



Comparative physico-chemical evaluation of microcrystalline cellulose from sugarcane peel and bagasse

Kenneth Chinedu Ugoeze and Nkemakolam Nwachukwu*

Department of Pharmaceutics and Pharmaceutical Technology, Faculty of Pharmaceutical Sciences, University of Port Harcourt, Port Harcourt. Rivers State, Nigeria.

Received 17th February 2018; Accepted 27th March 2018

Abstract

A comparative study of the physico-chemical properties of microcrystalline cellulose, MCC-P and MCC-B processed from sugarcane stem-bark and its bagasse respectively in comparison to the commercial product of MCC, Avicel PH 102 was carried out. Alpha cellulose was obtained from dried and pulverized powder of the stem-bark and bagasse of sugarcane stem through different sodium hydroxide and sodium hypochlorite treatments. Hydrolysis of the alpha cellulose with 2.5 N hydrochloric acid yielded MCCs coded as MCC-P and MCC-B from stem-bark and the bagasse respectively. The MCCs were identified using standard method. Physico-chemical properties such as the degree of polymerization, solubility, pH, flow parameters, densities, moisture studies, ash content, particle size and morphological studies using scanning electron microscopy (SEM) were done. The results of the physico-chemical assessments indicated that the MCC-P and MCC-B powders were microcrystalline cellulose. Their degree of polymerization, pH, moisture and ash contents conformed to the British Pharmacopeia, BP (2009) specifications for MCC. Their flowability was generally poor and these characteristics were comparable to those of Avicel PH 102. These results show that MCC is obtainable from the bio-wastes of various components of sugarcane stem in reasonable amounts, thus making such wastes economically feasible and enhancing a healthy environment.

Keywords: Microcrystalline cellulose; Sugarcane; Stem-bark; Bagasse; Bio-waste

INTRODUCTION

Waste composition is influenced by many factors, such as level of economic development, cultural norms, geographical location, energy sources and climate. As a country urbanizes and populations become wealthier, consumption of inorganic materials (such as plastics, paper, and aluminium) increases, while the relative organic fraction decreases. Generally, low and middle-income countries have a high percentage of organic matter in the urban waste stream, ranging from 40 to 85% of the total compared to 28%

in high-income countries [1]. According to the World Bank classification, Nigeria belong to the middle-income countries [2]. In high-income countries, an integrated approach for organic waste is particularly important, as organic waste may be recycled into economically viable products. Organic bio-waste include food scraps, leaves, grass, wood, other plant process residues, etc. [1]. Producing new products with secondary materials can save significant energy. The key advantages of recycling and recovery are

* Corresponding author. *E-mail:* nkemakolam.nwachukwu@uniport.edu.ng *Tel:* +234 (0) 8068573693
ISSN 0189-8442 © 2018 Faculty of Pharmaceutical Sciences, University of Jos, Jos. Nigeria.

reduced quantities of disposed waste and the return of materials to the economy [3,4].

A significant amount of waste is being generated in Nigeria each day, which contains high quantities of organic matter. The agricultural waste produced in a particular period of the year pose potential pollution problems. In most jurisdictions, public health concerns have been the basis for solid waste management programs, as solid waste management is essential to maintaining public health. Solid waste that is not properly collected and disposed of can be a breeding ground for insects, vermin, and scavenging animals, and can thus pass on air- and water-borne diseases. Surveys conducted by UN-Habitat show that in areas where waste is not collected frequently, the incidence of diarrhoea is twice as high and acute respiratory infections six times higher than in areas where a collection is frequent. Poorly collected or improperly disposing of waste can have a detrimental impact on the environment. In low- and middle-income countries, solid waste is often dumped in low-lying areas and land adjacent to slums. Lack of enforced regulations enables potentially infectious medical and hazardous waste to be mixed with solid wastes, which is harmful to waste pickers and the environment. Environmental threats include contamination of groundwater and surface water by leachate, as well as air pollution from burning of waste that is not properly collected and disposed of [3]. Therefore, an efficient utilization of such agricultural bio-waste is of great importance, not only minimizing the environmental impact but also to convert bio-waste into economically viable products [5].

Most of the pharmaceutical excipients such as starch, agar, alginates, guar gum, xanthan gum, acacia, tragacanth, in addition to cellulose-based excipients such as the microcrystalline cellulose also are of plant origin. Their advantages include low cost, biocompatibility, with a renewable source,

eco-friendliness, etc. [6,7]. The agro-biomass is composed mainly of cellulose, hemicellulose and lignin. There is a strong potential for low-cost cellulose-based polymers for commodity applications, particularly since the monomer can be obtained from renewable agricultural resources [8-11]. One of the robust economic agricultural products is the sugarcane. The global demand for sugar is the primary driver of sugarcane agriculture. Cane accounts for 80% of sugar produced. Other than sugar, products derived from sugarcane include molasses, rum, bagasse, ethanol, etc. In some regions, people use sugarcane reeds to make pens, mats, screens, and thatch [12]. Bio-fuel is obtained from the sugarcane bagasse. The sugarcane bark is another bio-waste that could be converted to microcrystalline cellulose (MCC) which finds great use pharmaceutically in the direct compression technology in tablet production.

Microcrystalline cellulose (MCC) is purified partly depolymerized cellulose produced by treating α -cellulose got as a pulp from a fibrous plant material using mineral acids. The MCC can be synthesized by different processes such as reactive extrusion, enzyme-mediated, steam explosion and acid hydrolysis. The later process can be done using mineral acids such as sulphuric acid (H_2SO_4) or hydrochloric acid (HCl). These reagents are added to destroy the amorphous regions remaining in the crystalline domains [13]. The microcrystalline cellulose is a white crystalline powder composed of agglomerated porous microfibers. Apart from its use in direct compression, it is used as a diluent in tablets prepared by wet granulation, as filler in capsules. Commercially, it is available as Avicel[®] and is marketed in several grades such as Avicel[®] PH 101, 102, etc. [14].

The purpose of this study is to compare the physicochemical properties of the microcrystalline cellulose derived from the stem bark and bagasse of sugarcane.

EXPERIMENTAL

Materials. The following materials were used as procured and include: sodium hydroxide (Tianye Chemicals, China), sodium hypochlorite (3.5 % w/v) (Multipro, Nigeria), hydrochloric acid (Loba Chemie, India), *n*-hexane (JHD, China) and Avicel PH 102 (FMC Biopolymers, USA).

Procurement and identification of the sample. Sugarcane stems were procured from Rumu-Okoro market in Port Harcourt. It was identified as *Saccharum officinarum* with identification number UPH/P/119.

Processing of alpha cellulose. The sugarcane stem bark (*SS-P*) was peeled off and gathered. The pulp was cut into smaller sizes and pressed to remove the juice to generate the bagasse (*SS-B*). The *SS-P* and *SS-B* were sundried for 3 weeks and later pulverized. The method of Ohwoavworhua & Adalokun [15] was adopted with slight modification. A 1.0 kg quantity each of *SS-P* and *SS-B* was macerated in 2.0 % w/v sodium hydroxide in a glass beaker and heated in a water bath (100 ° C) for 3 h to delignify the fibre. The respective resultant samples were washed with deionized water until the mass was neutral to litmus. The wet delignified mass was macerated with an aqueous dilution of a 3.5 % w/v sodium hypochlorite (1:1) and heated over a water bath (100 ° C) for 30 min. It was rinsed severally with deionized water until the mass was neutral to litmus. The subsequent mass was macerated in 17.5 % sodium hydroxide placed in a glass beaker and heated in a water bath (80 ° C) for 1h. The extraction process was completed by bleaching with a 1:2 ratio of water: 3.5 % w/v sodium hypochlorite heated in water bath (80 ° C) for 1 h and was rinsed with deionized water until neutral to litmus. The respective alpha cellulose obtained from *SS-P* and *SS-B* were dried in a hot air oven (Mettler, England) at 60°C for 2h.

Production of microcrystalline cellulose. A 50 g of the separate alpha cellulose obtained from *SS-P* and *SS-B* was placed in a glass beaker and hydrolyzed with 2.5 N hydrochloric acid solution at a temperature of 105 ±2 ° C (in a liquid paraffin bath) for 30 min. The individual hot acid-mixtures was transferred into a clean bowl containing deionized water and stirred vigorously, allowing it to stand for 15 min. The microcrystalline cellulose (MCC) obtained was filtered, washed with deionized water until neutral to litmus. The MCC obtained was dried in a hot air oven at 60 ° C for 4 h and sized using 250 µm stainless steel sieve (Retsch, Germany). The products obtained from *SS-bark* and *SS-bagasse* were coded as *MCC-P* and *MCC-B* respectively.

Evaluation of *MCC-P*, *MCC-B* or Avicel PH 102

Several verifications were carried out to characterize *MCC-P*, *MCC-B* or Avicel PH 102, a standard commercial product of microcrystalline cellulose for comparative purposes.

Identification test. A 0.5 g quantity of each of *MCC-P*, *MCC-B* or Avicel PH 102 was soaked in enough amount of iodine solution for 5 min and each was drained of excess iodine. Observations were made and noted. Two drops of 60 % v/v sulphuric acid were added to each sample, observed and noted. This test distinguishes MCC from other cellulose derivatives [16]. The respective samples were examined for odour, colour and taste. Their pH (2.00 % w/v) aqueous dispersion was determined at room temperature using a pH meter (Hanna, USA).

Iodinated zinc chloride test. This test was carried for out for *MCC-P*, *MCC-B* or Avicel PH 102 by preparing iodinated zinc chloride solution. A 20.0 g of zinc chloride and 6.5 g of potassium iodide was dissolved in 10.50 ml of water. A 0.5 g of iodine was added and shaken for 15 min. A 10.0 mg of the

respective samples was in turn placed on a watch glass and dispersed in 2.0 ml of iodinated zinc chloride solution and checking if the substance takes on a violet-blue colour [17].

Solubility. Deionized water, acetone, 0.1 N HCl and ethanol respectively was added dropwise to 0.5 g of samples of *MCC-P*, *MCC-B* or Avicel PH 102 until each sample was sufficiently covered with the solvent. The mixture was agitated for 15 min and observed for solubility.

Elemental analysis. This was carried out *MCC-P* and *MCC-B* only using an Atomic Absorption Spectrophotometer (AAS), Model AA-7000, ROM version 1.01, S/N A30664700709 (Shimadzu, Japan).

Moisture content. A digital moisture balance (Citizen, MB-50, China) was used. A 2.0 g of *MCC-P*, *MCC-B* or Avicel PH 102 was placed in the equipment and operated at 105°C. The equipment automatically switches off when an optimal moisture contained in the sample was up taken by heat. The equipment automatically displays digitally the value of the moisture content in percent.

Moisture sorption capacity. The moisture sorption ability of the *MCC-P*, *MCC-B* or Avicel PH 102 was determined by storing 1.0 g in respective airtight desiccators containing saturated aqueous solution of potassium sulphate, potassium chloride, sodium chloride and magnesium nitrate for 7 days at an ambient temperature of about 30 °C to sustain a relative humidity of 96, 84, 75 and 52 % respectively [18]. The rise in weight of the sample was calculated as percentage moisture gain as follows:

$$\% \text{ moisture gain} = \frac{\text{moisture gain}}{\text{original weight}} \times 100 \quad \dots\dots (1)$$

Ash content. The total ash content was evaluated using the USP (2017) [19] and the WHO (1998) quality control methods for herbal materials [20].

Hydration capacity. To determine this parameter, a triplicate study were conducted using 1.0 g each of *MCC-P*, *MCC-B* or Avicel PH 102 designated as y was placed in a 15.0 ml plastic centrifuge tube and each submerged with 10.0 ml of deionized water. The tubes were stoppered, shaken vigorously for 20 min and left to stand for 10 min. It was centrifuged for 10 min at 3000 revolutions per minute (rpm) in a benchtop centrifuge (PEC Medicals, USA). The resultant supernatant was decanted and the wet sediment was weighed, the new weight of the sample, x, due to the uptake of water was noted [21]. The hydration capacity was calculated using the equation below.

$$\text{Hydration capacity} = x/y \quad \dots\dots (2)$$

where: x is the weight of the wet sample after centrifugation and y is the weight of the dry sample.

Swelling index. A 5.0 g of *MCC-P*, *MCC-B* or Avicel PH 102 introduced into a glass measuring cylinder was tapped and its volume, V_x was noted. It was then dispersed in 85.0 ml of water and made up to 100.0 ml with deionized water. This was left for 24 h and the volume of the sediment, V_v was recorded [22]. This was carried out in triplicate and the swelling index was calculated as follows:

$$\text{Swelling index} = V_v / V_x \quad \dots\dots (3)$$

where V_v is the volume of sediment and V_x is the tapped volume occupied by 5 g of MCC.

Flow properties. The flow rate of each sample was studied using the funnel method [23]. The time for the complete outflow of 15.0 g of the sample placed in the funnel was recorded. The angle of repose was determined using the fixed funnel method as reported by Zeleznik and Renak [24]. The funnel was clamped with its tip 3.0 cm above the horizontal base. Each sample was, in turn poured through the funnel until the apex of the heap of the powder formed reached the tip of the funnel. The mean diameter of the base of the powder heap was determined for three

replicate readings. The angle of repose, θ was calculated after three replicate determinations from the equation:

$$\theta = \tan^{-1}\left(\frac{2h}{d}\right) \quad \dots\dots\dots (4)$$

where h = the height of the powder heap, d = base diameter of the powder heap.

Other derived properties of the MCC were calculated from the following equations:

The Hausner's ratio (HR) for *MCC-P*, *MCC-B* or Avicel PH 102 was calculated [25]:

$$\text{HR} = \frac{\text{Tapped density}}{\text{Bulk density}} \quad \dots\dots(5)$$

The Compressibility Index (CI) for *MCC-P*, *MCC-B* or Avicel PH 102 was calculated from the formula [26]:

$$\text{Carr's index} = \frac{(\text{Tapped density} - \text{Bulk density})}{\text{Tapped density}} \times 100 \quad \dots\dots (6)$$

The porosity for *MCC-P*, *MCC-B* or Avicel PH 102 was calculated from the equation:

$$\text{Porosity} = [1 - (\text{bulk density}/\text{true density})] \times 100 \quad \dots (7)$$

Bulk, tapped and particle densities. A 15.0 g quantity of each sample was used in the evaluation of the bulk and tapped densities using Stampfvolumeter (STAV 2003JEF, Germany). The particle density was determined by the displacement method using a 25.0 ml pycnometer and *n*-hexane as a non-solvent [27]. The weight of the pycnometer (w) was confirmed using an analytical balance (Mettler, Germany). The pycnometer was later filled with *n*-hexane and reweighed (w₁). The weight of *n*-hexane (w₂) was obtained by subtracting w from w₁. A 0.5 g (w₃) quantity of powder was introduced into the pycnometer containing *n*-hexane and weighed (w₄). The densities of the respective samples were calculated from the following equations after three replicate determinations:

$$\text{Bulk density} = \frac{\text{Weight of MCC}}{\text{Bulk volume of MCC}} \quad \dots\dots (8)$$

$$\text{Tapped density} = \frac{\text{Weight of MCC}}{\text{Tapped volume of MCC}} \quad \dots\dots (9)$$

Where: *v* is the volume of pycnometer, 25.0 ml, *W* = weight of empty pycnometer, *W*₁ = weight of pycnometer and *n*-hexane, *W*₂ = the difference between the *W* and *W*₁

*W*₃ = weight of sample, *W*₄ = weight of sample + *n*-hexane + pycnometer.

Scanning electron microscopy (SEM). The scanning electron microscopy of the sample of *MCC-P*, *MCC-B* or Avicel PH 102 was carried out using a scanning electron microscope model EVO MA-10 instrument (Carl Zeiss, Jena) at an acceleration voltage of 20Kv and probe current of 227Pa.

Statistical analysis. Data were analyzed by one-way ANOVA, using the IBM SPSS version 20. *P* < 0.05 was considered statistically significant.

RESULTS AND DISCUSSION

The results of the organoleptic properties of the *MCC-P* and *MCC-B* indicated that they were white, odourless, tasteless and coarse powders as specified for MCC [16]. Processing yields of 35.50 and 12.20 % correspondingly were obtained. The results of the physico-chemical examinations carried out on *MCC-P*, *MCC-B* and a commercial sample of Avicel PH 102 as a reference are presented in Table 1. The iodine solution and the sulphuric acid (60 % v/v) tests [16] carried out on *MCC-P*, *MCC-B* and Avicel PH 102 disclosed a reddish-brown and blue colour for the individual tests. The iodinated zinc chloride test for these samples also showed violet-blue colour. These results confirm that the materials of *MCC-P*, *MCC-B* or Avicel PH 102 are microcrystalline cellulose [17]. The pH obtained for *MCC-P*, *MCC-B* and Avicel PH 102 were 6.83±0.03, 6.00±0.03 and 6.72±0.02 respectively. Though there was a significant difference in these values (*p*<0.05), they are within the pH range of 5.0 -7.5 stated for Avicel PH 102 [16,28]. With this, MCC obtained from the sugarcane bagasse and the stem-bark may possibly be matched to any other commercial brand of MCC and could be used as an excipient in diverse drug delivery systems as a granulating agent, disintegrant, lubricant and diluent in wet granulation tableting or as

diluent-binders in direct compression tableting. A significant difference also existed in the values of the degree of polymerization for the three samples studied ($p < 0.05$), each of these values being lower than 350 units specified for the degree of polymerization for Avicel PH 102 [28]. Statistical analysis also showed a significant difference in the values of the molecular weight obtained for *MCC-P*, *MCC-B* and Avicel PH 102 respectively ($p < 0.05$).

The values of the ash content (Table 1) obtained for *MCC-P* and *MCC-B* were

comparable to that of Avicel PH 102. However, there was no significant difference between the values of the ash content amongst *MCC-P*, *MCC-B* and Avicel PH 102 ($p > 0.05$).

Elemental analysis was carried out to detect the presence of some heavy metals. Findings were as follows: Arsenic (1.58×10^{-10} %), Vanadium (2.0×10^{-5}). Lead and mercury were below a detectable limit. FDA recommended limits of 1.0×10^{-4} % for lead, 1.0×10^{-3} % for arsenic, and 1.0×10^{-4} % for mercury for potable water [29].

Table 1: Properties of MCC

Parameters	MCC-P	MCC-B	Avicel PH 102
pH	6.83±0.03	6.00±0.03	6.72±0.02
Degree of polymerization	231.17±0.31	228.82±0.23	234.43±0.35
Molecular weight	41,570.80±0.02	41,140.60±0.02	42,156.45±0.03
Particle size (µm)	7.82±0.03	5.55±0.03	7.62±0.03
Total ash (%)	1.30±0.05	1.45±0.05	1.39±0.05
Flow rate (g/s)	Poor flow	Poor flow	Poor flow
Angle of repose (deg.)	29.04±0.04	30.45±0.19	30.98±0.03
Bulk density (g/ml)	0.65±0.03	0.40±0.01	0.35±0.03
Tapped density (g/ml)	0.82±0.02	0.52±0.02	0.43±0.03
True density (g/ml)	1.33±0.02	1.23±0.02	1.24±0.02
Hausner's ratio	1.24±0.01	1.29±0.04	1.27±0.04
Carr's index (%)	20.50±0.02	24.03±0.05	19.90±0.01
Porosity (%)	51.32 ± 0.02	67.09±0.11	76.25±0.04
Swelling index (%)	154.04±0.24	146.00±0.02	111.51±0.03
Hydration capacity	4.17±0.08	3.51±0.04	3.51±0.04
Moisture content (%)	8.68 ± 0.02	6.31±0.02	6.52±0.05

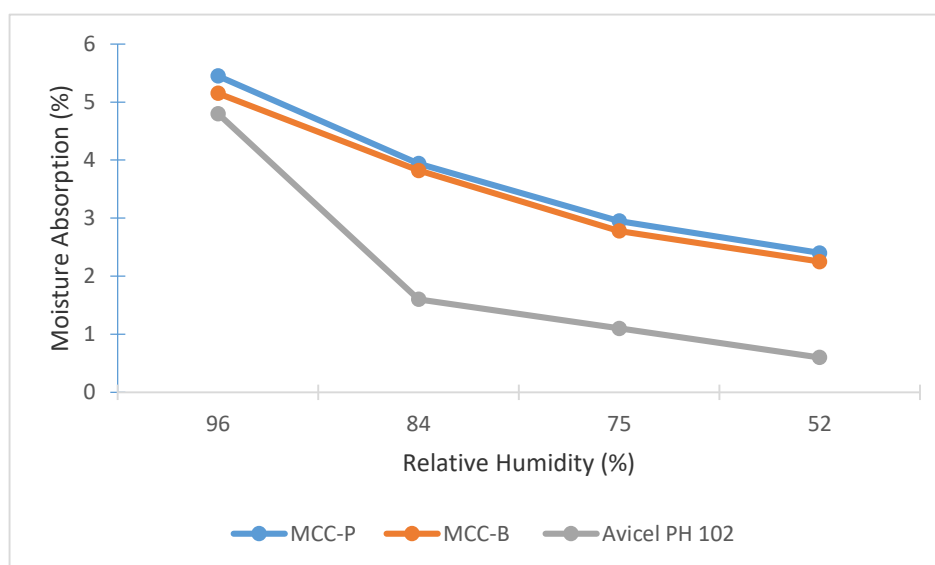


Figure 1: Moisture sorption at various relative humidity

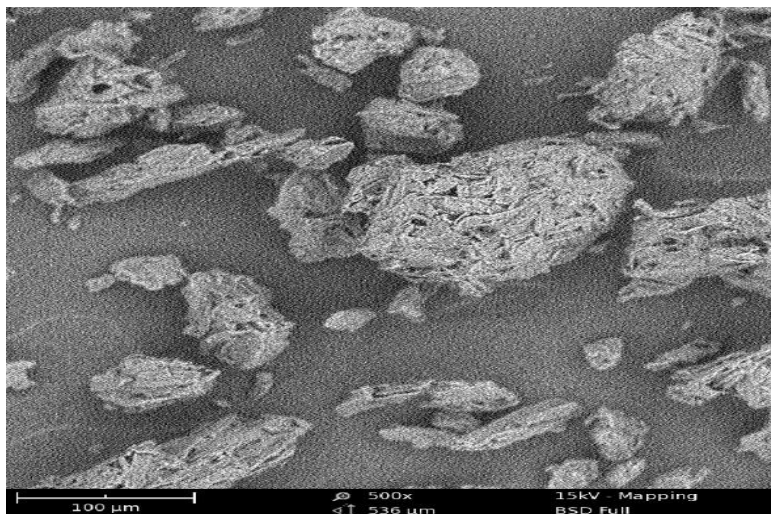


Figure 2: SEM of Avicel PH 102.

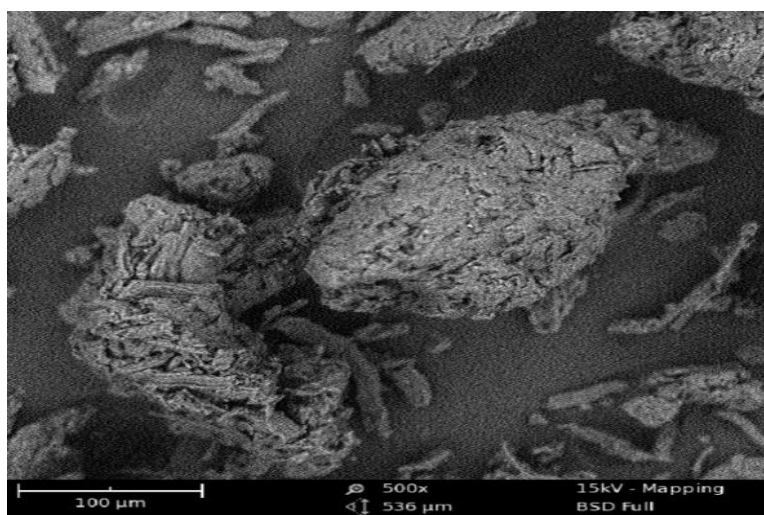


Figure 3: SEM of MCC-B

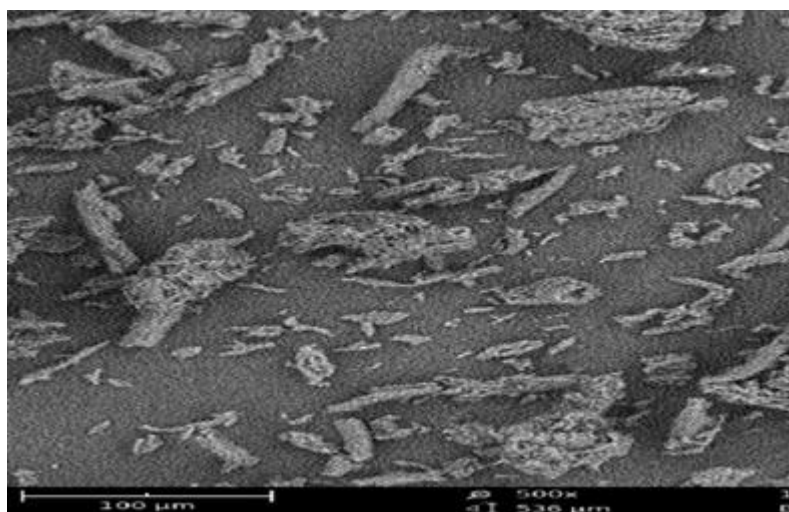


Figure 4: SEM of MCC-P

The values of the above heavy metal metals detectable from MCC-P or MCC-B were all below the FDA recommendation.

Elemental analysis was carried out to detect the presence of some heavy metals. Findings were as follows: Arsenic (1.58×10^{-10} %), Vanadium (2.0×10^{-5}). Lead and mercury were below a detectable limit. FDA recommended limits of 1.0×10^{-4} % for lead, 1.0×10^{-3} % for arsenic, and 1.0×10^{-4} % for mercury for potable water [29]. The values of the above heavy metals detectable from MCC-P or MCC-B were all below the FDA recommendation.

The results of the particle size analysis of the MCC-P, MCC-B Avicel PH 102 (Table 1) showed a significant difference in values and are generally less than 10 μm . Fine particles with a very high surface to mass ratios are more cohesive than coarser particles which are influenced more by gravitational forces. Particles larger than 250 μm are commonly comparatively free-flowing, but as the size decreases below 100 μm , powders develop cohesiveness and flow become poor. Powders taking a particle size lower than 10 μm are usually very cohesive and hinders flow under gravity, except possibly as large agglomerates [30]. This may be an indication to the possible poor flowability of MCC-P, MCC-B and Avicel PH 102.

The flow pattern of MCC-P, MCC-B and Avicel PH 102 were studied using the indirect methods of measuring flowability. Considering the results of some of these flow parameters, the values obtained for the angle of repose and Carr's index for the three powders were significantly different ($p < 0.05$) while their Hausner's ratio has no significant difference ($p > 0.05$). The flowability of loose solids particles emanates from the consistent forces imparting on separate particles such as van der Waals, electrostatic, surface tension, interlocking and friction [30]. In current years the compressibility index (*CI*) and the closely correlated Hausner's ratio (*HR*) takes the

simple, fast and widespread methods of evaluating powder flow properties. The *CI* has been proposed as an indirect style to quantifying bulk density, size and shape, surface area, moisture content and cohesiveness of solid materials since all of these can influence the determined value of *CI*. The generally established scale of flowability for *CI* and *HR* are defined below (19, 26): A *CI* (%) ≤ 10 and *HR* 1.00-1.11 show excellent flow features for the solid particles; *CI*, 11-15 and *HR*, 1.12-1.18 shows good flow; *CI*, 16-20 and *HR*, 1.19-1.25 point to fair flow; *CI*, 21-25 or > 38 and *HR*, 1.26-1.34 or > 1.60 is a sign of poor or very poor flow characteristics. Hausner [25] reported that values above 1.2 show inter-particulate friction. Also, values for angles of repose $\leq 30^\circ$ largely specify a free-flowing material and $\geq 40^\circ$ suggest a poorly flowing material [19]. The results for the MCC-P, MCC-B as well as the reference, Avicel PH 102 indicated that Hausner's ratio was a little above 1.2 and could result in poor flow. However, the results of Carr's index revealed that the two test powders and the reference MCC had poor flow and could be perceived by the failure of the respective powders to flow freely through the orifice of a funnel. However, their flowability may be better by the addition of glidants which will reduce the inter-particulate friction.

The results of the densities are also shown in Table 1. There was a significant difference between the true densities of MCC-P and Avicel PH 102; bulk and tapped densities of MCC-P, MCC-B and Avicel PH 102 ($p < 0.05$) was observed. However, there was no significant difference in the value of true density between MCC-B and Avicel PH 102 ($p > 0.05$). The bulk density of a powder is persistently less than the true density of its vital particles since the powder embraces inter-particle spaces. A reduction in bulk density could be associated to a decrease in particle size and yields a loose-packed

powder bed, which, although porous, is not likely to flow because of the inherent cohesiveness of the fine particles [30]. Since the inter-particulate interactions promoting the bulk behaviours of a powder are also the boundaries that affect powder flow, a distinction of the bulk and tapped densities can give a mark of the relative significance of these interactions in a given powder. Such an evaluation as the compressibility index (CI) or the Hausner's ratio is often used as a guide to the capability of the powder to flow. Though these factors have been dealt with above, they are processes of the inclination of a powder to be compacted, and an evaluation of the powder ability to settle and also allow an estimate of the relative consequence of inter-particulate interactions. In a free-flowing powder, such borders are less important, and the bulk and tapped densities will be closer in level. For poor flowing solid particles, there are often more inter-particulate interactions, and a better disparity in the values of the bulk and tapped densities will be detected. This is the case with the particle behaviour of *MCC-P*, *MCC-B* in comparison to the reference sample of the Avicel PH 102 since a statistical evaluation of the bulk and tapped densities of the three powders displayed a significant difference in their values ($p < 0.05$). This is further observed in the values of porosities for the respective powders ($p < 0.05$). This goes on to show that *MCC-P*, *MCC-B* and Avicel PH 102 are not very flowable powders [19,26,31].

The results of the moisture studies are also shown in Table 1 and show a significant difference in the moisture content of *MCC-P*, *MCC-B* and Avicel PH 102 in the order *MCC-P* > *MCC-B* > Avicel PH 102. The BP specifies moisture content (loss on drying) of 7.0 % [16]. The degree of variation in moisture content may be due to the effect of processing methods for the study samples with respect to Avicel PH 102. This trend in moisture content was also observed in the

swelling index with a significant difference in its values for the three powders. The values of hydration capacity showed a significant difference between *MCC-P* and Avicel PH 102 but an insignificant difference between *MCC-B* and Avicel PH 102. These variations may still be attributed to the effect of processing methods for both *MCC-P* and *MCC-B*. Considering the moisture sorption of the powders, generally, moisture sorption decreased as the relative humidity decreased from 92-52 %. The degree of moisture sorption was observed in the order *MCC-P* > *MCC-B* > Avicel PH 102.

The morphological studies of the powders using SEM show that *MCC-P* and *MCC-B* had a similar morphology which was similar to that of Avicel PH 102 (Figures 2-4).

Conclusion. Two batches of microcrystalline cellulose, *MCC-P* and *MCC-B* were derived from sugarcane stem-bark and its bagasse respectively and characterized along a commercial product of MCC, Avicel PH 102. The outcome of the physico-chemical assessments indicated that the individual powders had pH, moisture and ash content that conformed to the British Pharmacopoeia, BP (2009) specifications for MCC and were comparable to that of Avicel PH 102. The findings also showed that the powders had poor flow, which could be improved using glidants. However, both MCC from the different parts of the sugarcane stem were comparable to Avicel PH 102, but have advantages of accessibility locally and is relatively cheap. Manufacture of MCC from sugarcane stem-bark and bagasse could help to reduce pile-up of waste from these so that our surroundings could be free from litters from sugarcane bio-waste.

REFERENCES

1. Urban development series knowledge papers (2009); Waste composition. Available from: <https://worldbank.org/INTURBANDEVELOPMEN>

- T/Resources/336387-1334852610766/Chap5.pdf, Retrieved on 6th March, 2018.
2. World Bank (2012); What a waste: A global review of solid waste management. https://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/What_a_Waste2012_Final.pdf
 3. UN-Habitat (2009); Global report on human settlements: Planning sustainable cities. Available from <https://unhabitat.org/wp-content/uploads/2010/07/GRHS.2009.0.pdf>. Retrieved on 16th March, 2018.
 4. Hoornweg, D and Bhada-Tata, P (2012); What a Waste: a Global Review of Solid Waste Management. *Urban Development Series Knowledge Paper*. No. 15. Washington DC: The World Bank.
 5. Bin Wang, Faqin Dong, Mengjun Chen, Jingping Zhu, Jiangyue Tan, Xinmei Fu, Youzhi Wang & Shu Chen (2016); Advances in Recycling and Utilization of Agricultural Wastes in China: Based on Environmental Risk, Crucial Pathways, Influencing Factors, Policy Mechanism. *Procedia Environmental Sciences*, 31:12-17.
 6. WHO (2007); Training Workshop on Pharmaceutical Development with a Focus on Paediatric Medicines. 15-19. Available from: <http://studylib.net/doc/9264523/guidelines---world-health-organization>. Retrieved on 6th March, 2018.
 7. Wade A and Weller P.J. (1994); Handbook of Pharmaceutical Excipients. 11th Ed. The Pharmaceutical Press: London, 426-8.
 8. Anwar Z. Gulfranz M and Arshad M (2014); Agro-industrial lignocellulosic biomass a key to unlock the future bio-energy: A brief review. *Journal of Radiation Research and Applied Sciences*. 7:163-173.
 9. Iqbal H. M. N., Ahmed I., Zia, M. A and Irfan M. (2011); Purification and characterization of the kinetic parameters of cellulose produced from wheat straw by *Trichoderma viride* under SSF and its detergent compatibility. *Advances in Bioscience and Biotechnology*, 2(3): 149-156.
 10. Kumar P., Barrett D. M., Delwiche, M. J and Stroeve P. (2009); Methods for pretreatment of lignocellulosic biomass for efficient hydrolysis and biofuel production. *Industrial & Engineering Chemistry Research*, 48: 3713-3729.
 11. Malherbe S and Cloete T. E. (2002). Lignocellulose biodegradation: fundamentals and applications. *Reviews in Environmental Science and Biotechnology*, 1: 105-114.
 12. Lia D., Iwan K., Denta A and James M. R. (2009); Consumer Preference for Indigenous Vegetables. World Agroforestry Centre. Available from: <http://www.worldagroforestry.org/sea/Publications/files/poster/PO0251-10.pdf>. Retrieved on 6th March, 2018.
 13. Hindi S. S. Z. (2016); Microcrystalline cellulose: Its specifications and pharmaceutical processing. *Biocrystals Journal*, 1 (1): 26-38.
 14. Shangraw R. F., Wallace, J. W and Bowers, F. M (1987); Morphology and Functionality in Tablet Excipients for Direct Compression, *Pharm. Technol.*, 11: 136-143.
 15. Ohwoavworhua F.O and Adelakun T.A. (2005); Some Physical Characteristics of Microcrystalline Cellulose Obtained from Raw Cotton of *Cochlospermum planchonii*. *Trop J Pharm Res* 4 (2): 501-507.
 16. British Pharmacopoeia (2009); Her Majesty Stationery Office, University Press, Cambridge, A326-327.
 17. U.S Pharmacopoeia convention (2014); Revision bulletin (561). Available from http://www.pharmacopeia.cn/v29240/us_p29nf24s0_m14180.html. Retrieved on 6th March, 2018.
 18. Walter L (editor) (1994); The Pharmaceutical Codex. Principles and Practice of Pharmaceutics, 12th ed. The Pharmaceutical Press, London, p. 696.
 19. The United States Pharmacopoeia, U.S.P, NF (2007); The United States Pharmacopoeial Convention, Rockville.
 20. WHO (1988); Quality control methods for herbal materials. World Health Organization, Geneva, Available from: <http://apps.who.int/medicinedocs/documents/h1791e/h1791e.pdf>. Retrieved on 6th March, 2018.
 21. Ring S.G (1985); Some Studies on Gelatin. *Starch*. 37:80-87.
 22. Iwuagwu M.A and Okoli P.C (1992); The disintegrant properties of pregelatinised cassava and white yam starch. *Pharm. World J.* 9: 49 – 53.
 23. Carstensen J.T and Chan F.C (1997); Flow rates and repose angle of wet-processed granulations. *J. Pharm. Sci*; 66: 1235.
 24. Zeleznik, J. A and Renak, J.L. (2001); Flow and compaction properties of dibasic calcium phosphate blended with microcrystalline cellulose & silicified

- microcrystalline cellulose"; A paper presented at the American Association of Pharmaceutical Scientists Annual Meeting & Exposition, Denver, Colorado.
25. Hausner H.H (1967); Friction conditions in a mass of metal powder; *J. Powder Metal.* 3: 7-13.
 26. Carr R (1965); Classifying flow of solids. *Chemical Engineering*, 72:69-72.
 27. Odeku O.A, Awe O.O, Popoola B., Odeniyi M.A and Itiola O.A (2005); Compression & mechanical properties of tablet formulations containing corn, sweet potato and cocoyam starches as binders, *Pharm. Technol.*, 29(4): 82-90.
 28. FMC (2005); Avicel PH-102 microcrystalline cellulose, NF, Ph. Eur., product overview: Available from: <http://www.fmchealthandnutrition.com/>. Retrieved on 6th March, 2018.
 29. FDA (2011); Analysis of Foods for As, Cd, Cr, Hg and Pb by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS). <http://www.fda.gov/downloads/Food/FoodborneIllnessContaminants/Metals/UCM272693.pdf>. Retrieved on 6th March, 2018.
 30. Aulton M.E (2007); *Pharmaceutics; The Science of Dosage Form Design*, 3rd edn. Churchill Living Stone, Edinburgh, 198-210.
 31. Well J. (2003); *Pharmaceutical preformulation: the physicochemical properties of drug substances*. In: Aulton, M.E. (Ed.). *The science of dosage form design*, 2nd ed. Churchill Livingstone, Toronto, 113-138.