Investigation of α-Cellulose Content of Sugarcane Scrappings and Bagasse as Tablet Disintegrant

Bakre Lateef Gbenga* and Odumala Kehinde Fatimah

Department of Pharmaceutics and Pharmaceutical Technology, Olabisi Onabanjo University, Sagamu, Nigeria

Abstract: The aim of this study is to investigate the physicochemical and disintegrant properties of α – cellulose obtained from sugarcane scrapings and bagasse. The mechanical and release properties of paracetamol tablets containing the extracted celluloses and two standard disintegrants- corn starch B.P and microcrystalline cellulose - were determined using crushing strength, friability, disintegration time, the time taken for 50% (T_{50}) and 90% (T_{90}) drug dissolution as assessment parameter. α – cellulose obtained from sugarcane scrapings and bagasse possess better flow properties than cornstarch and microcrystalline cellulose and are capable of absorbing up to five times their own weight in water and swell considerably. α – cellulose obtained from sugarcane scrapings and bagasse have high moisture sorption capacity and they formed relatively softer tablets which became increasingly harder as their concentration increased. All the tablets formulated with cellulose derived from sugarcane scrapings and bagasse passed the official disintegration test for uncoated tablets. Cellulose obtained from sugarcane bagasse had superior disintegrant property to cornstarch and microcrystalline cellulose while cellulose obtained from sugarcane scrapings showed comparable disintegrant property to microcrystalline cellulose. Tablets containing 2.5% w/w cellulose derived from sugarcane scrapings and 5.0% w/w cellulose derived from sugarcane bagasse gave more optimum result as tablet disintegrant. Formulations containing cellulose derived from sugarcane scrapings and bagasse show faster drug release (lower T_{50} and T_{90}) than tablets containing corn starch and microcrystalline cellulose. There was a linear correlation between T_{90} and disintegration time ($r = 0.976$, $p< 0.05$) for tablets formulated with cellulose derived from sugarcane scrapings. Results show that α – cellulose obtained from sugarcane bagasse and scrapings are potentially useful as disintegrants in tablet formulations.

Keywords: α-cellulose, sugarcane bagasse and scraping, physicochemical properties, disintegrant, release properties.

INTRODUCTION

Many agricultural by-products from agricultural activities and agro-based processing litter the environments and constitute waste problems. The need for environmentally friendly processes as well as the need to slow down the fast global deforestation has stimulated renewed interest in agro-fiber plants waste. Today, the impact of agricultural by-products on the environment and other threatened ecosystems is an issue to be resolved. This problem is more frequent in developing countries where most of these residues are either burned or dumped into rivers. As a result, these by-products contribute to the green house effect, soil erosion, and pollution of the atmosphere and water sources. Since most of these residues are cellulose based materials (e.g sugarcane bagasse and scrapings, maize stem and cobs, plantain stem, raffia from *Raphia hookeri)*, they represent a potential source of inexpensive pharmaceutical excipients [1]. Furthermore, they are abundant and accessible, and so making the production process involved in the production of pharmaceutical excipients simple and economical.

Sugarcane belongs to the grass family Poaceae, an economically important seed plant family that includes maize, wheat, rice, and sorghum and many forage crops. The main product of sugarcane is sucrose, which accumulates in the stalk internodes. Sugarcane is the world's largest crop. In 2010, FAO estimates it was cultivated on about 23.8 million hectares, in more than 90 countries, with a worldwide harvest of 1.69 billion tons [2]. Sugarcane predominantly grows in the tropical and subtropical regions. Sugarcane scrapping is obtained by scraping the outer part of the stem (rind) with a sharp knife to remove the bark on the stem that affords protection to the underlying cells. The scrapings consist of the wax, pigments and fibrous materials of the rind, and a small quantity of the underline parenchyma cells. After scrapping, the material lies waste littering in both urban and rural settlements hereby constituting environmental pollution. Sugarcane bagasse is a residue produced in large quantities by sugar and alcohol industries. In general, 1 tonnes of sugarcane generates 280 kg of bagasse, the fibrous by-product remaining after extraction from sugarcane [3]. It is against this background that this study is aimed at investigating the disintegrant activity of α- cellulose obtained from sugarcane scrapings and bagasse; and evaluates it as a dissolution aid in compressed tablet formulations.

*Address correspondence to this author at the Department of Pharmaceutics and Pharmaceutical Technology, Olabisi Onabanjo University, Sagamu, P.O. Box 22613, UI Post Office, Ibadan, Nigeria;
E-mail: lateefbakr@yahoo.com

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MATERIALS AND METHOD

Materials

The materials used were paracetamol powder (May and Baker, Nigeria), microcrystalline cellulose and cornstarch (BDH chemicals, UK), lactose powder (DVM Veghel, Holland), Polyvinylpyrollidone, PVP (30,000 Merck, Germany). Water was double distilled and all other chemicals were of analytical grade.

Extraction of Cellulose

Cellulose was extracted using a modification of method used by Okhamafe *et al*. [4]. The sugarcane scrappings were washed and dried at an average temperature of 33 °C and relative humidity of 67 %. A 200g powder was delignified with 2% w/v aqueous sodium hydroxide for thirty minutes and the resulting slurry was filtered. The washed and filtered material was treated with 500 mL of 17.5% w/v sodium hydroxide at 80°C for 1 hr to digest the material. The resulting α cellulose was washed thoroughly with distilled water. The extraction process was then completed by bleaching with an aqueous dilution of 3.2% w/v sodium hypochlorite for 20 min at 80 ^{o} C and subsequent washing with water until filtrate was clear and the residue was neutral to litmus paper. The cellulose material was filtered, the water manually squeezed out to obtain small lumps which were dried at 60 °C for 6 h and labeled as SSC. Similar procedure was used to extract cellulose from sugarcane bagasse and labeled SBC.

Determination of Physicochemical Characteristics

The true density was obtained by the liquid displacement method using benzene as the displacement fluid. The bulk density of each powder was determined by pouring the powder at an angle through a short- stemmed glass funnel into a 50 mL graduated cylinder and the volume occupied was read and the bulk density calculated. The mean of three readings was taken as the bulk density [5]. Tap density was determined by tapping the powder 300 times using a standardized tapping procedure of 38 taps per minute [6]. The Hausner's ratio (i.e. the ratio of tapped density to bulk density) was calculated for all the powders. The angle of repose was measured using the fixed funnel method adapted by Iwuagwu and Onyekwelli [7]. The angle of repose was determined by calculating tanθ from the height and radius of the cone formed by the powders as they fall freely from the fixed funnel and subsequently obtaining the inverse of tanθ. The flow rate was calculated as the ratio of the mass of the samples to their time of flow. The hydration and swelling capacities were determined using previously reported established methods [8].

FTIR Analysis

100mg of KBr (Potassium bromide) salt was weighed and mixed with grounded samples (5mg) uniformly. The samples were placed in an evacuable KBr die and a 13mm clear disk was pressed in a hydraulic press which formed KBr pellets. The pelletized samples (which was formed inside the evacuated chamber) was placed in cell holders (universal demountable cell) and were inserted into the FTIR System (Spectrum BX, PerkinElmer, England) and scanned at a range of 350-4000nm. The spectrum was displayed on the computer screen and also the suspected compounds page.

Manufacture of Compressed Tablet

Tablets of Paracetamol (500 mg) were prepared by conventional wet granulation method employing polyvinylpyrollidone (PVP) (5%) as a binder, lactose as diluent and water as granulating fluid. SSC and SBC were incorporated extragranularly in the formulations as disintegrants at 1.5 % - 7.5 % w/w in each case. For comparison, tablets were also prepared employing corn starch and microcrystalline cellulose as disintegrant at 1.5 % - 7.5 % w/w. The granules were compressed into tablets for 30 seconds into tablets at pre-determined loads using a hydraulic hand press (Model C, Carver Jnc., Menomomee Falls, WI). The die and flat faced punches were lubricated with a 2 % dispersion of magnessium stearate in 96 % ethanol before each compression. The tablets obtained were stored over silica gel for 24 hours to prevent false low yield values.

Determination of Tablet Mechanical Strength

The crushing strength of tablets was determined at room temperature by diametrical compression using a Ketan Hardness tester. The tablet was placed between the anvil and the adjustable knob was screwed, to make contact with the tablet. Enough pressure was applied to cause tablet breakage. Results were taken only from tablets which split cleanly into two halves without any sign of lamination. Ten (10) tablets were randomly selected from each batch and all the determinations were made in triplicate.

Determination of Tablet Friability

Ten (10) tablets from each batch were weighed and carefully placed in a friabilator (Veego Scientific

Devices, Mumbai, India). The friabilator was operated at a rate of 25 revolutions per minute for 4 min. The tablets were dusted, final weight taken, and the percentage loss in weight calculated. Determinations were made in triplicate.

Tablet Disintegration

Six tablets from each batch were used for disintegration studies in distilled water at 37± 0.5C using BP Manesty disintegration test unit (Manesty Machines, Poole, U. K). The disintegration time was taken to be the time no granule of any tablet was left on the mesh of the apparatus. Determinations were made in triplicate.

Determination of *In Vitro* Drug Release

In vitro drug release studies were determined at 37 °C in a dissolution basket at 100 rpm. The basket containing the tablets was immersed in 900 mL of phosphate buffer at 37± 0.5 ^{o}C. Samples of 5 mL were withdrawn and replaced with fresh medium. The amount of paracetamol released was determined using a SP6-450 UV/VIS spectrophotometer (Pye Unicam, Middlesex, England). Determinations were made in triplicate.

RESULTS AND DISCUSSION

The percentage yield of cellulose from sugarcane scrapping and bagasse was 15.5 % and 34.4 % respectively. The physicochemical properties are dependent on various factors, and go a long way in affecting the final formulation. The density of a powder is dependent on particle packing and changes as the powder consolidates. Table **1** shows that SBC is the powder with the greatest particle density value. This indicates that the particle size of SBC is smaller and/or more spherical the shape of the powder particle. High particle density is an advantage in tableting because of reduction in the fill volume of the die. The tapped density values shows that SSC and SBC have particles less tightly packed particles than cornstarch and microcrystalline cellulose. Powders are required to flow and, the efficiency with which they do so is dependent on both process design and particle properties. The angle of repose has been used as indirect methods of qualifying powder flowability, because of its relationship with interparticulate cohesion. Powders with angle of repose greater than 50^{0} have unsatisfactory flow properties whereas values close to 25^{0} correspond to very good flow properties. The flow indices shows that SBC and SSC have good flow properties; even better than cornstarch and microcrystaline cellulose. FTIR is a powerful technique to examine the formation of inter- and intra- molecular hydrogen bonds in cellulose. The detailed database allows the establishment of strong correlation between the nature of hydrogen bonds and physical and mechanical properties of cellulose. The IR spectrum of SBC is shown in Figure **1**. The fingerprint region consists of a characteristic peak at 1044.31 cm^{-1} attributed to C-O band stretching. The band at 1639 cm^{-1} was assigned to C=C conjugated aromatic band while O-H stretching in the 3754 cm^{-1} region indicates the presence of a phenolic functional group. Weak stretches in the region 2000-3000 cm^{-1} suggests O=C-H bands. The presence of a new band at 367.09 cm^{-1} implies enhanced activity. Figure **2** shows that SSC has a similar IR spectrum to that of SBC. However, the fingerprint region for SSC is at 1046 cm^{-1} and it is attributed to C-O band stretching. The presence of sharp band at 350 cm^{-1} implies enhanced activity. This is all consistent with a polysaccharide structure that has long chains of anhydro-D-glucopyranose units (AGU) [9].

Table 1: Physical Parameters of Powder Samples

Powder sample	Particle Density(g/cm^3)	Bulk Density (g/cm^3)	Tapped Density (g/cm^3)	Angle of repose (^{o})	Hausner Ratio	Cars Index	Flow Rate (g/s)	Swelling Index	Hydration capacity	Loss on drying (%)	Porosity
SSC	1.582	0.200	0.220	32.28	1.10	9.17	0.072	2.00	10.90	5.2	9.2
SBC	3.283	0.369	0.400	24.28	1.08	7.70	0.266	1.25	5.38	10.0	7.7
CS	1.426	0.465	0.558	33.45	2.01	16.77	0.129	0.60	3.28	18.0	16.8
MCC	0.292	0.278	0.435	44.97	1.57	36.12	0.286	0.66	1.83	4.0	4.8

SSC- Cellulose from sugarcane scrapings.
SBC- Cellulose from sugarcane bagasse.
CS-Cornstarch.
MCC-Microcrystalline cellulose.

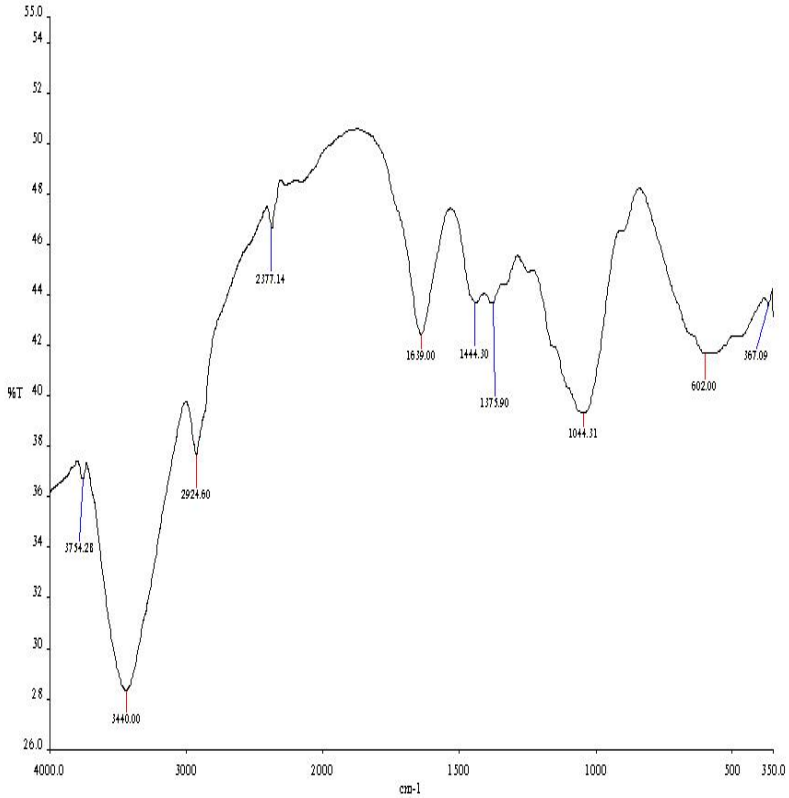

Figure 1: FTIR spectrum for SBC.

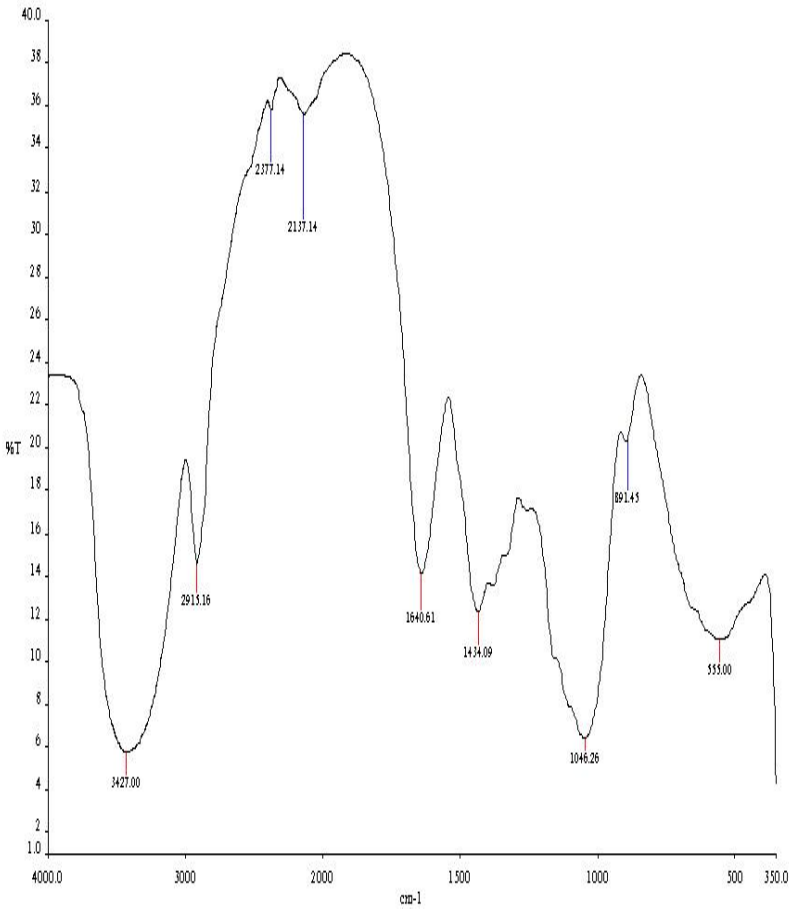

Figure 2: FTIR Spectrum for SSC.

Effective disintegrants that do not swell are believed to impart their action through porosity and capillary action. Swelling is believed to be one of the major mechanisms by which disintegrants impart their effect. By swelling in contact with water, the adhesiveness of other ingredients in a tablet is overcome causing the tablet to fall apart [10]. SSC and SBC have higher swelling capacities than cornstarch and microcrystalline cellulose hence they may be better disintegrants. The hydration capacity values shows SSC and SBC are capable of absorbing up to 5 times their own weight and they swell considerably in water. The mechanism of their disintegrant action might be through water uptake by capillary action and rupture of interparticulate bonds causing the tablet to break apart. The moisture sorption capacity is a measure of the moisture sensitivity of the material. Product quality can be compromised during manufacture, transport, storage and deterioration due to microbial spoilage or chemical transformation of the active or physical changes which may occur .SSC and SBC have high moisture sorption capacity and should be preferably stored in air-tight containers to prevent the absorption of moisture at atmospheric conditions. The loss on drying is higher for SBC while SSC and microcrystalline cellulose have values within the official limit of 7%. Therefore, SBC should be dried further before using it in tablet formulations. SSC and SBC are insoluble in some common solvents such as methanol, acetone, n-hexane and water. Cellulose is known to be insoluble in water and most organic solvents and their poor solubility is attributed primarily to the strong intra-molecular and intermolecular hydrogen bonding between the individual chains.

Hardness is an important parameter in the quality assessment of tablet formulations. If the tablet is too hard, it may not disintegrate in the required period of time to meet the dissolution specifications; if it is too soft, it may not be able to withstand the handling during subsequent processing such as coating or packaging and shipping operation. The results in Table **2** show that SSC and SBC formed relatively softer tablets than cornstarch and microcrystalline cellulose which became increasingly harder as their concentration increased. The tablet friability is a method to determine the physical strength of tablets upon exposure to

Table 2: Crushing Strength (CS), Friability (FR), and CSFR/D Values for Paracetamol Tablet Formulations

Disintegrant	Conc. (%w/w)	Crushing strength (N)	Friability (%)	D (s)	CSFR/D
SSC	1.5	24.40	1.46	17.75	0.94
	2.5	15.00	0.98	16.25	0.94
	5.0	24.40	0.36	16.25	4.17
	7.5	27.60	0.37	22.75	3.28
	10.0	27.60	0.44	18.50	3.39
SBC	1.5	17.60	2.99	17.00	0.35
	2.5	17.00	0.83	14.50	1.41
	5.0	19.80	0.67	13.75	2.15
	7.5	20.00	0.52	14.50	2.65
	10.0	25.20	0.37	15.75	4.33
CS	1.5	25.40	0.57	16.00	2.79
	2.5	25.40	0.63	15.50	2.60
	5.0	41.20	0.31	15.25	8.71
	7.5	35.00	0.26	16.25	8.28
	10.0	45.40	0.36	16.25	7.76
MCC	1.5	19.40	0.58	16.75	2.00
	2.5	27.60	0.30	18.75	4.91
	5.0	46.00	0.30	35.25	4.35
	7.5	47.40	0.26	36.00	5.06
	10.0	51.80	0.10	51.75	10.01

Table 3: Disintegration and Dissolution Parameters for Paracetamol Tablets

Disintegrant	Conc (%w/w)	D (s)	T_{50}(min.)	T_{90}(min.)
SSC	1.5	17.75	1.49	1.59
	2.5	16.25	1.38	1.52
	5.0	16.25	1.55	1.58
	7.5	22.75	1.67	1.77
	10.0	18.50	1.53	1.63
SBC	1.5	17.00	1.50	1.60
	2.5	14.50	1.51	1.63
	5.0	13.75	1.38	1.48
	7.5	14.50	1.50	1.55
	10.0	15.75	1.59	1.65
MCC	1.5	16.00	1.58	1.63
	2.5	15.50	1.63	1.88
	5.0	15.25	1.71	1.77
	7.5	16.25	1.67	1.81
	10.0	16.25	1.65	1.77
CS	1.5	16.75	1.58	1.61
	2.5	18.75	1.55	1.57
	5.0	35.25	1.56	1.59
	7.5	36.00	1.54	1.57
	10.0	51.75	1.56	1.59

mechanical shock or attrition. There are now requirements for it in the British Pharmacopoeia [11] but with no clear limits for acceptance or rejection of tablet batches probably because the principles of the test are not understood [12]. It was observed that tablets formulated with SSC and SBC at l.5% w/w had friability values greater than 1 %. By convention, tablets that lose not more than 1 % of their weight in the friability test are usually considered acceptable.

Tablets formulated with corn starch and microcrystalline cellulose had higher CS-FR/D values than tablets containing SSC and SBC. This suggests

Table 4: Correlations between Disintegration and Dissolution Parameters of Paracetamol Tablets Formulated with Disintegrants

Ordinate	Abcissa	Disintegrant	Correlation	p
D	T_{50}	SSC	0.870	<0.05
		SBC	0.460	>0.05
		CS	0.106	>0.05
		MCC	0.566	>0.05
D	T_{90}	SSC	0.976	<0.05
		SBC	0.562	>0.05
		CS	0.351	>0.05
		MCC	0.200	>0.05
T_{50}	T_{90}	SSC	0.954	<0.05
		SBC	0.912	<0.05
		CS	0.947	>0.05
		MCC	0.662	>0.05
CSFR/D	D	SSC	0.354	>0.05
		SBC	0.225	>0.05
		CS	0.499	>0.05
		MCC	0.554	>0.05
CSFR/D	T_{50}	SSC	0.571	<0.05
		SBC	0.176	<0.05
		CS	0.772	>0.05
		MCC	0.470	>0.05

that corn starch and microcrystalline cellulose formed stronger tablets than the extracted celluloses. CS-FR/D has been suggested as a better index of tablet quality because in addition to measuring tablet strength and weakness, it simultaneously evaluates any negative effects of these parameters on disintegration time [13].The values of the disintegration time for the samples are presented in Table **3**. All the tablets formulated with SSC and SBC disintegrated within the official limit of 15 minutes for uncoated tablets stated in the British Pharmacopoeia [14]. SBC had superior disintegrant property to cornstarch and microcrystalline cellulose while SSC showed comparable disintegrant property to microcrystalline cellulose. This is in concordance with the superior hydration and swelling capacities exhibited by SBC and SSC over the established disintegrants. Therefore, the disintegrant action of SBC and SSC may likely be by the penetration of liquid into the powder pores through capillary action and swelling to rupture the interparticulate bonds. It is believed that no single mechanism is responsible for the action of disintegration, but rather, it is more likely the result of interrelationships between these major mechanisms [15]. SSC and SBC at concentrations of 2.5 % w/w and 5.0 % w/w respectively gave the lowest reduction in disintegration time of formulated tablets. All the tablets formulated with SSC and SBC passed the BP dissolution test for tablets which specifies that at least 70 % of the drug substance should be in solution after 30 minutes. Formulations containing SSC and SBC show faster drug release (lower T_{50} and T_{90}) than tablets containing corn starch and microcrystalline cellulose. Moreover, tablets containing 2.5% w/w SSC and 5.0% w/w SBC gave more optimum result as tablet disintegrant. Table **4** shows that there was a linear correlation between T_{90} and disintegration time ($r = 0.976$, $p < 0.05$) and a fair linear correlation between T_{50} and disintegration time ($r = 0.870$, $p < 0.05$) for tablets formulated with SSC.

CONCLUSION

α - cellulose derived from sugarcane bagasse and scrappings gave a rapid and higher dissolution of the base drug when compared to cornstarch and microcrystalline cellulose; and may therefore be suitable alternatives in tablet formulation and production.

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