

Research Article

Some Physical Characteristics of Microcrystalline Cellulose Obtained from Raw Cotton of *Cochlospermum planchonii*

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Abstract

Purpose: The microcrystalline cellulose is an important ingredient in pharmaceutical, food, cosmetic and other industries. This study aimed at evaluating the physical characteristics of microcrystalline cellulose (CP-MCC), obtained from the raw cotton of *Cochlospermum planchonii*.

Methods: CP-MCC was obtained from the raw cotton by a two-stage sodium hydroxide treatment process followed by sodium hypochlorite bleaching and acid hydrolysis. It was examined for its physicochemical and powder properties. The powder properties of CP-MCC were compared to those of the well-known commercial microcrystalline cellulose grade, Avicel PH 101.

Results: The extraction yield of CP-MCC was approximately 21%. The cellulose material was composed of irregularly shaped fibrous cellulose particles with a moisture content of 7.2% and total ash of 0.12%. The true density was 1.38. The flow indices showed that CP-MCC has poor flow. The hydration, swelling and moisture sorption capacities were 4.7, 83.3 and 22%, respectively.

Conclusion: The cellulose product, CP-MCC, obtained from the raw cotton of *Cochlospermum planchonii* conformed to the official specifications in the British Pharmacopoeia (2004). The flow properties of a powder are critical in direct compression tableting; consequently, for the materials to be used for this purpose, it would require the addition of a glidant. Furthermore, the swelling parameters indicate that CP-MCC would be a better disintegrant than Avicel PH 101.

Keywords: *Cochlospermum planchonii*, microcrystalline cellulose, physical characteristics, pharmacopoeial requirements

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INTRODUCTION

Microcrystalline cellulose, (MCC), is described as purified, partially depolymerised cellulose prepared by treating α -cellulose, obtained as a pulp from fibrous plant with mineral acids. It is one of the most used filler-binders in direct tablet compression. Its popularity in direct compression is due to its excellent binding properties when use as a dry binder. It also works as a disintegrant and lubricant and has a high dilution potential in direct compression formulations. In addition to its use in direct compression formulations, MCC is used as a diluent in tablets prepared by wet granulation as well as a filler for capsules and spheres¹.

Commercially available MCC is derived from both gymnosperms (generally conifers) and other softwoods, and from hardwood dicotyledons. These woods differ considerably in chemical composition (proportions of cellulose, hemicelluloses and lignin) and structural organization which affect the composition of the α -cellulose extracted and the composition and crystallinity of MCC finally produced². Besides the wood pulp as a source of cellulose and its derivatives, the purified cotton linters obtained from *Gossypium* species are also a common source³.

Cochlospermum planchonii is a low shrubby savanna plant which grows up to 2.5m high and reproduces from seeds and rhizomes. It is a common weed of cultivated fields in both Guinea and Sudan savanna zones⁴. It produces 3- to 5 celled capsules containing numerous seeds whose epidermal trichomes are cotton. Although it has long been known that cotton linters from different plants are sources of cellulose and cellulose derivatives, there is paucity of information on the physical and tableting properties of microcrystalline cellulose obtained from these sources. Hence this study aims to evaluate the physical and tableting properties of microcrystalline cellulose obtained from raw cotton of *C. planchonii*. This paper reports on some of the physical characteristics of the obtained microcrystalline cellulose, here code named CP-MCC, in comparison with the well-known microcrystalline cellulose, Avicel PH 101.

MATERIALS AND METHODS

Materials

Sodium hydroxide (BDH, England), 3.5% w/v sodium hypochlorite as (Jik®, Reckitt and Colman Ltd, Nigeria), hydrochloric acid (Fisons, UK), Avicel PH 101 (FMC Corporation, USA), xylene, phloroglucinol and iodine crystals (Hopkin and Williams, London) were used as obtained. All other chemicals used were of analytical or reagent grade and water was double-distilled.

Matured bolls of *C. planchonii* were identified and collected in the herbarium unit of National Institute for Pharmaceutical Research and Development, Abuja, Nigeria. Microcrystalline cellulose, CP-MCC, was prepared in our laboratory as described below under 'Methods'.

Methods

Isolation of α - cellulose

The bolls were properly air dried, the hairs manually separated from the seeds and impurities such as immature and broken seeds and fragments of leaves removed. Isolation of α -cellulose was as described earlier⁵, with a slight modification. An 80 g quantity of this material was placed in a stainless steel container to which was added 4.0 L of 2% w/v sodium hydroxide and digestion effected for 4 h at 80 °C in a water bath (FGL 1083. Karl Kolb Scientific, West Germany). Following thorough washing and filtration, it was bleached with 2.0 L of a 1:1 aqueous dilution of sodium hypochlorite for 15 min at 80 °C. The material was then washed sufficiently with water and treated with 2.0 L of 17.5% w/v sodium hydroxide at 80 °C for 1 h. The resulting α -cellulose was washed thoroughly with water. The extraction process was then completed by whitening with a 1:2 aqueous dilution of sodium hypochlorite for 15 min at 80 °C and subsequent washing with water until neutral. The cellulose material was filtered, and the water manually squeezed out using calico cloth to obtain small lumps, which

were dried in a fluidized-bed dryer at an inlet air temperature of 57-60 °C for 1 h.

Production of microcrystalline cellulose (CP-MCC)

The procedure reported earlier⁵, with a slight modification, was used. A 50 g quantity of the α-cellulose obtained was placed in a glass container and hydrolyzed with 0.8 L of 2.5 N hydrochloric acid at a boiling temperature of 105°C for 15 min. The hot acid mixture was poured into 2.5 L of cold tap water which was followed by vigorous stirring with a spatula and allowed to stand overnight. The microcrystalline cellulose obtained by this process was filtered, washed with water until neutral, filtered, pressed and dried in a fluidised bed dryer at an inlet air temperature of 57 – 60 °C for 60 min. Following further milling and sieving, the fraction passing through 650µm sieve aperture was used for the characterization.

Physicochemical properties of CP-MCC

The organoleptic characteristic, identification, organic impurities, starch and dextrin, solubility, total ash and water-soluble substances were carried out in accordance with British Pharmacopoeia⁶ specifications. An optical microscope, model Larphot 2 (Nikon Inc., Japan) was used for preliminary assessment of the nature of particles in CP-MCC powder particles. The combination of low and high power objective lenses of x100 and x400 magnification, respectively, were used.

pH determination: This was done by shaking 2 g of the powder material 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)⁵.

Total ash determination: The method⁵ described in an earlier study was adopted. Ash content was estimated by the measurement of the residue left after combustion in a furnace at 550°C.

Powder Properties

Particle size analysis

A sieve-shaker, (Retak 3D, Retsch GmbH and

Co KG, Haan, Germany) was used for this assessment. Test sieves ranging from 850 to 150 µm were arranged in a descending order. A 20 g quantity of CP-MCC powder was placed on the top sieve and the set-up was shaken at an amplitude of 1.50 mm/'g' for 5 min. The weight of material retained on each sieve was determined. The average diameter was computed as reported by Ansel et al⁷ using the following equation:

$$\text{Average diameter} = \frac{[\sum (\% \text{ retained}) \times (\text{mean aperture})]}{100} \dots (1)$$

True Density

The true densities (D_t), of cellulose powders were determined by the liquid displacement method using xylene as the immersion fluid⁸ and computed according to the following equation:

$$D_t = \frac{w}{[(a + w) - b] \times SG} \dots (2)$$

Where w is the weight of powder, SG is specific gravity of solvent, a is weight of bottle + solvent and b is weight of bottle + solvent + powder.

Flow Properties

Angle of Repose

The static angle of repose, a , was measured according to the fixed funnel and free standing cone method⁹. A funnel was clamped with its tip 2 cm above a graph paper placed on a flat horizontal surface. The powders were carefully poured through the funnel until the apex of the cone thus formed just reached the tip of the funnel. The mean diameters of the base of the powder cones were determined and the tangent of the angle of repose calculated using the equation:

$$\tan a = \frac{2h}{D} \dots (3)$$

Where h is the height of the heap of powder and D is the diameter of the base of the heap of powder.

Bulk and Tap Densities

A 10 g quantity each of the powder samples was, placed in a 50 ml clean, dry measuring cylinder and the volume, V_o , occupied by each of the samples without tapping was determined.

After 500 taps using Stampfvolumeter (Model STAV 2003 JEF, Germany), occupied volumes, V_{500} , were determined. The bulk and tap densities were calculated as the ratio of weight to volume (V_0 and V_{500} respectively) ⁵.

immediately centrifuged at 1000 rpm for 10 min on a bench centrifuge (Gallenkamp, England).

The supernatant was carefully decanted and the sediment weighed. The hydration capacity was taken as the ratio of the weight of the sediment

Table 1: Some physicochemical properties of microcrystalline cellulose (CP-MCC)

TESTS	CP-MCC
Organoleptic Identification	Odourless, white, tasteless, coarse powder Turns violet-blue with iodinated $ZnCl_2$
Organic impurities	No red colour with acidified phloroglucinol
Starch and dextrans	No blue/reddish brown colour with iodine solution
pH	7.6
Solubility (in ammoniacal solution of copper tetrammine)	Complete and no residue
Water –soluble substance	< 0.2%
Total ash (%)	0.12 (0.004)
Microscopy	Irregularly shaped fibrous particles which are mixture of primary particles and spherical aggregates.

*Value is mean and standard deviation is in parenthesis, number of replicate =3

Hausner Index

This was calculated as the ratio of tap density to bulk density of the samples⁵.

Compressibility Index (C%)

This was calculated using bulk and tap densities data when fitted into the equation⁵:
Compressibility = (Tapped density – bulk density)/Tapped density x 100 % (4).

Powder Porosity

This was derived from the values of true and bulk densities when fitted into the equation:
 $e = 1 - B_b / D_t \times 10$ (5)

Where B_b is the bulk density , D_t is the true density and e is the porosity⁵.

Hydration Capacity

The method of Kornblum and Stoopak¹⁰ was used. A 1.0 g each of the samples was placed in each of four 15 ml plastic centrifuge tubes and 10 ml distilled water was added from a 10 ml measuring cylinder and then stoppered. The contents were mixed on a vortex mixer (Vortex-Gennie Scientific Industry, USA) for 2 min. The mixture was allowed to stand for 10 min and

to the dry sample weight.

Swelling capacity

This was measured at the same time as the hydration capacity determination using the method of Okhamafe et al⁸ and computed according to the following equation:
 $S = (V_2 - V_1) / V_1 \times 100$ 6

Where S is the % swelling capacity, V_2 is the volume of the hydrated or swollen material and V_1 is the tapped volume of the material prior to hydration.

Moisture Sorption Capacity

2 g of the cellulose material was accurately weighed and evenly distributed over the surface of a 70 mm tarred Petri dish. The samples were then placed in a large desiccator containing distilled water in its reservoir (RH = 100%) at room temperature and the weight gained by the exposed samples at the end of a five-day period was recorded and the amount of water sorbed was calculated from the weight difference⁵.

Loss on drying

Table 2: Powder properties of microcrystalline cellulose and Avicel PH 101

Parameters	CP-MCC	Avicel PH 101
True density (g/ml)	1.38 (0.05)	1.40 (0.06)
Bulk density (g/ml)	0.24 (0.006)	0.31 (0.04)
Tapped density (g/ml)	0.40 (0.006)	0.42 (0.12)
Porosity (%)	82.6	78
Flow properties:		
(a) Angle of repose	54.4 (0.9)	41.2 (0.5)
(b) Hausner index	1.65	1.35
(c) Compressibility index (%)	39.5	26
Hydration capacity	4.73 (0.17)	2.17 (0.01)
Swelling capacity (%)	83.3 (3.57)	21.4 (0.03)
Moisture sorption capacity (%)	22.8 (1.6)	16.6 (0.24)
Loss on drying (%)	7.2 (0.86)	7.4 (0.4)

Values are mean and standard deviations are in parenthesis; number of replicates, N=3

The powder sample (5 g) was transferred, each, into a *Petri* dish and then dried in an oven at 105 °C until a constant weight was obtained. The % moisture content was then determined as the ratio of weight of moisture loss to weight of sample expressed as a percentage⁵.

RESULTS AND DISCUSSION

The yield of α -cellulose was approx. 32 % w/w of the original material. The yield of the microcrystalline, CP-MCC, obtained from α -cellulose was 67 % w/w. Thus the yield of CP-MCC was 21 % w/w of the starting raw cotton material.

The results of the physicochemical properties investigated are shown in Table 1. The results indicate a high level of purity of the cellulose material. This is expected as raw cotton is regarded the purest form of cellulose, consisting of cellulose approximately 90% and moisture 7%, the remainder being wax, fat, remains of protoplasm and ash³.

The organoleptic qualities of the CP-MCC produced were good as the material was odourless, tasteless, white and granular in texture. The value obtained for the total ash was very low. The total ash figure is of importance and probably indicates, to some extent, the level

of care taken in the preparation of the substance³. In general, the results were as specified in the British Pharmacopoeia 2004.

POWDER PROPERTIES

The powder properties of CP-MCC and Avicel PH 101 are presented in Table 2 while the result of particle size analysis is shown in Fig. 1. The figure represents a unimodal frequency distribution which is positively skewed. The particle size is in the range of 70-1000 μ m. Thus, CP-MCC powder belongs to the classification, 'conventional powder'¹¹. Over 85 % of the particle population is less than 250 μ m, and the calculated average diameter was 113 μ m.

The loss on drying of CP-MCC was about 7.2%. This is slightly above the official limit of 6 % stated in British Pharmacopoeia 2004⁶. Consequently, CP-MCC would need to be dried further if it is to be used as a diluent in the formulation of hydrolysable drugs such as aspirin.

The flow properties of a powder are essential in determining its suitability as a direct compression excipient. The angle of repose, Hausner index and Carr's % compressibility are considered as indirect measurements of powder

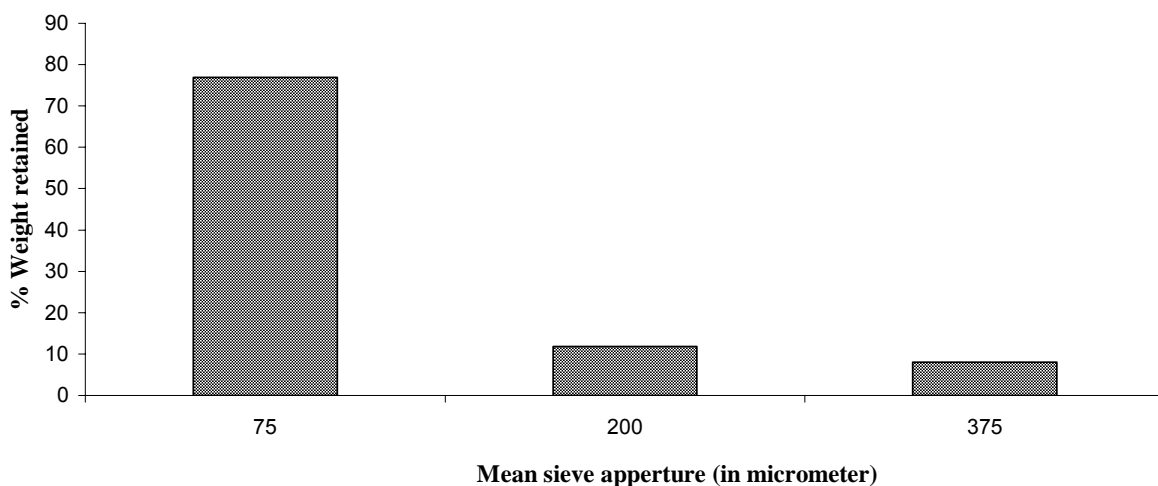


Figure 1: Particle size distribution of microcrystalline cellulose powder (CP-MCC) obtained from raw cotton of *C.planchonii*

flowability¹² and the high angle of repose of CP-MCC (Table 2) is indicative of poor flow¹³. While the Hausner index is indicative of interparticle friction, the Carr's index shows the aptitude of a material to diminish in volume¹². As the values of these indices increase, the flow of the powder decreases. In general, however, Hausner ratio greater than 1.25, indicate poor flow; Carr's compressibility index below 16 % indicates good flowability while values above 35 % indicate cohesiveness¹². The flow indices showed that CP-MCC and Avicel PH 101 powders have poor flow. Consequently, a glidant will be needed when these materials are to be used in solid dosage production processes.

Swelling which is generally accepted as an indication of tablet disintegration ability¹⁴ can be assessed by the determination of hydration capacity, swelling capacity and moisture sorption profile. The hydration capacity value obtained for CP-MCC, (Table 2), indicates that it is capable of absorbing about five times its own weight of water and approximately twice more water than Avicel PH 101. The swelling capacity, which reflects the increase in volume of

cellulose following water absorption was 83.3 % (Table 2). Thus, if the cellulose was incorporated in tablet formulation as a disintegrant it would probably produce tablet disintegration by two mechanisms: capillary or wicking due to interparticulate water and swelling. In addition, the slightly higher hydration and swelling capacities values observed for CP-MCC compared to Avicel PH101 could possibly be due to the higher powder porosity of CP-MCC (Table 2).

The moisture sorption capacity is a measure of the moisture sensitivity of material. The values for CP-MCC and Avicel PH 101 (Table 2) are significantly different ($p < 0.05$). Stamm¹⁵ reported that the crystallite portion of cellulose does not adsorb water and that the extent of water adsorption by cellulose should thus be proportional to the amount of amorphous cellulose present. Thus, the result is indicative of the high amount of amorphous cellulose in the unit fibrils of CP-MCC. Also, study of water sorption is of importance since it reflects the relative physical stability of tablets made from CP-MCC when stored under humid conditions.

In all, this property showed that the cellulose powders are sensitive to atmospheric moisture and should therefore be stored in air-tight container.

CONCLUSION

The cellulose product, CP-MCC, obtained from the raw cotton of *Cochlospermum planchonii* conformed to the official specifications in the British Pharmacopoeia (2004). The flow properties of a powder are critical in direct compression tableting; consequently, for the materials to be used for this purpose, it would require the addition of a glidant. Furthermore, the swelling parameters indicate that CP-MCC would be a better disintegrant than Avicel PH 101.

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