Research Article

Physico-Chemical Properties of Microcrystalline Cellulose Derived from Indian Bamboo (*Bambusa vulgaris*)

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ABSTRACT

The high demand and importance of microcrystalline cellulose used in pharmaceutical industries has led to the utilization of locally and naturally occurring materials in the production of microcrystalline cellulose. In this study, the physicochemical properties of a locally produced microcrystalline cellulose derived from premature stems of sprouts of Indian bamboo (*Bambusa vulgaris*) coded MCC-BV was evaluated and compared with a commercial grade (Avicel PH101). MCC-BV was prepared from the partial acid hydrolysis of α-Cellulose obtained through a "pulping" process of the premature sprouts. The comparative physico-chemical properties evaluated include: Particle size analysis, tapped, bulk and true densities; hydration capacity, moisture content and moisture sorption profile; the degree of polymerization and molecular weight. The cohesion and compactibility of MCC-BV were assessed and derived from the kawakita plots. The results obtained for these parameters are: moisture content (4.90%), hydration capacity (1.55), swelling capacity (47.12), degree of polymerization (112.26), viscosity (138.35) and average molecular weight (3273501.6* 10^6). These results indicates that MCC-BV had a significantly ($p < 0.05$) close resemblance to Avicel PH101 in terms of physicochemical properties. Both MCCs showed the same organoleptic properties, similar particle size distributions although the particle shapes or MCC-BV was different and it had poor flowability. The overall results indicated that MCC-BV compared favourably with Avicel PH101 in terms of its physico-chemical properties and complied with the specifications in the British Pharmacopoeia and Handbook for pharmaceutical excipient for microcrystalline cellulose.

Keywords: Microcrystalline cellulose, Indian bamboo (*Bambusa vulgaris*), Avicel PH101, physicochemical properties.

INTRODUCTION

One of the most important requirements of a pharmaceutical excipient is its ability to comply with pharmacopoeial requirements, relating to purity, inertness and compatibility. Microcrystalline cellulose (MCC), according to many publications is an excipient of outstanding merit and remains the most widely used direct compression excipient serving as a strong dry binder, tablet disintegrant, an absorbent, filler or diluent, a lubricant and anti-adherent.[1] MCC, a purified alpha cellulose, has been widely used as an additive for direct compression because of its good flowability, compactibility and compressibility.[2-4] Ofoefule and Chukwu examined Cissus gum blend with the microcrystalline obtained from India bamboo in the formulation of zinc oxide and sulphadimidine suspensions.[5] *Bambusa Vulgaris* (Poaceae) is a perennial plant found mostly in the all the southern parts of Nigeria except Lagos and from literature reviews in America and Asia.[6-7] It is known for its ability to check erosion as well as its tensile strength for construction in building.[7] It has been used in paper making. The extracts has been used to treat inflammatory conditions; the resin has been known to have astrigent, expectorant, constipating, cardiotonic, haemostatic, aphrodisiac and diuretic properties.[6-7] The stems sheaths has been used as covers for beehives.[7] As part of on-going efforts to develop local raw materials for pharmaceutical industry, we have in the present work obtained microcrystalline cellulose from the dried stem bark of Indian bamboo (*Bambusa vulgaris*) and the physicochemical properties were compared with the best commercial grade of microcrystalline, Avicel PH101.

MATERIALS AND METHODS

Sodium hydroxide (May and Baker, England), Sodium hypochlorite (Jik, Reckitt and Colman Nig. Ltd.), Hydrochloric acid (Fisins, UK), Avicel PH101 (FMC Corporation, USA), Distilled water (Lion water, Nsukka, Nigeria). Premature stems of sprouts of Indian bamboo (*Bambosa vulgalis*) were collected from Nimo in Anambra state, Nigeria and the MCC-BV was prepared in our laboratory. All other chemicals used were of analytical grade and water was double distilled.

Extraction of Alpha Cellulose

The MCC-BV was prepared from the partial acid hydrolysis of α-Cellulose obtained through a pulping process of sprouts of Indian bamboo; a modified method used by Baichwal et al and Gupte et al.[5, 8-9] Simply, the green bark of the Indian bamboo was peeled off, cut into chips and dried. 750g of the cut chips was macerated overnight with 1.5L of ethanol (46.6%) at room temperature and the ethanol decanted. This was replaced with 2.5 L of 3.5% sodium hydroxide and digestion affected for 4hr at 100 ^{0}C in a sand bath. This step removes lignin in the form of soluble complexes. Following thorough washing, the material was further treated with 2L of 17.5% sodium hydroxide at 100 ^{0}C for 2 hrs. The resulting α-cellulose was neutralized to pH of 6 with 0.1N acetic acid, bleached with 2L of 0.4% sodium

hypochlorite for 30 min at 50^{0}C and washed with water. The extraction process was completed by whitening with 0.2% sodium hypochlorite for 30 min at 50^{0}C and washing with water until neutral. The cellulose material was filtered, pressed and manually reduced to small lumps which was dried in a fluidized bed drier (Copely laboratory model, England) at an in-let air pressure of 40-45^{0}C for 4 hr.

Preparation of a grade of microcrystalline cellulose from Indian Bamboo

50.5g of the α-cellulose obtained was further treated by a process reported by Corey[10] with 2L of 2.5N hydrochloric acid under vigorous stirring at 100^{o}C ± 2^{o}C for 30 min. The resultant powder mass was bleached with 0.1% ^{w}/v solution of sodium hypochlorite and washed with water. The final product was dried at 60^{0}C ± 0.5^{o}C using a fluidized bed drier and pulverized with an end runner mill and passed through a 75µm sieve.

Physicochemical Studies

The organoleptic characteristics, identification, organic impurities and solubility were done in line with BP specifications.[11] An optical electronic microscope, Nikon model Larphot2 (Nikon inc., Japan) was used for preliminary assessment of the nature of particles in MCC-BV. A combination of both low and high power objective lens of 100 and 400x magnifications was used.

pH Determination: This was done by shaking 2g of MCC-BV with 100 ml of distilled water for 5 min and the pH of the supernatant liquid was determined using a pH meter (Corning model 10, England)

POWDER PROPERTIES AND MICROMERITIC STUDIES

Particle size analysis

Test sieves ranging from 1.18 to 25µm were arranged in descending order with a collector pan underneath the shaker. A 20g quantity of MCC-BV powder was placed on the top sieve and was shaken for 5 min using an Endicott's sieve shaker (Endicott's Ltd., UK). The weight of the material retained on each sieve was determined.

Bulk and Tapped Density

A 50g quantity of the MCC-BV powder was placed in a 10 ml measuring cylinder and the volume occupied by the material was noted as the bulk volume. The bulk density was obtained by dividing the mass of the material by the bulk volume as shown in Equation 1:[12-14]

$$Bulk\ Density = \frac{Mass\ of\ the\ material\ (M)}{Bulk\ volume\ of\ the\ material, (V_B)} \ldots\ldots\ldots (1)$$

The cylinder was tapped on a wooden platform by dropping the cylinder from a height of one inch at 2 seconds intervals until there was no change in volume reduction.

The volume occupied by the material was then recorded as the tapped volume. The tapped density was calculated using the formula:

$$Tapped\ Density = \frac{Mass\ of\ the\ material\ (M)}{Tapped\ volume\ of\ the\ material, (T_B)} \ldots\ldots\ldots (2)$$

True Density

The densities of the cellulose powders were determined by the liquid displacement method using kerosene as the immersion fluid.[15]

Hydration capacity and Swelling capacity

The principle of Kornblum and Stoopak[16] was used to determine the hydration capacity of MCC-BV. A 2.0 g of MCC-BV was each placed in four 15 ml plastic centrifuge tubes and 10 ml of distilled water was added and stoppered. The content was agitated for 3 min, allowed to stand for 10 min and immediately centrifuged using a Gallenkemp bench centrifuge (Gallenkemp, England) at 1000 rev per minute for 10 min. The supernatant was carefully decanted, the stopper replaced and the sediment was weighed.

The hydration capacity was calculated using the formula:

$$Hydration\ capacity\ (HC) = \frac{weight\ of\ sediment - weight\ of\ tube}{Sample\ weight\ (dry\ sample)} \ldots\ldots (3)$$

Swellability

This was measured at the same time as the hydration capacity determination using the method of Okhamafe et al.[15]

Compactibility and Powder Cohesion.

The cohesion and compactibility of MCC-BV were assessed and derived from the kawakita plots[17] by determining the tapped density and the behavior of MCC-BV during the tapping process.

A 5.0 g quantity of the sample was poured into a 25 ml measuring cylinder and leveled with a thin metallic spatula and the bulk volume (V_0) was measured. The cylinder was mechanically tapped and values of the volume, V of the powder after N number of taps were measured.

The process was repeated and the values V and V_0 were used to calculate the degree of volume of reduction.

The cohesion and compactibility of MCC-BV was calculated using the following kawakita equation for powder densification:

$$^N/_C = N/a + 1/ab \ldots\ldots\ldots\ldots (4)$$

$$C\ is\ obtained\ from\ \frac{V_0 - V}{V}$$

1/b describes the cohesiveness of the powder and a, is considered to be the compactibility of the powder.

A graph of N/C against N gives 1/a as the slope and 1/ab as the intercept.

Moisture Sorption Profile

A 2.0 g sample of MCC-BV was evenly distributed over the surface of 70 mm tarred Petri dish and placed in a large dessicator (RH=100%) at room temperature. The daily weight gained by the sample over a period of 5days at various time intervals was recorded and the amount of moisture absorbed was calculated from the difference.

Molecular weight and Degree of Polymerization Determinations

The molecular weight of the MCCs was determined using solution viscometry.[18] The U-tube viscometer (Technicu size C100, 1983) was used and 40% $^{v}/_{v}$ of acetone was used as the solvent for the polymer. All determinations were done at 25°C. The time taken for 40% $^{v}/_{v}$ acetone to flow through the viscometer was determined using a stop watch. Triplicate determinations were made in each case and the viscosity of each was calculated using the equation

$$\frac{\eta_1}{\eta_2} = \frac{t_1}{t_2} \quad \text{---------- (5)}$$

The specific viscosity (η_{sp}) of the polymer solution was calculated from the equation: $\eta_{sp} = \frac{\eta_2}{\eta_1} - 1$ --- (6)

The intrinsic viscosity (η_0) was calculated from the graphical form of the Huggins equation:[19]

$$^{\eta_{sp}}/_{C} = \eta + K_H[\eta]^2 C \quad \text{---------- (7)}$$

Where K_H is Huggin's constant

The molecular weight was calculated using the integral form of Mark-Houwink equation:

$$[\eta] = KM_v^{a} \quad \text{---------- (8)}$$

where k and a are constants characteristic of the polymer-solvent temperature system. K ranges from 0.5 and $5x10^{-4}$.

The degree of polymerization was then calculated using the equation:

$$D_p = M/M_0 \quad \text{---------- (9)}$$

M = molecular weight of the material
M_o = Molecular weight of glucose

RESULTS AND DISCUSSION

Table 1: Some Physicochemical Properties of MCC-BV and Avicel PH101

TEST	MCC-BV	Avicel PH101
Organoleptic	Odourless, white, tasteless coarse powder	Odourless, white, tasteless coarse powder
Starch and Dextrins	Nil	Nil
Solubility in ammonical solution of copper	Complete and no residue	Complete and no residue
Water soluble-substance	≤0.5%	<0.2%

The yield of MCC-BV, obtained from α-cellulose was approximately 25% and 6.9% of the starting plant material. Both MCCs showed the same organoleptic properties, solubilities and identification as shown in Table 1. The bulk and tapped densities of powders and granules provides an insight on their packing and densification behaviour.

There was an increase from bulk density to bulk density as a result of densification. The tapped density of MCC-BV is lower than that of Avicel PH101 as shown in Table 2. The true density, 1.642 for MCC-BV is high when compared to 1.204 for Avicel PH101. The high value for MCC-BV suggests that it has a high degree of crystallinity than Avicel PH101.[20] This is in accordance with the report by Stamm[21] that the greater the degree of crystallinity, the greater will be the true density of its substance determined in a non polar liquid. The flow properties of a powder are essential in determining the suitability of a material as a direct compression excipient. The Hausner's quotient, carr's index and angle of repose are considered as indirect measurements of powder flowability.[22] The Hausner's quotient and angle of repose of MCC-BV (Table 2) are relatively high indicating increased inter particulate friction between the particles and hence very poor flow. The results for the molecular weight and degree of polymerization of MCC-BV as compared to Avicel PH101 is also presented in Table 2.

Table 2: Powder Properties of MCC-BV and Avicel PH101

Parameters	MCC-BV	Avicel PH101
True density (g/ml)	1.642	1.204
Bulk density (g/ml)	0.327 ± 0.00	0.415 ± 0.02
Porosity (%)	41.00	48.59
Angle of repose (Φ^0)	57.44 ± 0.47	65.04 ±0.86
Hausner's quotient	1.61	1.59
Compressibility index	37.87	37.22
Hydration capacity	1.55	2.00
Swelling capacity (%)	47.12	21.56
Moisture sorption capacity (%)	49 ± 18.51	76 ± 19.81
Degree of Polymerization	181.90	112.26
Molecular weight	53052388.7	3273501.6

Values shown are mean ±SD (*n=3). Values obtained are a mean of three replicate determinations. Data was analyzed using using one-way ANOVA with SPSS version 14.0 (SPSS Inc. Chicago, ILUSA). $P < 0.05$ was considered statistically significant. Differences between the means were asessed using the Student T-test.

The results as presented in Table 2 indicates that the powder properties of MCC-BV compares favorably with stated official requirements for microcrystalline cellulose, Avicel PH101 as specified in the Handbook for pharmaceutical excipient.[23] There was a significantly ($p < 0.05$) close resemblance in the physicochemical and powder properties of MCC-BV and Avicel PH101. Following the kawakita equation for powder densification, a graphical representation of N/C against N

number of taps for MCC-BV and Avicel PH101 gave a linear relationship as shown in Fig. 1. Compactibility, a, and cohesiveness, 1/b were obtained from the gradient, 1/a and intercept, 1/ab respectively (Table 3). This indicates the differences in behavior of MCC-BV and Avicel PH101 during tapping. Compactibility, a, for MCC-BV was higher than that of Avicel.

Table 3: Parameters from Kawakita plots

Parameter	MCC-BV	Avicel PH101
Compactibility, a (%)	40.0	32.4
Cohesiveness 1/b	2.4	1.5

The relationship between compactibility, a, and fluidity has been clearly shown from experimental correlations that fluidity worsens as reported by Yaroshima[17] because carr's index number for fluidity decreases as compactibility increases. Hence MCC-BV with a higher compactibility value probably has worse fluidity in comparison to Avicel under tapping pressure. Also the cohesiveness 1/b of MCC-BV was higher than that of Avicel. This indicates that MCC-BV is more cohesive than Avicel, a behavior consistent with values obtained for the indices of fluidity as very cohesive powders exhibit poor flow.

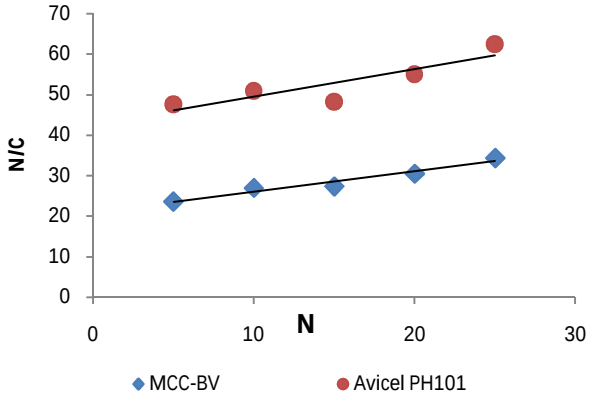

Figure 1: N/C against N for MCC-BV and Avicel PH101

The hydration capacity value shows that MCC-BV is able to absorb one and half of its own weight of water while Avicel absorbs equal weight of water.

Swellability indicates increase in volume after water absorption and values of 47.12% and 21.56% (Table 2) were obtained for MCC-BV and Avicel PH101 respectively. It is likely that only a small portion of absorbed water actually penetrated the individual cellulose particles causing them to swell and the remaining bulk would exist in free-state between particles.

Therefore, when this cellulose is incorporated in tablet formulation as a disintegrant, the tablet will disintegrate by two processes: capillary or wicking due to inter-particulate water and swelling. The moisture sorption profile of MCC-BV and Avicel shown in Fig. 2 explains the materials moisture sensitivity. MCC-BV has a low rate of moisture sorption than Avicel PH101. Stamn reported that the crystallite portion of cellulose does not adsorb water and the extent of water adsorption by cellulose is proportional to the amount of amorphous cellulose present.[20] Thus, the result is indicative of the high crystallinity expected of this material.

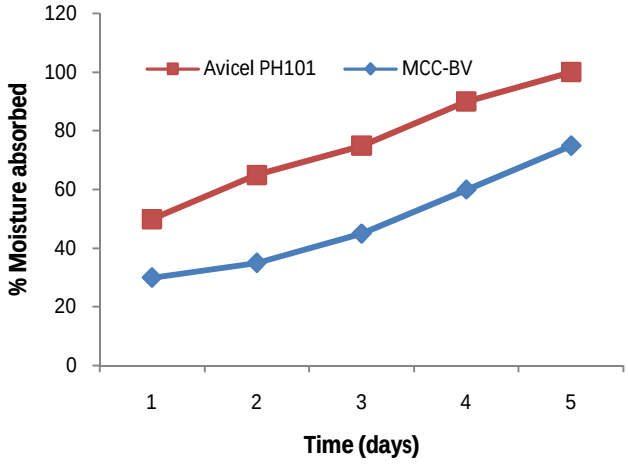

Figure 2: Moisture Sorption Profile for MCC-BV and Avicel PH101

Furthermore, larger surface area sequel to small particle size of Avicel powder could have in part, accounted for higher amount of moisture taken up by Avicel.

The study of moisture sorption capacity is particularly important in this study because it shows the relative stability of tablets made from MCC-BV when stored under humid condition.

Furthermore, the lower the rate of moisture sorption, the lower the deteriorating effect on incorporated drugs that undergo hydrolytic decomposition.

CONCLUSION

The overall results indicate that the cellulose material, MCC-BV compares favorably with Avicel PH101 with a significantly ($p<0.05$) close resemblance in physicochemical properties as well as complying with the official requirements specified in the British Pharmacopoeia and Handbook for pharmaceutical excipient for microcrystalline cellulose.

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