ion exchangers show similar trends in the range of 100 – 200% [48]. Degree of swelling of adsorbents/resins is an important requirement for materials intended to be used as ion exchangers which should be partially or completely insoluble in the solvent [44].

An average pH value of 6.4 and a coir suspension and exchange capacity of 2.39 mmolg^{-1} were obtained from the coir sample (Table 1). Other authors have reported natural pH of coir suspension of 5.2 – 6.3 [2]. Changes in coir pH are a function of total H$^+$ or OH$^-$ ions added or removed from the coir suspension. Buffering by the coir is due to weakly acidic functional groups such as carboxylic and phenolics groups. These functional groups act as buffers by accepting protons from acidic functional groups in coir dust puts and by dissociating protons when base is added [30].

Also the magnitude of the cation exchange capacity of a material is a measure of the quantity of its exchangeable ions. This depends on the number of active groups per unit weight of the ion exchanger; the higher the number of its exchangeable ions, the greater the value of exchange capacity. Its ion exchange/adsorption properties can be utilized to adsorb important plant nutrient e.g N in its NH$_4^+$ and/or NH$_3$ form, protecting it from losses such as during compositing of N-rich wastes. Coir dust is being used in mixes of growing ornamental plants in containers (Bunt, 1988).

Multi-elemental Contents in the Coir Dust

The elemental analysis of coir dust based on dry weight was carried out according to standard methods [1], and the result presented in Table 2. This Study shows that the Coir Dust contain light metals such as Na(463.20), K(711.60), Ca(227.40) and Mg(172.00), all in micrograms which as exchangeable with heavy metals such as Pb, Cd, Zn, Fe, Mo, in aqueous solution. The elemental composition of Coir Dust as shown in Table 2, fitted with those reported in the literature [15, 26]. It is believed that the ion exchange properties of coir dust is due to its ability to take up heavy metal ions from solution in exchange for the light metals such as Na, Ca, and Mg [28]. Heavy metals easily form multidenatate stable complexes with the functional groups (COO-, OH), present in coir dust than light metal [5]. However, the amounts of the light metals in this study, were in trace amounts – in micrograms.

Table 2: Multi-elemental contents in the Coir (based on air dried weight)

Metal	**µg metal/g coir dust present study**	**µg metal/g coir dust literature study (Conrad and Hansen,2007)**
Na	463.20	861.0
K	711.60	3630
Ca	227.40	564
Mg	172.00	474
Pb	0.180	0.175
Cu	1.60	3.12
Cd	0.04	0.020
Cr	0.20	0.238
Zn	4.286	4.32
Fe	285.20	121.0
Mn	1.094	5.94
Mo	0.020	0.035
Co	0.060	0.054
Ni	1.00	0.715
As	ND	ND
Hg	ND	ND
V	ND	ND

pH = 7.0; temp = 30°C; dose 500mg/50ml solution; ND = not detected; particle size = 500µm;

Extraction of Coir Dust with Polar Solvent - Water

Coir dust of different particle size in polar solvent coconut coir dust of particle sizes (63 – 850µm) were extracted using hot water of volumes $100, 200\ and\ 400ml$ respectively and the results are shown in Table 3. The amount of residues obtained ranges from $72.5\%\ to\ 90\%$ which is higher than the extracts 8.30% (particle size – 425µm in 100mL of water) - 27.0%. (particle Size - 63µm in 200mL water). The amount of extract obtained from $1g$ coir dust for all particle sizes increased with increase volume of water used for the extraction (Table 3). The general trend is that amount of residue obtained ranges from over $70\% - 98\%$ much higher the amount of extracts $(4.30 - 27.0\%)$. This is because coir dust contain high solid matter of over 90% of cellulose and lignin while extractives constitute less than 10% of its composition. Moreover, these constituents are cemented together through hydrogen bonds in the crystalline regions of its matrix.

Table 3: Results of Extraction of 1g of Coconut Coir Dust(of Different Particle Sizes) in Hot Water

Volume of Water (ml)	Particle Size (µm)	Mass of Residue (g)	Mass of Extract (g)	% Residue	% Extract
100	63	0.878±0.12	0.120±0.01	87.80	12.00
	75	0.862±0.04	0.10±0.04	86.20	10.00
	150	0.84±0.05	0.131±0.05	84.0	13.10
	212	0.799±0.02	0.165±0.02	79.90	16.50
	300	0.788±0.02	0.182±0.01	78.80	18.20
	425	0.901±0.01	0.083±0.01	90.10	8.30
	600	0.83±0.03	0.147±0.01	83.0	14.70
	850	0.881±0.02	0.097±0.02	88.10	9.70
200	63	0.785±0.01	0.180±0.01	78.50	18.0
	75	0.791±0.02	0.090±0.02	79.10	9.0
	150	0.765±0.05	0.196±0.05	76.50	19.60
	212	0.756±0.02	0.185±0.02	75.60	18.50
	300	0.786±0.01	0.185±0.01	78.60	18.50
	425	0.780±0.01	0.185±0.01	78.0	18.50
	600	0.831±0.03	0.151±0.01	83.10	15.10
	850	0.792±0.02	0.148±0.02	79.20	14.80
400	63	0.725±0.01	0.27±0.02	72.50	27.00
	75	0.770±0.02	0.211±0.02	77.0	22.10
	150	0.850±0.02	0.119±0.02	85.0	11.90
	212	0.750±0.02	0.2150±0.016	75.0	21.50
	300	0.790±0.015	0.201±0.02	79.0	20.10
	425	0.805±0.01	0.178±0.01	80.05	17.80
	600	0.833±0.03	0.143±0.01	83.30	14.30
	850	0.850±0.02	0.121±0.02	85.0	12.10

Hence, solubilization of such a structure with water is hindered by these cementing materials [41]. From Table 1, the amount of extracts for all particle size increased with increase in volume of water used for the extraction. The trend in this increase is the order of $400mL > 200mL > 100mL.$ For examples, for a particle size of $63\mu m, 1g$ of extract for volume of water $400mL is 27.0\%, 200mL is\ 18.0\%$ while for all particle size (Table 3), for a volume of $100mL$ of water the extract is 11.0%. This may be attributed to the nature of the coir dust of high capillary and high water holding capacity. It has been reported that the coir consist of millions of micro sponges that can absorb and hold nearly 1000% of their own weight in water [34].

Also since coir dust is a biopolymer and the solubility of polymers usually involves two stages-swelling and disintegration [7]. These stages require large quantity of solvent because of coir dust is highly hydrophilic in nature.

Effects of Mass and Particle Size of Coir Dust on its Extraction

The effects of the masses of coir dust $(0.5 - 1.5g)$ on the amount of extract obtained by using $100mL$ of water to extract these masses for $150, 300\ and\ 850\mu m$ particle sizes are studied. The results are presented in Table 4. The plots of % extract and % residue versus the Mass of coir dust(g), are presented in Figures 2 and 3 respectively.

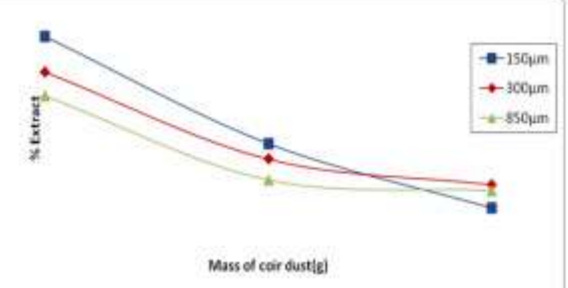

Fig. 2 - Plot of % Extract versus Mass of coir dust(g) of particle sizes for 150µm, 300µm, and 850µm.

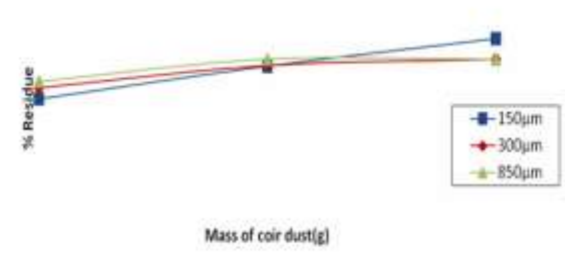

Fig. 3 - Plot of % Residue versus Mass of coir dust(g) of particle sizes for 150µm, 300µm, and 850µm.

The amounts of residue obtained for all particle sizes $(150, 300\ and\ 850\ \mu m)$ increased with the masses of the coir dust while the reverse was the case for the extracts obtained (Fig. 2 and 3)

The amount of residue was greater than for extract for all the masses $(0.5 - 1.5g)$. The amounts of extracts were dependent on the masses of the coir dust, the smaller the mass, the higher the amount of extract (Table 4). This is attributed to the fact that coir dust is highly porous, hydrophilic with high water absorptivity, absorbing about eight times its original mass of water [22, 34]. As the masses increased with no corresponding increase in quantity of solvent, there is less solubilization and surface area which results in low extracts.

Extraction of Coconut Coir Dust with Non-Polar Solvent-Acetone

Table 5 show the result of extraction of coconut coir dust using $150mL$ of acetone with soxhlet extractor with different masses $(0.5-1.5g)$ of different particle sizes $(63-850\mu m)$. The plots of % extract and % residue versus the mass of coir dust of different particle sizes are presented in Figures 4 and 5, respectively.

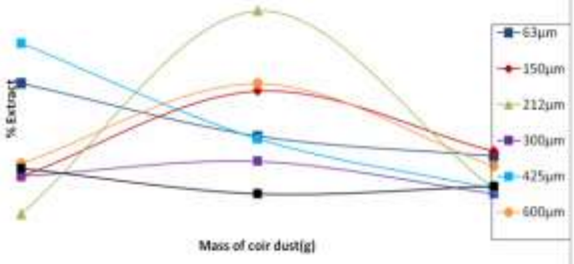

Fig. 4 - Plot of % Extract versus Mass of coir dust(g) of particle sizes for 63µm, 150µm, 212µm, 300µm, 425µm, 600µm and 850µm.

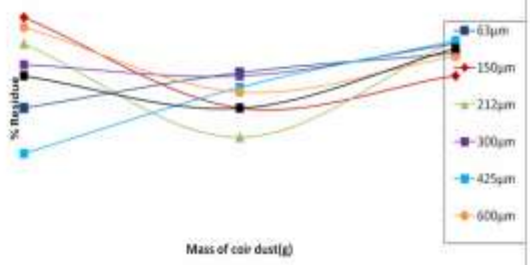

Fig. 5 - Plot of % Residue versus Mass of coir dust(g) of particle sizes for 63µm, 150µm, 212µm, 300µm, 425µm, 600µm and 850µm.

The amount of extracts using acetone as solvent is lower than that from using water (Table 4, 5). The difference in the amount of extract from water and acetone is attributed to the differences between the two solvents. Water is polar with high polarizability, boiling point, solubility parameter and dielectric constant. Acetone is non-polar, low boiling point, dielectric constant and polarizability and solubility parameter.

The solubility parameter of water is $\delta_{water} = 23.1$ while that of acetone $\delta_{acetone} = 9.71$ lower than of water [8]. As expected, smaller particle sizes yielded more extract than larger sizes. [42] reported increase in quantity of extracts with decreased particle sizes for the extraction of tannins from walnut (*Juglens regia L*). Similar results on the effect of particle sizes on the amount of extracts have been reported [24, 29].

Table 4: Extraction of 1g of Coconut Coir Dust (150µm) using Different Solvent Mixtures

Solvent (100ml)	Mass of Extract	% Extract
Water	1.131±0.05	13.1
Acetone	0.066±0.001	6.60
Acetone/Water (70/30)	0.20±0.001	20.0
Acetone/Water (50/50)	1.042±0.001	4.20

Table 5: Phytochemical Screening of Acetone Extract of Coconut (*Cocos nucifera L.)* Coir Dust

Test	Observation	Inference
Tannins 10ml of acetone extract filtrate + few drops of $FeCl_3$ reagent.	Blue-black precipitate	Tannins present
5 drops of filtrate from acetone extract + 10ml of deionized water + 3 drops of bromine water.	Brownish colour of filtrate was decolorized	Tannins confirmed
Flavanoids Few pieces of magnesium ribbon + 5ml of filtrate + 3 drops of conc. Hcl.	Red coloured solution	Flavaniods present
Polyphenols 1ml of filtrate from acetone extract + 2 drops of mixture of 1ml 1% $FeCl_3$ solution with 1ml of 1% Potassium Ferricyanide.	Green-blue coloration	Polyphenols present
Phlobatannins 2ml of filtrate from acetone extract + 1ml dil. Hcl and boiled for 2 minutes in a test tube.	Pale yellow colour	Phlobatannins present
Anthraquinone 2ml of filtrate from acetone extract + 2 drops of 3% NH_4OH.	No red coloration	Anthraquinone absent
Saponnins *Frothing test:* 1ml of filtrate from acetone extract shakened vigorously.	No formation of lather	Saponnins absent
Emulsion test: Two drops of olive oil was added to the mixture in frothing test above.	No emulsion formed	Saponnins absent

Extraction of Coconut Coir of Particle Sizes (150 μm) using Different Solvent System

The extraction of $1g$ of coconut coir dust of particle size $150\mu m$ using different solvent mixtures-water, acetone, Acetone/water $\left(\genfrac{}{}{0pt}{}{\frac{70}{30v}}{v}\right)$ and acetone/water $\left(\genfrac{}{}{0pt}{}{\frac{50}{50}v}{v}\right)$ and results are presented in Table 4.

From the result acetone/water $\left(\frac{70}{30}\right)$ was found to be best solvent systems as it extracted the highest quantity (20%) of extractives from $1g$ of coir dust while the least was acetone/water $\left(\frac{50}{50}\right)$ extracting only 4.2%. [40] have reported acetone/water $\left(\frac{70}{30}\right)$ as the best solvent system for extraction of tannins in tropical forage and tannins from black wattle (Acacia mearnsii). The high efficiency of this solvent combination for the extraction of coir dust may be attributed to an optimum level of interplay of the properties of the two solvents - water and acetone at this combination. It seems that there is a synergistic interplay of the properties of these two solvents. These properties of solvents that play significant role in dissolution of solutes include polarity, dielectric constant, polarizability, polarizing power, hydrogen bonding and solubility parameter. Water is polar aprotic solvent while acetone is non-polar protic solvent with low dielectric constant having no hydroxyl (OH) groups as found in water. Water solvent extract negative species in the solute through hydrogen bonding while acetone $CH_3-C(=O)-CH_3$ with its large dipole solvents extract only positively charged organic species [40].

Water extracts through hydrosolubilization and hydro cracking of sugar components in the coir dust, hence more extracts from water than that from acetone. The least amount of the extract (4.20%) obtained from acetone-water $\left(\frac{50}{50}\right)$ may be due to the low level of interaction of solute/solvent properties with coir components at this solvent combination. Poor tannin and lipid extractions with acetone from black acacia (Acacia mearnsii) and walnut (*Juglan regia L*) have been reported [20, 40, 42].

Phytochemical Screening of Acetone Extract of CoconutCoir Dust

Phytochemical screening of acetone coir extract for the presence of active ingredients such as tannins, flavonoids, polyphenols, phlobatannins, saponins, anthraquinone's are presented in Table 5. Tannins, flavonoids, polyphenols, phlobatanins were present but absence of anthraquinones and saponins in the acetone coir extract. The presence of tannins and polyphenols been reported in coir dust [25, 45]. Tannins are the major polyhydroxy compounds extractable from plant materials-barks, fruits, leaves, seeds and roots using polar, non-polar or mixed solvent systems. They are not pure chemical compounds with known structures but contain numerous components with phenolic moieties such as catechol and pyrogallol condensed into a complicated polymeric structure [27].

Conclusion

The present investigation was undertaken to evaluate the effectiveness of unmodified coir dust (a coir industry based lignocellulosic material) and acetone extract of coir dust in removing metal ions from aqueous solution. The phytochemical screening of the acetone extract indicated the presence of tannins, flavonoids and other polyphenols. The characterization of unmodified coir dust determined according to standard methods showed the moisture content, ash, cellulose and lignin and pH of aqueous solution of coir dust were 25.2%, 9.0%, 35.99%, 33.5% and 6.4 respectively. Unmodified coir dust is composed of lignin (53.0%), cellulose (35.5%) with extractables which makes it a more efficient low cost agricultural biomass for metal detoxification of waste water and industrial effluent for reuse and convenient disposal into the environment.

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