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Preparation and Characterization of Biochar and Activated carbon derived from Cashew Bagasse Waste

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Abstract

Biochar and Activated carbon derived from cashew bagasse waste (CBB and CBAC), are veritable materials produced from agro-waste. They are currently under-utilized owing to paucity of information in their recycling methods which reduces agricultural waste from the environment. This study investigates the use of under-utilized cashew bagasse waste in the production of biochar and activated carbon using pyrolysis and chemical activation methods, respectively. Cashew bagasse waste was pyrolysed at 400⁰C for 20mins at 10⁰C/min. The biochar was chemically activated using 0.3M orthophosphoric acid (H₃PO₄) at an impregnation ratio of 1:2.36(w/w). It was heated at 100⁰C to form a paste and placed in a muffle furnace at 500⁰C for 30 mins. This was cooled and washed until pH was neutral. It was oven dried at 105⁰C for 24 hours to a constant weight to produce CBAC. Characterization of CBB and CBAC for its pH, bulk density, and moisture content, dry matter, volatile matter, and fixed carbon were determined. FTIR and SEM analysis on CBB and CBAC was done to determine the functional groups and surface morphology, respectively. The Data obtained were analyzed using descriptive statistics and ANOVA at P value ≤ 0.05. This study, therefore, revealed CBAC to have better characteristics than CBB.

Introduction

Cashew (*Anacardium occidentale*) is a tree of potential significance in the developing tropical world. They are widely grown and distributed in South Western and North Central Nigeria, due to the economic potential of the seeds. Manufacturing confectionery companies in Nigeria, process cashew fruits in combination with other fruits into fruit juice, as they are rich in mineral nutrients such as (calcium, iron, potassium) and vitamin C [1].

However, cashew bagasse, residue remaining after nut and juice extraction are discarded as agricultural waste, due to its astringent taste and high tannin content of 0.64mg/100g that decreases palatability and digestibility [1]. This agro-waste is however a potential material contributing to the productivity and sustainability of animal farming (aquaculture) in Nigeria.

Biochar are pyrogenic materials of porous carbonaceous nature with various processing potentials [2]. They are produced during thermochemical decomposition of biomass feedstock or agro waste materials in the presence of little or no oxygen [3]. The conventional carbonization method for biochar production is pyrolysis, as biochars from other methods generally do not meet biochar definition as specified in the European Biochar Certificate guidelines [4].

The biomass feedstock or agro waste materials for biochar production include organic waste materials like crop and forest residues such as; wood chip, algae, sewage sludge, manures, and organic municipal solid wastes [5]. Biochar after chemical activation are precursors of activated carbon of high adsorption and coagulation ability [2, 6, 7]. They are amorphous compounds produced from carbon containing materials, with their quality depending on several other factors, such as carbonization temperature, activation time, residence time and particulate matter size [7]. Several modification processes are involved in activated carbon production; which includes physical and chemical modification [7].

The preparation, processing, application of biochar and activated carbon from cashew bagasse, has become a current veritable material that are under-utilized in sustainable aquaculture practices in the developing world. This is due to paucity of information in their recycling methods, which help reduce agro-environmental waste. This study therefore investigates the use of under-utilized cashew bagasse waste in the production of biochar and activated carbon using pyrolysis and chemical activation methods, respectively.

2. Experimental

In this study, fresh cashew fruits were harvested from Landmark University, Omu-Aran Kwara State, Nigeria. The fruits were firstly washed thoroughly with distilled water to remove physical dirt and impurities. Thereafter, the nuts were removed manually and the juice squeezed out using muslin cloth after blending to a paste, leaving behind the residue (cashew bagasse). The bagasse was later sundried for 2 hours and weighed on OHAUS electronic weighing sensitive scale (PA4102). It was later oven dried at 105⁰C for 24 hours using Gen Lab oven (B8A76740) till a constant weight was obtained. This was further crushed with mortar and pestle to reduce the particle size.

2. 1 Preparation of cashew bagasse biochar (CBB)

Pyrolysis of cashew bagasse was carried out at Animal Science Laboratory, Landmark University, Omu-Aran, Kwara State, using a box type muffle furnace (NC-26) at 400⁰C for 20 mins, at a heating rate of 10⁰C/min. The carbonized sample was then placed in Clifton water bath (NE2-22D) to cool down furnace heating effect on the biochar. It was then crushed with Euro premium grinder (EP-06) to reduce particle size and sieved with 2mm sieve to obtain fine particle size. It was then packaged in air tight bottles in preparation for further analysis.

2. 2 Preparation of cashew bagasse activated carbon (CBAC)

Preparation for CBAC was done according to methods carried out by Ekpete and Horsfall, [8], with slight modifications. 50g of CBB was carefully weighed and placed in 1 liter beaker containing 1000ml of 0.3mol/dm³ of diluted ortho-phosphoric acid (H₃PO₄) as the activating agent. The content of the beaker was thoroughly mixed using a magnetic stirrer and boiled down on a hot plate, at a mild temperature of 100⁰C until a paste was formed.

The paste was later transferred to an evaporating dish and placed in the furnace at a temperature of 500⁰C for 30mins, to remove impurities. It was then allowed to cool down in a desiccator and washed with distilled water to remove the acid until a neutral pH was obtained.

Afterwards, it was oven dried at 105⁰C for 24 hours to a constant weight and sieved to 100µm mesh size to obtain fine powdered activated carbon and later kept in air tight plastic containers prior to other analysis.

2. 3 Biochar yield and characterisation of biochar and activated carbon

Biochar and activated carbon produced from cashew bagasse and kariya leaf were characterised to determine their basic properties. The characterisation includes analysis of; pH, bulk density, volatile matter, fixed carbon, moisture content, dry matter, and biochar yield.



Figure 1. Cashew bagasse (CB)



Figure 2. CB biochar



Figure 3. CB activated carbon

2.3.1 Biochar yield

The biochar yield (percentage of biochar obtained after pyrolysis) was calculated using the formula adopted from Omoniyi and Salami [9].

$$\% \text{ Biochar yield} = \frac{W_1}{W_2} \times 100$$

Where,

W_1 = Weight of the plant materials after pyrolysis

W_2 = Weight of plant materials before pyrolysis (the oven dry weight of the sample)

2.3.2 pH determination

The pH of CBB and CBAC were determined according to a method carried out by Anisuzzaman *et al.*, [10]. 1g of each sample was put into a 250ml Erlenmeyer flask. Afterwards, 100ml of distilled water was added and heated up on a hot plate at 100°C for 5 mins under gentle boiling conditions. After cooling to room temperature, it was further diluted to 200ml with distilled water. The solution was stirred with a magnetic stirrer, with pH readings recorded using a digital pH meter (PHS-3C). All biochar and activated carbon samples were run in triplicates.

2.3.3 Bulk density determination

The Bulk Density for CBAC and CBB were determined following Dada *et al.*, [11] method using Archimedes' principle. Empty measuring cylinder of 10cm³ was weighed and recorded. This was followed by weighing and recording the measuring cylinder after filling it with distilled water, up to the 10cm³ mark. The measuring cylinder was later emptied and dried, before filling it with CBAC and CBB to 10cm³ mark and later reweighed.

The weight of CBAC and CBB samples in the measuring cylinder was determined from the difference in weight of filled and empty measuring cylinder. The volume of water in the cylinder was ascertained by taking the difference in weight of the empty and water filled-measuring cylinder. The bulk density of samples were determined using the equation below;

$$\text{Bulk density} = \frac{W_2 - W_1}{V}$$

Where,

W₁= Weight of empty measuring cylinder

W₂ = weight of cylinder filled with sample

V = volume of cylinder

2.3.4 Volatile matter and fixed carbon determination

This was determined according to a method carried out by Ekpete and Horsfall, [8], with slight modifications. An evaporating dish was pre-heated in the muffle furnace to 500°C, allowed to cool in a desiccator and weighed. Ig each of CBAC and CBB in the dish were placed in the oven at 105°C for one hour.

The weight of the dried sample was taken and placed in a muffle furnace at 500°C for 10 mins to determine the measure of non-water gases formed from the sample. This was later removed and allowed to cool in a desiccator to room temperature to prevent atmospheric moisture absorption and reweighed. Volatile matter was determined using the equation below;

$$\% \text{ Volatile matter} = \frac{\text{Weight of sample after oven dry-weight of sample after furnace}}{\text{Weight of sample after oven dry}} \times 100\%$$

The Fixed carbon content of CBAC and CBB samples were determined using the formula;

$$\% \text{ Fixed carbon content} = 100\% - (\% \text{ Volatile matter} + \% \text{ Ash content}).$$

2.3.5 Moisture content and dry matter determination

The moisture content of CBAC and CBB were determined according to method carried out by Ekpete and Horsfall, [8]. 1g of each sample was weighed into a washed crucible that has been dried and weighed. The sample was then oven dried at 110⁰C for 2 hours to constant weight, using Gen Lab oven (B8A767400).

The samples were later removed from the oven and rapidly transferred into the desiccators to cool down to prevent moisture absorption from the atmosphere. It was later reweighed immediately to determine moisture loss.

The moisture content was determined using the formula;

$$\% \text{ Moisture content} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

Where,

W_1 = weight of crucible,

W_2 = initial weight of crucible with sample before oven dry,

W_3 = final weight of crucible with sample after oven dry

The Dry matter content of biochar and activated carbon samples were determined using the formula;

$$\% \text{ Dry matter} = 100 - (\% \text{ Moisture content})$$

2.4 SEM and FTIR analysis

Scanning Electron Microscopy (S.E.M) and Fourier Transform Infrared Spectroscopy (F.T.I.R) analyses were carried out to determine the surface morphology and functional groups present in CBAC and CBB, respectively. The SEM analysis was carried out using PRO: X: Phenom World machine, Serial number MVE01570775 and Model Number 800-07334. The FTIR analysis was carried out using (FTIR-IR Affinity-1S Shimadzu, Japan).

3. Result

3.1 Biochar yield of cashew bagasse

The result of biochar yield obtained after pyrolysis of cashew bagasse is presented in Table 1.

Table 1. Biochar yield

Plant material	Dry weight	Pyrolysis temperature	Residence time	Weight of biochar	% yield
Cashew bagasse	230.17g	400 ⁰ c	20mins	92.82g	40.33

3.2 Characterisation of biochar and activated carbon

The characterisation results of CBB and CBAC based on pH, bulk density, volatile matter, fixed carbon, moisture content and dry matter are depicted in Table 2 and 3, respectively.

Table 2. Characterisation result of cashew bagasse biochar

Coagulants	pH	Bulk Density	Ash content	Moisture content	Dry matter	Volatile matter	Fixed carbon
CBB	7.68±0.06 ^c	0.18±0.01 ^{ab}	1.09±0.03 ^a	6.67±0.33 ^b	93.33±0.33 ^a	68.67±3.18 ^a	30.24±3.20 ^c

Table 3. Characterisation result of cashew bagasse activated carbon

Coagulants	pH	Bulk Density	Ash content	Moisture content	Dry matter	Volatile matter	Fixed Carbon
CBAC	6.13±0.03 ^f	0.20±0.01 ^a	1.01±0.06 ^a	16.00±0.58 ^{ab}	84.00±0.58 ^{ab}	29.67±5.21 ^c	69.32±5.16 ^a

Legend: CLAC = Cashew Leaf Activated Carbon; CLB = Cashew Leaf Biochar; KLAC = kariya leaf Activated Carbon; KLB = kariya leaf Biochar; CBAC = Cashew Bagasse Activated Carbon; CBB = Cashew Bagasse Biochar. Means with different superscript alphabets along horizontal columns are significantly different ($p < 0.05$) while means with the same superscript alphabet are not significantly different ($p > 0.05$). Means with different superscript alphabets along the vertical column are significantly different ($p < 0.05$) while means with the same superscript alphabet are not significantly different ($p > 0.05$).

4. Discussion

4.1 Biochar yield of cashew bagasse

Studies have shown that increase in pyrolysis temperature and residence time of biomass feedstock, generally decreases biochar yield [12, 13]. This observation is in agreement with studies carried out by Nwajiaku *et al.*, [12], as sugarcane bagasse of 10kg pyrolysed at 400°C for 10 mins with 24% biochar yield, dropped to 22% when pyrolysed at 700°C for 10mins. Although sugarcane bagasse yield at 400°C, is still lower compared to 40.33% obtained for cashew bagasse from 230.17g when pyrolysed at 400°C for 20 mins. However, this may be due to the high lignin content of cashew bagasse contributing to high biochar yield, since lignin generally contains more than 60% carbon as shown in previous findings of lignocellulosic and cellulose materials [14, 15].

4.2 pH

The pH of carbon materials affects their surface charge, stabilization and solubility of coagulants aids in wastewater which ultimately affects their ability to remove pollutants from wastewater [16]. The pH of CBB after carbonization of 7.68 ± 0.06 ° was alkaline in nature. Similar findings have also been obtained by Nwajiaku *et al.*, [12], for sugarcane bagasse biochar, having pH value of 8.3 ± 0.1 . This observation is in agreement with the statement of Ortiz *et al.*, [17], that biochar pH are generally alkaline in nature. The pH ranges from of 7.1 to 10.5 especially when pyrolysed at high temperature resulting in the loss of acidic functional groups that are replaced with alkali salts and alkaline earth metals such as carbonates and silicates that contribute to biochar alkalinity [18, 19, 20].

However, the observed pH for CBAC of 6.13 ± 0.03 ° was slightly below neutral, showing it has some acidic property [21]. Studies have also shown that biochar modification using acid generally introduces acid functional groups onto the surface of activated carbons [4].

This also agrees with the study carried out by Ekpete and Horsfall, [8], on chemical activation of biochar from fluted pumpkin stem with (H_3PO_4) as activation agent, with pH value of 6.7 under similar condition. Ortho-phosphoric acid (H_3PO_4) has shown according to several literatures as the most effective activating agent used in the production of activated carbon with more pores, surface area and functional groups for effective coagulation and adsorption [21, 22, 23].

4.3 Bulk density

The bulk density of CBB and CBAC was carried out to determine their floatability property, whether they will either sink or float in contact with wastewater, since carbon materials with bulk densities less than 1 g/cm^3 will generally float and may also suffer from handling and processing difficulties. Thus, requiring biochar materials to be in granules or pellet form before usage [24, 25]. The bulk densities for CBB and CBAC were $0.18 \pm 0.01 \text{ g/cm}^3$ and $0.20 \pm 0.01 \text{ g/cm}^3$. This shows they will both initially float when in contact with water. However, as water penetrates the air-filled pores of both biochar and activated carbon, their functional densities gradually increase, causing both biochar and activated carbon to sink afterwards [25].

Bulk density results obtained in this study were similar to results obtained from a study on plantain fruit stem pyrolysed at 400°C for 1 hour as carried out by Ekpete *et al.*, [8]. The plantain fruit stem had bulk density value of $0.32 \pm 0.05 \text{ g/cm}^3$ after activation with ortho-phosphoric acid (H_3PO_4). However, bulk density 0.27 g/cm^3 and 0.56 g/cm^3 obtained for biochar and activated carbon respectively by Berger [26], were higher compared to the results obtained in this study.

4.4 Ash content

Carbonaceous materials which are inorganic, unstable, inert and amorphous in nature, are burnt off during carbonization leaving a residue called ash [21]. The ash content of CBB and CBAC were carried out to know the amount of carbon materials burnt off during the carbonization process, as it affect their quality [27]. CBB and CBAC with low ash content values of $1.09 \pm 0.03\%$ and $1.01 \pm 0.06\%$ respectively, is normal particularly for pure organic materials bereft of impurities, which makes them more controllable especially when incorporated into soils.

This also implies that CBB is suitable for use as phyto-coagulants since almost all was converted to carbon [8], compared to high ash content values observed in other studies, which indicates high mineral impurities, majorly sand [15,20, 28,]. Increase in pyrolysis temperature causes build-up of inorganic elements, formation of mineral salt and silica content present in the raw materials, might have also contributed to the high ash content values observed in other studies [27, 29, 30]. In addition, excessive ash content clogs the pores attached to the surface of carbon materials, which further reduces their surface area, mechanical strength and coagulative ability

4.4 Moisture content and dry matter

The moisture content of CBAC and CBB were carried out to determine their hygroscopic properties. As carbonization time increases more pores unclog with more water given off [31]. CBB has moisture content and dry matter of $6.67\pm 0.33\%$ and $93.33\pm 0.33\%$, respectively. This low moisture content shows it has high potential for storage over an extended period of time without absorbing excessive moisture within the environment [32].

However, the moisture content and dry matter for CBAC of $16.00 \pm 0.58\%$ and $84.00 \pm 0.58\%$ respectively, was higher than that of rice husk activated carbon of 6.20% at 400°C for 90mins [33]. This was slightly above 15% maximum for moisture content present in activated carbon according to Indonesian Standard SNI No. 06-3730-199 [33].

In addition, some biochar materials when stored under humid conditions tend to absorb considerable amounts of moisture up to 25 to 30 % from the atmosphere during their cooling process, due to their hygroscopic characteristics [32, 34].

Although, they tend to look dry while weighing and packing them for further analysis. However, this is because, after activation the pores present on the surface of the activated carbon becomes bigger, which automatically increases its surface area. This results in further increases the capacity of activated carbon to absorb more moisture from the atmosphere [35].

Also, the activation process of CBAC using orthophosphoric acid (H_3PO_4) further introduces functional groups like carboxyl and hydroxyl groups onto the surface of the activated carbon. This increases its absorption capacity for polar molecules like water vapour, which increases its moisture content [36]. In addition, the washing process of activated carbon with deionised water to remove orthophosphoric acid (H_3PO_4) as part of the activation process, causes the activated carbon to swell, hence its observed high moisture content compared to its biochar [37].

4.5 Volatile matter

The volatile matter of CBB and CBB were carried out to determine the portion of carbon materials given off as gases and volatile liquids, during pyrolysis. Examples of such gases given off includes; methane (CH_4), carbon monoxide (CO), hydrogen (H_2), including non- combustible gases like CO_2 and H_2O [38]. Volatile matter of CBB of $68.67\pm 3.18\%$, was lower than that of CBAC of $29.67\pm 5.21\%$. The high volatile matter content present in CBB shows they are good precursors for activated carbon.

Volatile matter are mostly released at high levels when pyrolysis temperature is between 400-500°C [39]. This was actually observed in the case of CBB having high volatile matter content of 68.67 %, when pyrolysed at 400°C for 20 mins. Similarly, a study by Chen *et al.*, [40] on municipal sewage sludge when pyrolysed at 900°C for 20min had volatile matter of 87.5%. However, when present in high concentration, they generally affect the stability and coagulation activity of the biochar as they fill the micropores attached to the biochar surface [41, 42].

Both CBAC and CBB exceeded the maximum volatile matter permitted by SNI 06-3730-1995 of 25% [43]. This significant reduction in volatile matter for activated carbon could be attributed to the activating agent used (H_3PO_4), as it has the ability to reduce the volatile matter content. It does this by modifying the properties and structure of activated carbon, as they degrade the organic material present in them, thereby weakening the surface structure of activated carbon. In the process, volatile matter is released and the level present in the activated carbon is further reduced [27, 37, 44].

4.6 Fixed carbon

The fixed carbon which represents the amount of solid carbon residue remaining after pyrolysis, is an important quality index for both biochar and activated carbon [45]. The lignin content in biomass feedstock majorly contributes to this and it is influenced by moisture content, volatile matter and ash content of carbon materials [46]. CBB had fixed carbon of $30.24 \pm 3.20\%$ and CBAC had fixed carbon of $69.32 \pm 5.16\%$.

The fixed carbon for CBAC was greater than that required by SNI 06-3730-1995 of 65% [43]. The formation of a large amount of ash content actually reduces the amount of fixed carbon [45]. This was observed in the case of CBB having the least fixed carbon content of $30.24 \pm 3.20\%$ with the highest level of ash content of $1.09 \pm 0.03\%$.

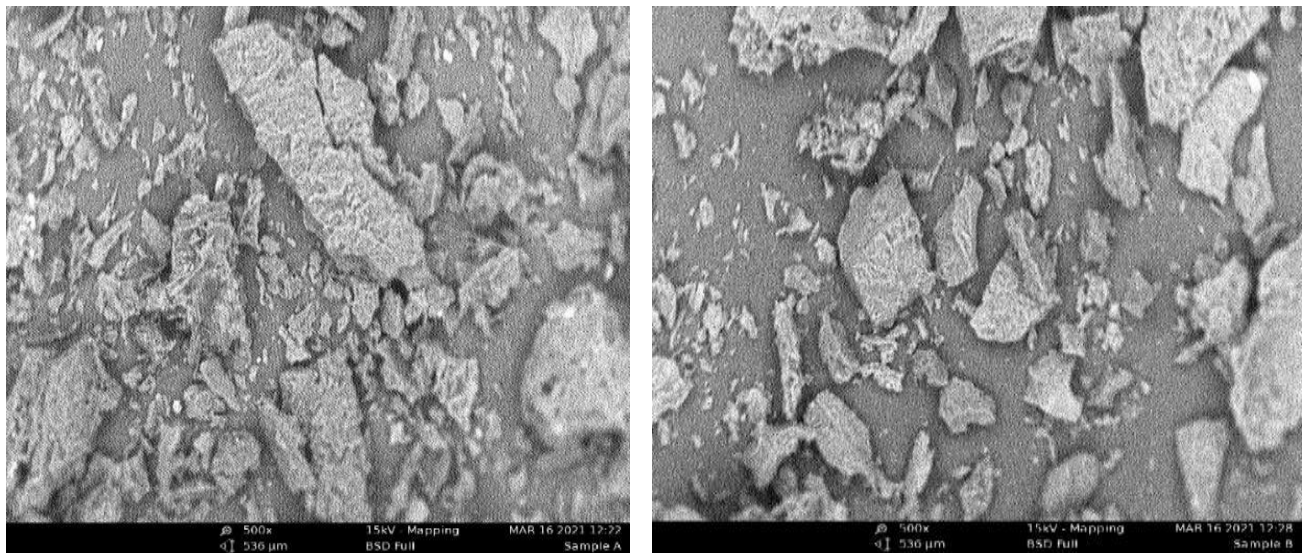
However, results obtained for sugarcane bagasse as observed in another study, contained more fixed carbon content of 54.55% with ash content of 10.25% under pyrolysis condition of 400°C for 20 mins [24]. This high value observed in sugarcane bagasse was because volatile matter was more released leaving a more stable biochar with volatile matter of 35.20%, compared to cashew bagasse biochar with a volatile matter content of $68.67 \pm 3.18\%$.

4.7 Scanning Electron Microscope (SEM) Analysis

The surface morphology for CBB and CBAC at 500 x magnification are shown in Figure 4. CBB showed the presence of whitish particles and sticky structures on the biochar surface. This might be due to incomplete combustion during the carbonization process in the muffle furnace [47]. CBB also showed more coarse and compacted characteristics, including few pores and cavities.

This observed morphology must have been attributed to countless volatile components in the form of organic matter and impurities present in the biochar before activation. Organic matter decomposition during carbonization process however, must have led to the escape of several volatile components in the biochar which must have resulted into it having such morphology [48]. Also the heterogeneous surface nature, and irregular shape of CBB suggests its efficient feasibility in the coagulation of heavy metals and organic pollutants [47].

However, for CBAC the SEM result was less compacted, having an uneven surface with well-developed micropores of different shape and sizes. The developed micropores of different shape and sizes, resulting from the hollow structures must have been an indication of successful activation process of orthophosphoric acid (H_3PO_4), as a result of the heat treatment which erodes fine particles and open up the pores in the process [47]. In addition, the particle size for CBAC was smaller compared to CBB. This suggests a high degree of decomposition and chain break resulting from the various functions of H_3PO_4 and O_2 . [49].



(a) Biochar

(b) Activated carbon

Figure 4. Scanning Electron Microscope (500x)

4.8 Fourier Transform Infra-Red (FTIR) Analysis

The analysis of CBAC and CBB showed the presence of several functional groups detected on their exterior at their peaks at different wavelengths as depicted in Figure 5. CBB had functional groups of O–H stretching, C–H stretching, C≡C stretching, C=O stretching, and C–N stretching. The presence of OH bonds shows that CBB tends to be more polar. However, CBAC had functional groups of C=O stretching, C=C stretching, C–C stretching, C–H stretching, C–N stretching and C–Cl stretching. The spectra for CBB had a long stretch bandwidth around 3500–3200 cm^{-1} , while CBAC long stretch bandwidth was around 3500–2300 cm^{-1} , both showing the presence of O–H and C–H functional groups located at different bandwidths.

Also the wavelength located around peak 1620.40 cm^{-1} had the O–H functional group. The presence of O–H functional group could be attributed to some adsorbed water possibly from hydroxyl, carboxyl, alcohol or phenol groups confirming the hydrophilic nature of the biochar [50], while C–H could be due to pyrolysis process as well as chemical reactions taken place by the carbon surface material [51]. Also CBB, had its weak band at 2910.08 and 2752.11 cm^{-1} which were characteristic of aliphatic C–H and alkynes C≡C stretching. However, the CBAC weak band was at 2300.15 cm^{-1} which was characterized by O–H stretching. Also, the coagulation band of CBB had a sharp wavelength at peak 1698.10 cm^{-1} and characterized by carbonyl C=O stretching.

In the same vein, CBAC coagulation bands located around 1750.82 and 1698.10 were also attributed to the presence of carbonyl C=O functional group stretching. According to El Qada *et al.*, [52], the presence of carbonyl functional groups in biochar makes them dissociate and become negatively charged which promotes the activities of electrostatic attraction between negatively charged pollutants.

Also, CBB peaks at 1300.48 cm^{-1} were attributed to C–H bending vibration of alkenes, while peaks at 1224.60 cm^{-1} were attributed to C–H stretching alkane or alkyl groups associated with proteins. Whereas, CBAC sharp peaks of 1499.99 cm^{-1} were attributed to C–H bending vibration of alkenes. Also, CBB peaks at 749.11 cm^{-1} had CH out-of-plane deformation, while at peak of 624.30 cm^{-1} was CH bending vibrations observed. Also, at peak 592.25 cm^{-1} there was deformation of the C–H rocking vibration and at 520.00 cm^{-1} peak, there was a broad C–O–H twist. In contrast for CBAC, C–C functional groups were found around 700.65 cm^{-1} band width.

More so, a slight decrease in intensities of various peaks that were observed in the case of CBAC compared to CBB. This might be due to loss of some acid-soluble components present in CBB [53]. Biochar activation using orthophosphoric acid, helped increase the number of oxygen-containing functional groups including hydroxyl groups, carboxyl groups, and carbonyl groups on the carbon surfaces of CBAC. This is noticed in the higher removal of heavy metals by CBAC compared to CBB. This observation is also similar to findings obtained by [54]

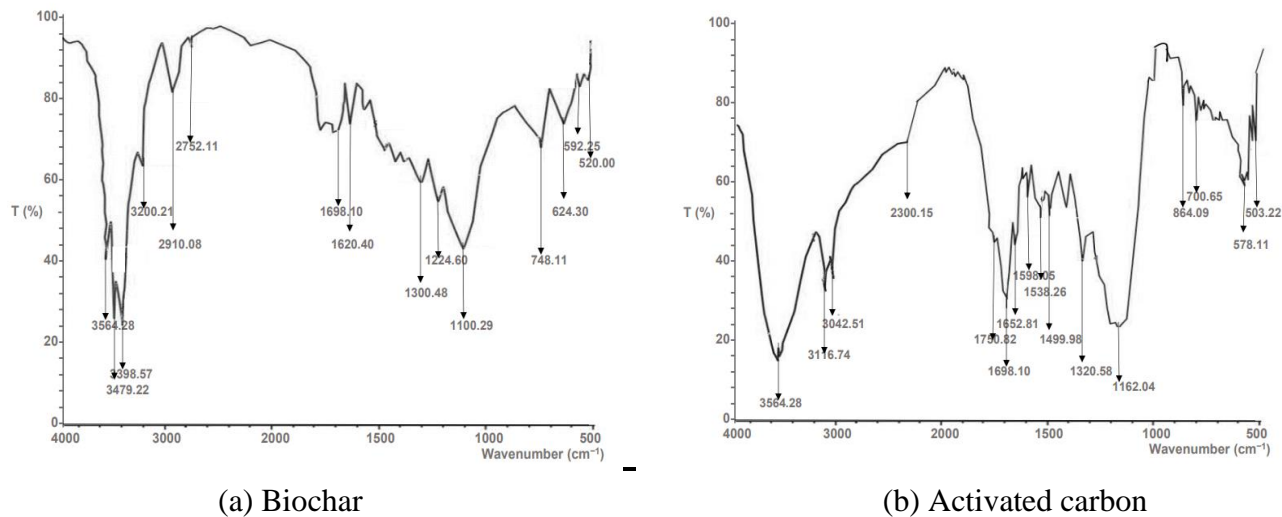


Figure 5. FTIR spectrum of cashew bagasse

5. Conclusion

Characterisation of biochar and activated carbon produced from cashew bagasse showed that CBB had pH, bulk density, ash content, moisture content, dry matter, volatile matter and fixed carbon of 7.68, 0.18%, 1.09%, 6.67%, 93.33%, 68.67% and 30.24%, respectively. However, the pH, bulk density, ash content, moisture content, dry matter, volatile matter and fixed carbon for CBAC was 6.13, 0.20%, 1.01%, 16.00%, 84.00%, 29.67% and 69.32%, respectively.

The moisture content and ash content of CBB met the requirements of the National Industrial Standard 06-3730-1995. Also activation of CBB with orthophosphoric acid (H_3PO_4) to produce CBAC further helped to improve the biochar characteristics. Hence, it can be concluded that CBAC can be used for other analyses like wastewater treatment.

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