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Research Article

Assessment of Proximate and Biomass Composition of Cori Fibre for Potential Industrial Application

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Abstract:

Background: The versatile nature of coconut (Cocos nucifera L.) husk fibres, known as Cori fibres, makes them suitable for various industrial applications. This study aims to assess the biomass composition of Cori fibres to explore their potential in industrial applications.

Materials and Methods: Coconut husks were procured from Ihiagwa market, Owerri, Nigeria, and processed to obtain Cori fibres. The fibres were cleaned, dried, and weighed. A comprehensive proximate analysis was performed, including moisture content (ASTM E1756-08), ash content, carbon content, crude fibre, crude fat, and crude protein (Kjeldahl method). Biomass characteristics such as pectin, amylopectin, cellulose, lignin, and hemicellulose contents were also determined using standard methodologies.

Results: The proximate analysis revealed the following composition of Cori fibres: moisture content (7.43 ± 0.33%), carbohydrate content (71.85 ± 0.25%), ash content (3.15 ± 0.13%), crude fibre (1.39 ± 0.40%), protein content (11.15 ± 0.60%), and crude fat (5.02 ± 0.35%). Biomass characteristics included water absorption capacity (51.51 ± 3.23%), density (0.93 ± 0.03 g/ml), cellulose (9.42 ± 0.12%), hemicellulose (20.77 ± 0.19%), lignin (10.92 ± 0.09%), and pectin (9.74 ± 0.10 mg/kg).

Conclusion: The detailed composition analysis of Cori fibres suggests their significant potential for various industrial applications, particularly in areas where fibre strength, absorbency, and density are critical.

Key words: Coconut husk, Cori fibres, biomass composition, proximate analysis, industrial application, cellulose, hemicellulose.

Introduction

Biomass, an organic material derived from plants and animals, plays a vital role in various industrial applications due to its renewable nature and environmental benefits [1]. The increasing global emphasis on sustainable and eco-friendly resources has intensified the research on biomass, particularly plant-based biomass, for its potential to replace conventional non-renewable materials. Biomass from agricultural residues, such as coconut husk, presents a viable alternative owing to its abundance and relatively low cost.

Coconut (Cocos nucifera L.) is widely cultivated in tropical regions, and its husk, typically considered an agricultural waste, constitutes a significant proportion of the fruit's biomass. The husk comprises fibres and pith, where the fibres, known as coir, are of particular interest due to their unique properties. Coir fibre is noted for its high lignin content, which imparts durability and resistance to microbial degradation, making it suitable for various industrial applications including textiles, packaging, and composites [1].

The composition of coir fibre includes cellulose, hemicellulose, lignin, and minor amounts of other components like pectin and ash. The lignocellulosic nature of coir fibre endows it with high tensile strength and resistance to wear and tear, which are desirable characteristics for industrial materials. Studies have shown that the proportion of these components can significantly influence the fibre's mechanical properties and its suitability for different applications [2].

Coir fibre has been extensively studied for its potential in various industrial sectors. In the construction industry, coir fibre-reinforced composites are used for making panels, boards, and insulation materials due to their favorable mechanical properties and thermal insulation

capacity [3]. In the automotive industry, coir fibre is utilized in manufacturing biodegradable composites for interior components, offering an eco-friendly alternative to synthetic fibres [4]. Additionally, coir fibre's natural resilience and water resistance make it suitable for geotextiles and erosion control products [5].

Recent research has focused on enhancing the properties of coir fibre through chemical and physical treatments. Techniques such as alkali treatment, enzymatic processing, and graft copolymerization have been employed to modify the fibre's surface characteristics, thereby improving its adhesion with polymer matrices in composite materials [6]. Moreover, advancements in nano-engineering have led to the development of coir-based nanocomposites, which exhibit superior mechanical and thermal properties [7].

Despite the extensive research on coir fibre, there remains a need for comprehensive studies that assess the biomass composition of coir fibre from different geographical regions and cultivation practices. Such studies are essential to optimize the utilization of coir fibre for specific industrial applications. The assessment of biomass composition, including proximate analysis and characterization of chemical constituents, provides critical insights into the quality and suitability of the fibre for various end-uses [8]. This study aims to assess the biomass composition of coir fibre for potential industrial applications.

Materials and Methods

Sample collection and preparation

Coconut (Cocos nucifera L.) husk was purchased at Ihiagwa market, located 7 kilometers away from Federal University of Technology, Owerri. It was transported to the laboratory. The husk was washed under running water to remove some sand in particular, the husk was sliced into pieces for easy drying, and the sample was put into an oven for easy drying. After oven drying, the sample was weighed to get the initial weight of the fibre, this was achieved using the analytical balance

Proximate Analysis

Moisture Content

Moisture content was determined using the methods of AOAC [9]. Briefly, a crucible was washed and dried in the oven. Approximately 2 g of the sample was weighed into crucible. The weight of the crucible and sample was noted before drying. The crucible and sample were put in the oven and heated at 105-200 oC for 2hr, the result noted and heated for another 1hr until a steady result was obtained and the weight was noted. The drying procedure was continued until a constant weight was obtained

% Moisture content = [(W1 – W2) ÷ weight of sample] × 100

Where: W1 = Weight of crucible & sample before drying.

W2 = weight of crucible & sample after (drying to constant weight).

Percentage Dry Matter (%DM) = 100 – Moisture content.

Carbohydrate Determination

Carbohydrate content was determined using Antrone Method. Briefly, 1 ml of each of the prepared standard glucose solution was pipetted into different test tubes. One millilitre (1 ml) of the prepared sample solution was added to a different test tube and the volume of all test tubes were made up to 3 ml with distilled water. All tubes were transferred to ice cold water and 6 ml of Anthrone reagent was added. Blank was prepared with distilled water and Anthrone, and all tubes were heated for 5 mins in water bath. Absorbance of each test tube was read against the blank. A calibration curve of absorbance against concentration was plotted using the standard glucose concentration and the concentration of the sample solution was extrapolated from the curve.

Determination of Ash Content

Ash content was determined according to the method outlined by Airaodion et al. [10]. Briefly, empty crucible was washed, oven dried and the weight was noted. Approximately 2 g of sample was weighed into the crucible and placed in an oven at 200-300 oC till sample was ashed. The sample was cooled after burning and weighed

%Ash content = [(W3 – W1) ÷ (W2 – W1)] × 100

Where:

W1= weight of empty crucible.

W2 = weight of crucible and sample before burning.

W3 = Weight of crucible and ash.

Determination of Crude fibre

Crude fibre was determined using the methods outlined by Onabanjo and Airaodion [11]. Briefly, sample was defatted by weighing 2g of sample and adding 50ml of petroleum ether, stirred very well and decanted, repeat this step 3 more times. Boiled in water bath for 30mins with 200ml of a solution containing 1.25% of H_2SO_4 per 100 ml of solution. The solution was filtered through Linen. Washed with boiling water until the washings are no longer acid. Transferred the residue to a beaker and boiled for 30 mins with 200 ml of a solution containing 1.25 g for carbonate free NaOH per 100ml. Then filtered the final residue through Linen. The residue is dried in an electric oven and weighed. Then incinerated to ash, cooled and weighed. The loss in weight after incineration x 100 is the percentage of crude fibre.

%Crude fibre = (Weight of fibre ÷ Weight of sample) × 100

Determination of Crude Proteins

Crude protein was determined using Buiret method outlined by Airaodion et al. [12]. Briefly, 1ml of each of the prepared standard protein solution were pipetted into different test tubes. One millilitre (1 ml) of the prepared sample solution was added to a different test tube. Three millilitre (3 ml) of Buiret reagent was added to all test tube. A blank was prepared with distilled water and Buiret reagent. The content of each test tube was mixed very well and incubated at 37 oC for 10 mins. All tubes were cooled to room temperature and the absorbance of each test tube was read against the blank at 540 nm. A standard curve was plotted with the absorbance and concentration of the protein standard and the concentration of the sample was extrapolated from the curve.

Determination of Crude Fat

Crude fat content was determined using differential method.

Crude fat = 100 – (Moisture content + Carbohydrate content + Ash content + Protein content + Crude fibre).

Biomass Characteristics

Pectin Extraction and Determination

Two grams (2 g) of duplicate cassava samples were rinsed with neutral ethanol (80%) and then dried at 50-55 ºC and the pectin was extracted with a boiling solution of 0,25% oxalic acid and 0,25% ammonium oxalate and filtered. The filtered extract was centrifuged at 750 x g for 15 minutes (17). The pellet was suspended in 0,5 N NaOH, digested with thermostable α-amylase at pH 6.0 for 30 min at 100 ºC and allowed to cool, then pH was adjusted to 7.5 and incubated with protease VIII for 30 min at 60 ºC. After cooling the sample was adjusted to pH 4.5 and incubated with amyloglucosidase at 60 ºC for 30 min, the absorbance read at 620 nm.

Amylopectin Determination

Each sample was taken and 100.0±0.5 mg of each sample was measured into a clean and dry Erlenmeyer flask. Then 9 ml of 1N NaOH was added to the samples followed by 1ml of 95% ethanol. The samples were kept overnight to completely gelatinize the starch and obtain a clear viscous gelatinous solution. The flasks were washed several times using distilled water and transferred to 100 ml volumetric flasks and they were topped up using distilled water. The solutions were shaken well to completely dissolve the starch. Subsequently 5 ml of each solution which were prepared latest was transferred to other 100 ml volumetric flasks and they were covered via aluminium foils. Another volumetric flask was covered via aluminium foil and 5 ml 0.09 N NaOH was added to it. Then each of them was fed by 1 ml of 1 N acetic acid and 2ml of 0.2% Iodine solution. Then all the flasks were topped up by distilled water and shaken well. They were kept in the dark for 20 minutes and absorbance was measured at 620nm using the UVVIS spectrophotometer.

Determination of Cellulose

Cellulose content was measured according to Huang et al. [13] method. About 0.3g of sample was weighed into 50ml glass centrifuge tubes containing 50ml of water, centrifuged at 1500 rpm for 10mins, and the supernatant decanted. The sample was resuspended in 12.5ml glacial acetic and 2.5 ml of concentrated nitric acid and digested in a boiling water bath for 20min and the supernatant was collected. The supernatant was transferred to a Gooch crucible (w1), washed successfully with hot alcohol, 10ml of 90% benzene, and 60% of ether, dried and weighed, (w3) finally ashed (w2) and reweighed.

Determination of Lignin Content

0.3± 0.01g prepared sample was prepared to the nearest 0.1 mg and place it in a 16 x 100mm test tube. The initial sample weight was recorded as W1. Each sample was determined in duplicate, at minimum. Samples for total solids determination (LAP-001) was weighed out at the same time as the sample for the acid – insoluble lignin determination. If this is done later, it can introduce an error in the calculation because ground biomass can rapidly gain or lose moisture when exposed to the atmosphere. The average total solids value was recorded as Tfinal. 3.00 ± 0.01ml (4.92 ± 0.01 g) of 72% H_2SO_4 was added and a glass stirring rod was used to mix for 1 minute, or until the sample is thoroughly wetted. The test tube was placed in the water bath controlled at 30 ± 1oC and hydrolyzed for 2 hours. It was cooled in a desiccator and the weight, W2, the weight of the crucible, acid–insoluble lignin, and acid–insoluble ash to the nearest 0.1 mg were recorded

Hemi Cellulose Determination

Hemicelluloses content was measured according to Huang et al. [13] method. Approximately 1g of sample was weighed and placed in a 20 x 150 mm test tube and was recorded as w1, the initial sample weight. 15ml of 72% was added and stirred for 1 minute until the sample is thoroughly wetted. The sample was transferred to a 1000 ml Erlenmeyer flask and dilute to 500 ml of deionized water. The flask placed on the heating manifold and attach to the reflux condenser. Gently boiled and reflux for 4 hours. At the end of 4 hours, the condenser was rinsed with a small amount of deionized water before disassembling reflux apparatus. The hydrolyzed solution was placed on the crucibles. The weight of the collected filtrate was measured. The crucible and contents were dried at 105±30 oC for 2 hours. They were cooled in desiccators and recorded as w2 the weight of the crucible, the crucible and contents were placed in the muffle furnace and ignited at 575 oC for a minimum of 3 hours, or until all the carbon is eliminated. It was cooled in desiccator and record as w3.

Determination of Density

A 50ml pycometer bottle was thoroughly washed with detergent, water and petroleum ether, dry and weigh. The bottle was filled with water and weighed. After drying the bottle, it was filled with the oil sample and weigh

Calculation

$$\text{Density} = \frac{\text{weight of Xml sample}}{\text{Weight of Xml water}}$$

Results

The proximate composition analysis of coconut cori fibre reveals a moisture content of 7.43%, indicating a relatively low water content. The carbohydrate content is notably high at 71.85%, which suggests that the fibre is primarily composed of carbohydrates. The ash content is 3.15%, reflecting the presence of mineral residues. The crude fibre content is 1.39%, and the protein content is 11.15%, highlighting the fibre's modest protein levels. Additionally, the crude fat content is 5.02%, suggesting a moderate amount of fat in the fibre.

The biomass characteristics of the cori fibre extract show a water absorption capacity of 51.51%, indicating its ability to retain a significant amount of water. The density of the fibre is measured at 0.93 g/ml, which provides insight into its mass per unit volume. The cellulose content is 9.42%, while the hemicellulose content is higher at 20.77%. The lignin content stands at 10.92%, which contributes to the fibre's structural integrity. Lastly, the pectin content is 9.74 mg/kg, suggesting the presence of this polysaccharide, which is important for gel formation and stabilization.

Parameter (%)	Composition (%)
Moisture content	7.43 ± 0.33
Carbohydrate content	71.85 ± 0.25
Ash content	3.15 ± 0.13
Crude fibre	1.39 ± 0.40
Protein content	11.15 ± 0.60
Crude fat	5.02 ± 0.35

Table 1: Proximate composition of coconut cori fibre

Parameter	Composition
Water absorption capacity (%)	51.51 ± 3.23
Density (g/ml)	0.93 ± 0.03
Cellulose (%)	9.42 ± 0.12
Hemicellulose (%)	20.77 ± 0.19
Lignin (%)	10.92 ± 0.09
Pectin (mg/kg)	9.74 ± 0.10

Table 2: Biomass Characteristics of Cori Fibre Extract

Discussion

The proximate analysis of coconut (Cocos nucifera L.) cori fibre presents significant insights into its potential for industrial applications. The proximate composition (Table 1) reveals that the coconut cori fibre is primarily composed of carbohydrates, followed by protein, crude fat, ash, moisture, and crude fibre.

The moisture content of coconut cori fibre was found to be 7.43 ± 0.33%. This relatively low moisture content is advantageous for storage and industrial applications, as lower moisture content reduces the risk of microbial growth and degradation during storage. A study by Amuthavalli et al. [14] reported a similar moisture content of 7.5% in coconut husk, suggesting that the moisture content of different parts of the coconut plant is consistent and suitable for industrial applications. Lower moisture content is also beneficial for thermal processing, reducing the energy required for drying [15].

The carbohydrate content was found to be 71.85 ± 0.25%, indicating that coconut cori fibre is rich in carbohydrates. This high carbohydrate content makes it a suitable raw material for bioethanol production. Previous studies have reported comparable carbohydrate content in various parts of the coconut plant. For instance, a study by Reddy and Yang [16] found that coconut coir pith had a carbohydrate content of 75%, which aligns closely with our findings. High carbohydrate content in biomass is crucial for bioethanol production as it can be easily converted into fermentable sugars [17].

The ash content in coconut cori fibre was 3.15 ± 0.13%. Ash content represents the inorganic mineral content of the biomass. Lower ash content is preferable for biofuel production as high ash content can lead to fouling and slagging in combustion systems [18]. Our findings are consistent with those of Ali et al. [19], who reported an ash content of 3.4% in coconut husk. The consistency in ash content across different studies suggests that coconut cori fibre has a stable inorganic mineral composition, making it suitable for biofuel applications.

The crude fibre content of coconut cori fibre was found to be 1.39 ± 0.40%. Crude fibre represents the indigestible part of the plant cell wall, including cellulose and lignin. Previous studies have reported varying crude fibre content in different parts of the coconut plant. For example, Arumughan et al. [20] reported a crude fibre content of 1.5% in coconut husk. The slight variation in crude fibre content could be due to differences in the part of the plant analyzed or the methods used. Crude fibre is an important parameter for evaluating the suitability of biomass for paper and pulp production [21].

The protein content in coconut cori fibre was 11.15 ± 0.60%, which is relatively high for plant biomass. High protein content in biomass can be advantageous for animal feed applications. Our findings are in agreement with the study by Kumar et al. [22], who reported a protein content of 11.0% in coconut husk. The high protein content in coconut cori fibre suggests its potential use as a protein supplement in animal feed, enhancing its industrial applicability.

The crude fat content of coconut cori fibre was 5.02 ± 0.35%. This value is comparable to the crude fat content reported in other parts of the coconut plant. For instance, a study by Sridhar and Bhat [23] reported a crude fat content of 5.1% in coconut coir. The crude fat content is relevant for evaluating the energy content of the biomass. Higher fat content can increase the calorific value, making it suitable for energy production [24].

The proximate composition of coconut cori fibre shows remarkable consistency with previous studies and literature. The high carbohydrate and protein content, along with the low moisture and ash content, highlight the potential of coconut cori fibre for various industrial applications, including bioethanol production, animal feed, and biofuel production.

The consistency in the proximate composition across different studies suggests that coconut cori fibre has a stable biochemical composition, making it a reliable raw material for industrial applications. The slight variations observed in the crude fibre and crude fat content could be attributed to differences in the specific part of the plant analyzed or the methodologies used in the analysis.

The biomass composition of Cori fibre was also in this study. The water absorption capacity (WAC) of Cori fibre was found to be 51.51 ± 3.23%. This relatively high value suggests that Cori fibre has significant potential for applications requiring moisture absorption, such as in the production of absorbent materials and bio-based products. Comparatively, studies on other natural fibres such as jute and kenaf have shown WAC values ranging from 45% to 55%, indicating that Cori fibre's water absorption capability is competitive with these commonly used fibres [25,26].

The density of Cori fibre was measured at 0.93 ± 0.03 g/ml. This low density is advantageous for applications where weight reduction is critical, such as in the automotive and aerospace industries. Natural fibres such as flax and hemp typically exhibit densities in the range of 0.9 to 1.5 g/ml [27]. Thus, Cori fibre's density aligns well with these materials, making it a promising candidate for lightweight composite materials.

The cellulose content in Cori fibre was determined to be 9.42 ± 0.12%. Cellulose is a vital component contributing to the mechanical strength and structural integrity of the fibre. However, this value is relatively lower compared to other natural fibres like cotton and flax, which typically have cellulose contents of 85-90% and 60-70% respectively [28,29]. This lower cellulose content may influence the tensile strength and stiffness of composites made with Cori fibre, suggesting a potential need for reinforcement or blending with higher cellulose fibres for certain applications.

The hemicellulose content of Cori fibre was found to be 20.77 ± 0.19%. Hemicellulose contributes to the flexibility and biodegradability of fibres. Compared to other natural fibres, Cori fibre's hemicellulose content is relatively high. For instance, jute fibres have hemicellulose contents ranging from 13% to 21% [21]. The high hemicellulose content in Cori fibre could enhance its flexibility and processing characteristics, making it suitable for applications where pliability is required, such as in paper and textile industries.

Lignin content was measured at 10.92 ± 0.09% in Cori fibre. Lignin contributes to the rigidity and resistance to microbial attack in natural fibres. This lignin content is comparable to other fibres like sisal and kenaf, which have lignin contents of approximately 10-15% [30]. The lignin content in Cori fibre suggests good durability and potential for use in applications requiring resistance to degradation, such as in outdoor composites and construction materials.

The pectin content in Cori fibre was found to be 9.74 ± 0.10 mg/kg. Pectin is known for its gel-forming abilities and contribution to the binding properties in natural fibres. While specific comparisons with other fibres are less common in the literature, the presence of pectin in Cori fibre suggests potential applications in the food industry and biopolymer production, where pectin's binding properties can be advantageous [31].

Previous studies on coconut husk fibres have reported varying compositions, often influenced by geographical and environmental factors. For example, a study by Satyanarayana et al. [32] found that the cellulose content in coconut husk ranged from 36-43%, significantly higher than the 9.42% found in this study. Such discrepancies can arise from different extraction and preparation methods or environmental growth conditions.

Similarly, lignin content in coconut husk reported by earlier studies was in the range of 29-45% [16], much higher than the 10.92% reported here. This variation might be due to the different parts of the husk being analyzed or the maturity of the coconuts at the time of fibre extraction.

The findings from this study suggest that Cori fibre, with its unique composition, holds potential for a variety of industrial applications. The high carbohydrate content (71.85 ± 0.25%) makes its fibre an excellent candidate for bioethanol production. The carbohydrates can be hydrolyzed into fermentable sugars and then fermented to produce bioethanol [17].

The relatively high protein content (11.15 ± 0.60%) suggests that coconut cori fibre can be used as a protein supplement in animal feed. This can enhance the nutritional value of the feed and provide a sustainable source of protein [22].

The low moisture (7.43 ± 0.33%) and ash content (3.15 ± 0.13%) are advantageous for biofuel production, as they reduce the risk of fouling and slagging in combustion systems. The crude fat content (5.02 ± 0.35%) also contributes to the energy content of the biomass [18].

The crude fibre content (1.39 ± 0.40%) indicates the presence of cellulose and lignin, which are essential components for paper and pulp production. The fibre can be processed to produce high-quality paper and other cellulose-based products [21].

Its high-water absorption capacity and low density make it suitable for lightweight and absorbent materials. The relatively low cellulose content, however, indicates that for applications requiring high mechanical strength, Cori fibre might need to be combined with other higher-cellulose fibres or materials.

Moreover, the high hemicellulose and moderate lignin content provide a balance between flexibility and durability, making Cori fibre a versatile material for both flexible and rigid composite applications. The presence of pectin further enhances its potential in binding and gel-forming applications, extending its usability to food and biopolymer industries.

Conclusion

The comprehensive analysis of Cori fibre's biomass composition indicates its high carbohydrate content and significant levels of cellulose, hemicellulose, and lignin, which are beneficial for industrial applications. The findings support the potential use of Cori fibre in the production of biodegradable materials and other industrial products.

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