Potential of Onion Skin, *Luffa cylindrica*, and Corn Cob as Cellulose Sources: A Study of Their Proximate, Ultimate, and Morphological Properties

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Abstract

Nigeria grows a lot of onions and Corn, which are popular foods widely eaten within the population. *Luffa cylindrica* also grows widely in most areas of the country as a wild plant or weed due to the warm climate, which favors its growth. The onion skin, *Luffa cylindrica*, and corn cobs are agro-wastes that pose disposal challenges but offer potential as renewable sources of cellulose for industrial applications. These biomasses were processed into powdered form and subjected to characterization for evaluation of their suitability for cellulose extraction. The biomass was dried, ground, and sieved to uniform particle sizes. Proximate, ultimate, and chemical composition analyses were conducted, alongside Scanning Electron Microscopy coupled with Energy Dispersive X-Ray Spectroscopy (SEM/EDX). Differential Thermal/Gravimetric Analysis (DTA/TGA) was also carried out on these samples.   The proximate analysis revealed high carbohydrate contents (86.065%, 83.868%, and 76.997%) for onion skin, *Luffa*, and corn cobs, respectively, reflecting a higher proportion of cellulose, a polysaccharide found in higher proportions in plant biomass. EDX analysis confirmed the presence of high carbon at 47.06%, 56.9%, and 55.05%, as reflected in the ultimate analysis at 48.38%, 59.33%, and 57.92%, respectively. Meanwhile, SEM images revealed rough, well-defined surface morphologies favorable for chemical interaction. TGA results showed significant thermal degradation from 200–400 °C, correlating with cellulose decomposition. Chemical composition analysis showed cellulose contents of 59.05±0.1%, 58.82±0.1%, and 55.86±0.2% for onion, luffa, and corncob, respectively. These findings give confirmation that these biomasses possess high cellulose content and suitable structural characteristics that make them good choices for cellulose extraction. The cellulose can be used in environmentally friendly technologies, such as industrial wastewater treatment.

Keywords: Cellulose, characterization, extraction, biomass, wastewater.

1.0 Introduction

Population growth has necessitated the mechanization of farm activities on a larger scale, resulting in increased agricultural plant waste generation [1]. In Nigeria, [2] reported that plant wastes were estimated at 12.07 million tonnes, which are usually discarded in and around farmlands, often creating environmental nuisances and necessitating the open burning of these wastes. Unmanaged Agro-waste leads to pollution through microbial infestations, release of toxic gases, which pose great health risks [2]. As challenging as these problems are, these agro-wastes possess untapped potential as valuable resources, particularly as sources of cellulose. Hence, this study investigates the potential of onion skin, corncobs, and *Luffa cylindrica* for cellulose extraction by studying their proximate, ultimate, and morphological properties.

Biopolymers have attracted a lot of attention due to their environmental advantages, such as biocompatibility and biodegradability. Cellulose is one of such biopolymers found to exhibit these environmentally friendly properties [3]. Its properties include biodegradability, biocompatibility, renewability, and non-toxicity, which make it a sustainable alternative to synthetic materials [4]. It is found abundantly in the plant cell wall, where cellulose is part of the complex matrix that also includes hemicellulose and lignin, making up the structural integrity of the plants. Structurally, cellulose is a polysaccharide that is made up of D-glucopyranose units linked by β-1,4-glycosidic bonds, and its extraction from biomass offers a viable route to convert wastes into valuable materials [5].

Characterization techniques such as proximate and ultimate analyses are essential to evaluate the potential of the biomass for cellulose extraction. [6] reported that proximate analysis provides insight into moisture, volatile matter, ash, and fixed carbon content, which are critical indicators for industrial applicability. When coupled with

ultimate analysis, the elemental composition, like carbon (C), hydrogen (H), oxygen (O), nitrogen (N), and sulfur (S) of the biomass is revealed, offering a comprehensive understanding of its elemental building blocks that shows its organic material content which cellulose is one [6]. Chemical composition analysis also quantifies the cellulose, hemicellulose, and lignin content, confirming the biochemical viability of the biomass for cellulose recovery [7].

Morphological characterization gives a better understanding of the structural arrangement of plant biomass. Diverse morphological analysis techniques, such as scanning electron microscopy (SEM/EDX), show the surface texture and porosity, which influences reactivity and processing efficiency [8]. The FTIR provides unique data that shows the plant biomass chemical composition by identifying the functional groups of its major constituents linked to high cellulose content [8].

The three cellulose sources considered in this study includes onion skin which is a widely generated household waste due to Nigeria's large-scale production [9], *Luffa cylindrica* which is a vine that grows wildly in most parts of the country is viewed as an emerging cash crop [10] and corn cobs which is a waste from maize where Nigeria remains one of the top producers in Africa as reported by [11].

Therefore, this research aims to determine the properties of biomass (Onion Skin, *luffa cylindrical,* and corncob) that can guide the cellulose extraction method effectively.

2.0 Materials and Methods

Analytical-grade chemicals were sourced from Fin Laboratory, manufactured by BDH England, including sodium hydroxide, Sulfuric acid, distilled water, acetone, and acetic acid. Onion skin obtained from Maiduguri, corncob from Bauchi, and *Luffa cylindrica* from Lugbe, FCT, were washed, oven-dried, pulverized, and stored in airtight containers. The sampling of Onion Skin from Borno, Luffa from the FCT, and corn cob from Bauchi state stems from the large-scale availability of these wastes in these states. Borno is one of the large onion-producing states with good post-harvest practices [12], as compared to Kano (though the largest producer) farmers take their produce to market immediately after harvest, as reported by [13]

Proximate analysis was carried out using the method of [6] to determine moisture, volatile matter, ash content, and fixed carbon. Moisture content was measured by mass loss after heating 0.5 g of the sample at 105°C for 2 hours under a nitrogen purge. Volatile matter (VM) was determined by heating samples to 850°C in a nitrogen-purged stainless-steel box and estimated as;

$$\text{VM} = \left(\frac{B-C}{B}\right) * 100 \tag{1}$$

where B is the air-dried weight of the sample and C is the furnace calcined weight of the sample at 900°C.
Ash content (AC) was evaluated by combustion at 730°C under air for 8 hours and estimated as:

$$AC = \left(\frac{D}{B}\right) * 100 \tag{2}$$

where D= Weight of ashed residue and B is the Weight of the initial sample
Fixed carbon was calculated by computing the difference using Equation (3) [1].

$$FC\% = 100 - (VM\% + AC\%) \tag{3}$$

Ultimate analysis was carried out using the LECO CHNS 2000 Analyzer, with CO_2 and H_2O captured using NaOH and Mg $(ClO_4)_2$, respectively, allowing determination of C, H, N, S, and O by difference. Chemical composition was determined gravimetrically. Extractives were removed using Soxhlet extraction with acetone. Hemicellulose, Ash, and lignin contents were determined gravimetrically, while Cellulose content was estimated by computing the difference using the equation below:

$$Cellulose\ \% = 100 - (hemicellulose + lignin + Ash) \tag{4}$$

Structural properties were examined using SEM-EDS (Phenom ProX) for morphology, which works by directing a beam across the surface of the sample to produce an electron signal. EDS provides both qualitative and quantitative elemental analysis [14]. The TGA (Q500) was used for thermal properties, to determine changes in the sample's mass in response to changes in temperatures.

3.0 Results and Discussions.

Results obtained for each of the lignocellulosic biomass (Onion skin, *Luffa Cylindrica*, and Corn Cob) in this study are discussed in the following sections.

3.1 Proximate Analysis

The results of the proximate analysis for the plant biomass (onion skin, *luffa cylindrical*, and corn cob) are presented in Table 1. It was found that onion skin had the highest value for fixed carbon at 45.85±0.2%, *followed by Luffa cylindrica at 41.03±0.1% and corncob at* 36.21±0.2%. Fixed carbon is a measure of the solid residue portion of plant biomass after volatile matter has been removed, indicating the cellulose, hemicellulose, and lignin components [6]. A higher value hints at a higher proportion of the solid residues, of which cellulose is a major component. The volatile matter values obtained show that corncobs have the highest value at 53.15±0.1, while onion skin has the lowest value at 47.63±0.2. This indicates the potential of the plant biomass as higher volatile matter shows that a higher proportion of organic matter (cellulose, hemicellulose, and lignin) [6]. The moisture content of the three biomass shows relatively low values of moisture, signifying that the drying processes utilized were efficient and ensure that there will be no moisture interference during cellulose extraction. A low moisture content of less than 20% ensures that there is no degradation of the cellulose, while also improving extraction efficiency and yielding better quality cellulose [15].

In Table 1, the Ash content was found to be highest in corn cob (6.6±0.2) and lowest in *Luffa cylindrica* (4.4±0.1). Ash content reflects the inorganic, non-combustible mineral content; hence, a high value indicates a lower organic material content, such as cellulose. Low ash content values, as found in these biomasses, support a higher yield of cellulose and better extraction efficiency [16]. The highest carbohydrate content was found in onion skin (86.065±0.1) and the lowest in corn cob (76.997±0.1). Carbohydrate content in biomass can be said to be directly proportional to cellulose content, indicating the potential of biomass as a cellulose source, since it is a polysaccharide [17]. The values of proximate analysis on the onion skin were almost identical to the results obtained by [18], while those of the sample luffa powder were in line with the report of [19], except for differences in crude protein and crude fat content, which could be due to the species of *Luffa cylindrica*. [20] studied varieties of maize in Bangladesh and concluded that the species of the corn has an impact on proximate and ultimate composition.

Table 1. Proximate analysis for onion skin, *Luffa cylindrica*, and corn cob

Parameter	Plant Biomass	Values
Onion skin	Fixed Carbon	45.85±0.2
	Volatile Matter	47.63±0.2
	Moisture Content	2.02±0.2
	Ash Content	4.5±0.15
	Carbohydrate	86.065
Luffa cylindrica	Fixed Carbon	41.03±0.1
	Volatile Matter	51.21±0.1
	Moisture Content	3.36±0.1
	Ash Content	4.4±0.1
	Carbohydrate	83.868
Corn cob	Fixed Carbon	36.21±0.2
	Volatile Matter	53.15±0.1
	Moisture Content	3.87±0.2
	Ash Content	6.6±0.2
	Carbohydrate	76.997

3.2 Ultimate Analysis

The results obtained from the ultimate analysis are as shown in Table 2. [2] reported that lignocellulosic biomasses are made up mainly of carbon, and a higher proportion of carbon means a higher proportion of the carbonaceous materials (cellulose, hemicellulose, and lignin) is contained in these biomasses. The values of carbon in the sample conform to this and suggest that cellulose content may be in a higher proportion. The high carbon and hydrogen values in an ultimate analysis of biomass reflect its high energy production potential, which is typically associated with higher carbonaceous materials [3]. The Nitrogen content seen in the three biomass is present due to nitrogen being an important component in the chlorophyll molecule. Sulfur content is also found to be low in the raw biomass, as expected, since they constitute impurities that can cause unwanted compounds during cellulose extraction, hence contaminating the cellulose. In general, the ultimate analysis of these raw biomasses to determine the elemental composition is an essential step, as these elements can influence the choice of extraction method, optimization parameters, and even the purity of the cellulose extracted [3]. A comparison of the ultimate analysis of the onion skin with literature [23] revealed that there are slight variations in the ultimate properties, which could be accounted for by the species and source (Spain) of the onion skin. The variances observed for Luffa cylindrica from comparison with the literature by [24] can be attributed to the difference in the origin of the Luffa cylindrical (Tunisian) and also the species. A higher nitrogen content in the luffa cylindrica is

also due to the need for this element in most vine crops, which allows them to flourish and yield better fruits, as reported by [4]. The ultimate properties of the sample corncob also varied from those identified in the literature. This has been established by [5] where they found that various varieties from exact location displayed different proximate and ultimate properties. The variances were hence attributed to the sample species, growing conditions, and maturity of the sample, varying from that contained in literature.

The EDS composition of the onion skin, *Luffa cylindrica*, and corn cobs was also similar to that obtained by ultimate analysis, with carbon contents of 47.06%, 56.90%, and 55.05%, respectively.

Table 2. Ultimate analysis results for onion skin, *Luffa cylindrica* and corn cob.

Parameter	Plant Biomass	Values
Carbon	Onion Skin	48.38
	Luffa Cylindrica	59.33
	Corn Cob	57.92
Hydrogen	Onion Skin	7.97
	Luffa Cylindrica	1.74
	Corn Cob	1.07
Oxygen	Onion Skin	22
	Luffa Cylindrica	12.44
	Corn Cob	9.76
Nitrogen	Onion Skin	2.13
	Luffa Cylindrica	2.64
	Corn Cob	3.12
Sulfur	Onion Skin	0.33
	Luffa Cylindrica	0.13
	Corn Cob	0.03

3.3 Chemical Composition

The results for the chemical composition of the three biomasses are reported in Table 3. The gravimetric method was used to obtain the cellulose, hemicellulose, and lignin contents of the onion skin, luffa cylindrical, and corncob. This revealed cellulose contents of 59.05±0.1% for onion skin, 58.82±0.1% for Luffa cylindrica, and 55.86±0.2% for corn cob. [6] reported cellulose content of 41.2% for the onion skin that could be attributed to different sources and species, harvesting and storage protocols, as reported by [7]. For the *luffa cylindrical*, [8] and [9] reported lower cellulose content (45.80% and 37.70%), respectively, which could be attributed to the species and source location of the *Luffa cylindrica* gourd. The chemical composition of the sample corn was in line with the results of [10] (52%) and [31] (45.2%).

Table 3. Chemical composition of onion skin, *Luffa cylindrica*, and corn cob.

Parameter	Onion Skin	*Luffa cylindrica*	Corn Cob
Hemicellulose (%)	19.13	20.04	18.44
Lignin (%)	17.31	16.73	19.22
Cellulose (%)	59.05±0.1	58.82±0.1	55.86±0.2

3.4 SEM/EDS

The images shown in Figure 1 represent the SEM images of onion skin, *Luffa cylindrica*, and corn cobs, while the elemental compositions are as shown in Table 4.
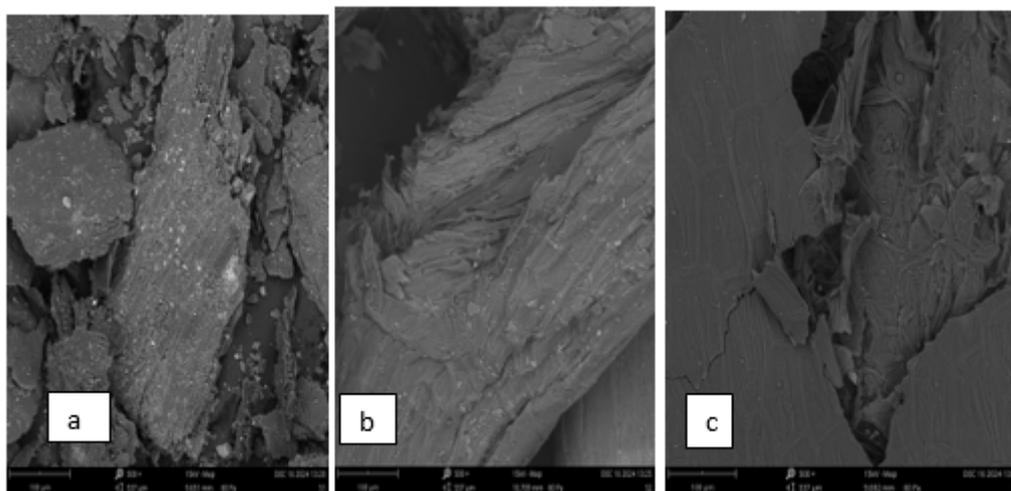
Figure 1: SEM Images at x500 magnification; a) Onion skin b) Luffa Cylindrica c) Corn Cob

The structure of the onion skin (Figure 1a) reveals a fibre structure where multicellulose fibres are bound by lignin and hemicellulose, indicating that the fibres are untreated and maintain their structure, covered by extractives, wax, and lignin. [6] reported the difference between the untreated and treated fibres, showing that after treatment, there is a defined structure with a cleaner surface. The EDS (Table 4) revealed that the composition was 47.06% carbon, 7.45% calcium, 6.55% potassium, 6.49% sodium, and 4.64% silicon, while other elements were present in trace quantities.

The image of *Luffa cylindrica* (Figure 1b) aligns with the image of untreated luffa fibre reported by [11]. The EDS (Table 4) result of the Luffa sample revealed a 56.9% carbon, 8.07% potassium, 4.58% aluminium, and 1.74% calcium, while other elements were in trace quantities.

The image of a corn cob (Figure 1c) is in line with the image of raw corn cob fibre reported by [12]. The EDS (Table 4) of the corn cob sample revealed that it contained 55.05% carbon, 5.07% aluminum, 2.52% potassium, while other elements were in trace quantities.

Table 4. EDS composition of onion skin, *Luffa cylindrica*, and corn cobs.

Element Symbol	Element Name	Onion Atomic Conc.	Weight Conc.	Luffa Atomic Conc.	Weight Conc.	Corncob Atomic Conc.	Weight Conc.
C	Carbon	47.06	33.87	56.9	45.36	55.05	48.89
N	Nitrogen	35.71	29.97	33.32	30.97	42.15	43.65
Ca	Calcium	6.38	15.31	5.1	13.24	0.68	1.57
K	Potassium	3.23	7.57	1.55	3.65	0.54	1.55
Si	Silicon	1.74	2.93	0.63	1.68	0.47	0.94
Na	Sodium	1.99	2.74	0.7	1.25	0.29	0.77
Al	Aluminium	1.61	2.6	0.59	0.95	0.09	0.68
Mg	Magnesium	1	1.46	0.29	0.54	0.23	0.68
Cl	Chlorine	0.54	1.14	0.26	0.54	0.26	0.54
Sr	Strontium	0.16	0.86	0.09	0.53	0.15	0.52
S	Sulfur	0.35	0.68	0.34	0.52	0.09	0.22
Ti	Titanium	0.15	0.44	0.06	0.43	0	0
Ag	Silver	0.06	0.42	0.15	0.32	0	0
P	Phosphorus	0	0	0	0	0	0
Zn	Zinc	0	0	0	0	0	0
Fe	Iron	0	0	0	0	0	0

3.5 Thermo Gravimetric Analysis/Differential Thermal Analysis (TGA/DTA)

TGA/DTA is a thermal analysis technique that combines two methods: TGA, which measures weight changes of a substance as it's heated, and DTA, which measures the temperature difference between a sample and a

reference material during heating. This combined approach provides insights into both the thermal stability and phase transitions of a material.

TGA/DTA analysis was carried out on the samples: onion skin, *Luffa cylindrica* and corn cobs to get information about their thermal stability and phase transition behavior during heating.
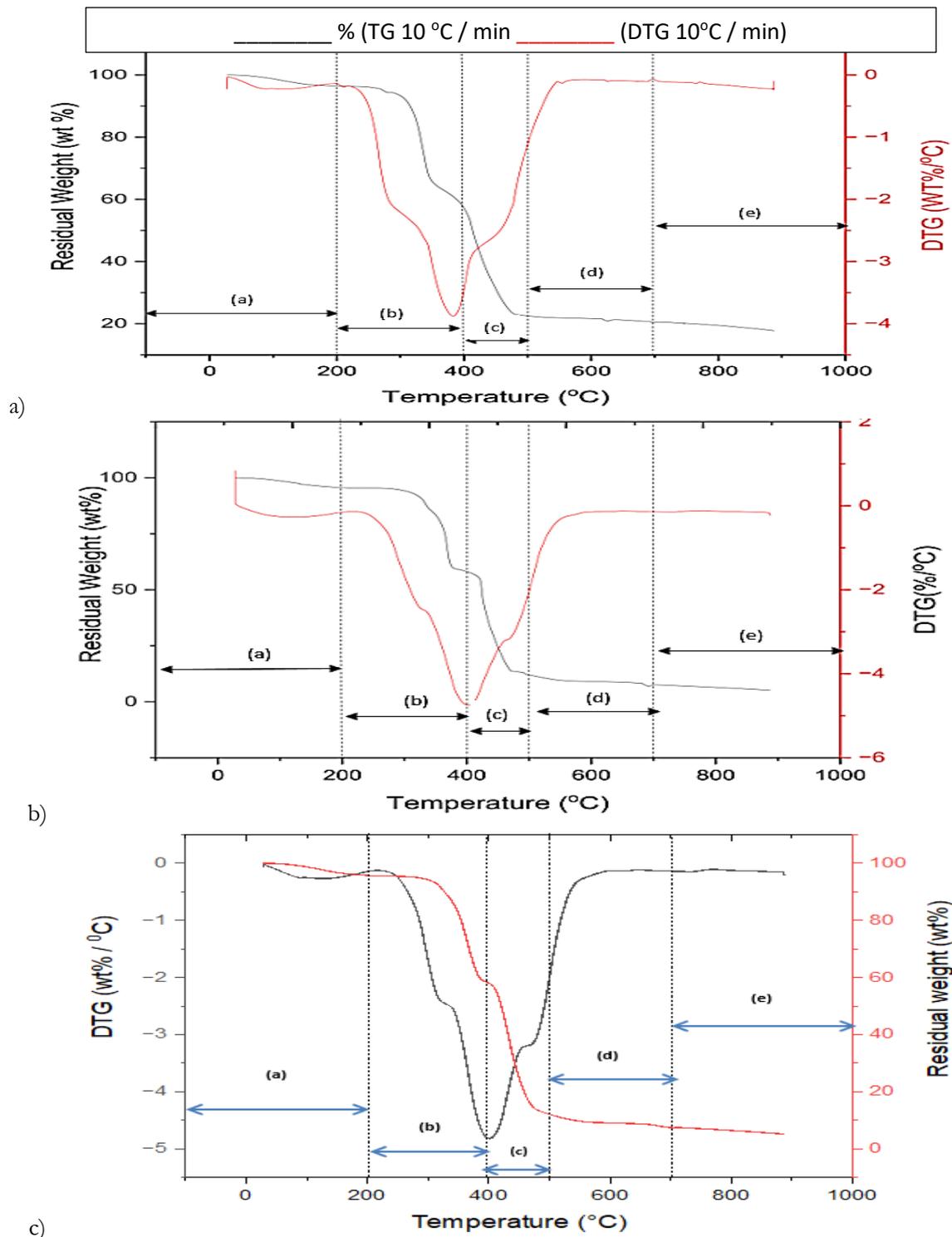

a)

b)

c)

Figure 2. TGA/DTG for   a) Onion Skin   b) Luffa Cylindrica   c) Corn cobs

The TGA chart in Figures 2a, b, and c presents the thermal decomposition behavior of lignocellulose biomass (onion skin, Luffa cylindrica, and corn cob) across five distinct phases. The temperature range of 0-200°C depicts the evaporation of moisture and low-boiling compounds. The temperature range of 201-400°C exhibits a significant and rapid reduction in mass, indicating the degradation of hemicellulose and cellulose. Temperatures between 401-500°C depict the degradation of substances such as lignin. The temperature range of 501-700°C represents the breakdown of residual organic matter, such as carbonaceous residues. 700-1000°C, minimal weight loss, reflecting the stability of residual inorganic components like ash.

4.0 Conclusion

The three selected biomasses were characterized, focusing on proximate, ultimate, thermo-gravimetric, and structural/morphological properties to understand their suitability as cellulose sources. The carbon contents determined by ultimate analysis and those indicated by SEM-EDS were consistent, emphasizing the presence of carbonaceous compounds in the biomass, where cellulose is typically the primary component. Chemical composition analysis of the three biomass samples revealed that onion skin had the highest cellulose content, at $59.05\pm0.1\%$, followed by *Luffa cylindrica* at $58.82\pm0.1\%$ and corn cobs at $55.86\pm0.2\%$. The thermogravimetric analysis results revealed the temperature gradients for each biomass with a description of their thermal stability and phase transitions. In view of the various analyses carried out on these three samples (onion skin, *Luffa cylindrica*, and corn cob), it can be inferred that all three biomasses have the potential to serve as a cellulose source. It is recommended that onion skin, *Luffa cylindrica*, and corn cob be included in global cellulose isolation frameworks, as they have potential as sustainable sources of cellulose.

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