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Material and Compression Properties of *Cedrela odorata* Gum Co-Processed with Plantain Starch and Microcrystalline Cellulose

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A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation; D – writing the article; E – critical revision of the article; F – final approval of the article

Abstract

Background. Many excipients used in tableting exhibit some undesirable properties such as poor flow, cohesion and lubricating characteristics, thus necessitating some modification to achieve the desired product.

Objectives. The objective of this study was to enhance the material, flow and compressional properties of *Cedrela odorata* gum (COG) (Family: *Meliaceae*) by co-processing with plantain starch (PS) and microcrystalline cellulose (MCC)

Material and Methods. The COG was co-processed with PS (or MCC) by physical co-grinding at ratio 1 : 1, 1 : 2 and 1 : 4, and characterized using morphological analysis, swelling index viscosity measurements, particle size analysis and FTIR spectra. The material, flow and compressional properties of the co-processed excipients were also evaluated. Results were analyzed using mean and standard deviation of data.

Results. There was a decrease in the degree of agglomeration of COG and a reduction in the size of the powdered gum. The co-processed excipients were more spherical than the native excipients. The COG had the highest viscosity, while MCC and COG : PS (1 : 2) showed the highest and lowest degrees of swelling at $27.0 \pm 0.05^\circ\text{C}$ respectively. Water absorption capacity of the component excipients improved with co-processing COG : MCC increasing from 171.8 ± 1.54 (1 : 1) to 214.8 ± 1.07 (1 : 2), while COG : PS increased from 95.2 ± 0.08 (1 : 1) to 206.2 ± 0.13 . There was a decrease in the percentage solubility of the co-processed excipients with the highest and lowest solubility observed in COG ($54.1 \pm 0.07\%$) and PS ($3.7 \pm 0.16\%$), respectively. The FTIR spectra indicate no significant interaction between the excipients. The poor flow of the component excipients did not improve with co-processing; however, there was a significant increase in compressibility. Generally, COG co-processed with MCC showed better compression properties when compared with COG co-processed with PS.

Conclusions. Co-processing of COG with MC or PS enhanced the characters of the component excipients, thus making the co-processed excipients suitable for direct compression of tablets without altering the chemical nature of the component excipients (Polim. Med. 2016, 46, 1, 35–43).

Key words: co-processing, Cedrela gum, packing properties, microcrystalline cellulose, plantain starch.

Tablets have been defined as solid preparations, each containing a unit dose of one or more medicaments that are prepared by compressing uniform particulate volumes of the medicament or mixture of medicaments usually with added substances [1]. Tablets remain popular as dosage forms because of the advantages afforded both to the manufacturer (such as, simplicity, economy of preparation, stability and convenience in packing, shipping and dispensing) and the patient (for example, accuracy of dosage, compactness, and portability, and

ease of administration). Although the basic mechanical approach for their manufacture has remained the same, tablet technology has undergone a lot of improvement. Efforts are continually being made to understand more clearly the physical characteristics of powder compaction and the factor affecting the availability of the drug substance from the dosage form after oral administration [2].

In nearly all cases, medicaments cannot be tableted on their own. Therefore, a tablet does not only contain the active pharmaceutical ingredient (API) but also

includes substances, known as excipients, which have specific functions [3], and which are the largest components of any pharmaceutical formulation [4]. The International Pharmaceutical Excipients Council (IPEC) defines excipients as “substances, other than the API, in finished dosage form, which have been appropriately evaluated for safety and are included in a drug delivery system to either aid the processing or to aid manufacture, protect, support, enhance stability, bioavailability or patient acceptability, assist in product identification, or enhance any other attributes of the overall safety and effectiveness of the drug delivery system during storage or use” [5]. Increased research activities in the field of tablet excipient development and manufacturing have increased over the past two decades. These activities have been directed towards the discovery and manufacture of multifunctional directly compressible excipients, which are aimed at achieving better characteristics and tableting properties than a single substance or the physical mixture [6]. Such excipients may be manufactured by a science of particle engineering known as co-processing [7], and have been developed primarily to address the issues of powder fluidity, compressibility, and disintegration potential.

The aim of this study was to evaluate the material, flow and compressional properties of *Cedrela odorata* gum (COG) co-processed with plantain starch (PS) and microcrystalline cellulose (MCC) with the aim of determining the effect of co-processing on the material and compression properties of the starting materials.

Materials and Methods

The materials used were MCC (Aqualon, Hercules Inc. USA), PS (prepared in our laboratory from the tubers of unripe *Musa sapientum*) and COG (obtained from the incised trunk of *Cedrela odorata* tree available as a tree crop in the Botanical Gardens of the University of Ibadan, Ibadan, Nigeria, and prepared in our laboratory). All the other reagents used were of analytical grade.

Extraction of PS

The PS was extracted from *Musa sapientum* using documented procedures [8]. The unripe plantain was peeled, cut into small pieces and soaked in water for 24 h to allow it to soften. The softened pieces were blended and ultra-pure deionized water was added to dilute the slurry which was then sieved using a 120 µm mesh sieve. The diluted slurry was filtered through a muslin cloth and rewashed with ultra-pure deionized water. This procedure was repeated until the PS was fully extracted as confirmed by a negative iodine test on the chaff. The extracted PS was then dried at 50°C in hot air oven (Llenkamp BS Oven, Model OVH 200-01OH, USA) until a constant weight was obtained.

The dried starch was pulverized at a temperature of 26°C using a laboratory mill (GEC Machines, Model BS 220BH, United Kingdom) set at a speed of 1200 rpm. The powder obtained was sieved through a 250 mm pore size sieve and stored in an air-tight amber bottle.

Preparation of COG

The COG was extracted from the incised trunk of a *Cedrela odorata* tree available in the Botanical Garden of the University of Ibadan, Ibadan, Nigeria, and purified using a modified method of Adetunji and Odole [9]. The exudate was hydrated in 0.5 : 95.5 (v/v) chloroform water mixture for five days with intermittent stirring. Extraneous materials were removed by straining the mixture through a muslin cloth. The gum was precipitated from the solution using absolute ethanol and the precipitated gum was filtered, washed with diethyl ether, and then dried in a hot air oven at 40°C for 18 h. The gum was pulverized using a laboratory blender and sieved through a 250 mm pore size sieve.

Co-Processing of the Excipients

An equal amount, each of the dried COG and PS, were triturated together using a porcelain mortar and pestle for 10 min to ensure uniform size reduction and mixing of the two powders. The resulting product was passed through a 250 mm pore size sieve. The process was carried out for the mixture of the dried COG and MCC. Various ratios (1 : 1, 1 : 2 and 1 : 4) of the co-processed excipients (COG : PS and COG : MCC) were obtained and the resulting products were stored in air-tight amber bottles until ready for use.

Morphology and Material Properties of Native and Co-Processed Excipients

Particle Size and Shape

The mean particle size and morphological features of 500 granules each of COG, PS and MCC, and the various ratios of COG : PS and COG : MCC were determined using an optical microscope (Olympus light microscope XSZ-107BN).

Determination of Swelling Index

Exactly 5 g each of COG, PS and MCC, and the various mixtures of COG : PS and COG : MCC was transferred into a 100 mL cylinder (V_1), 90 mL of distilled water was added and the slurry was shaken for 5 min, bringing it to 100 mL. The suspension was allowed to stand for 24 h and the sedimentation volume (V_2) was measured. The swelling index was calculated from Eqn (1). The procedure was repeated for all the other samples.

$$\text{Swelling index} = V_2/V_1 \quad (1)$$

Water Absorption Capacity (WAC)

Exactly 1 g each of COG, PS and MCC, and the various mixtures of COG : PS and COG : MCC was suspended in 15 mL of distilled water in a weighed 25 mL centrifuge tube. The tube was agitated in a vortex mixer for 2 min and centrifuged at 4000 rpm for 20 min. The clear supernatant was discarded and the residue was weighed (W_1). The adhering drops of water were removed by drying the residue at 60°C to constant weight (W_2). The water absorption capacity (WAC) was expressed as the water bound by 100 g of dry starch.

Solubility

One gram each of COG, PS and MCC, and the various mixtures of COG : PS and COG : MCC was weighed into a 100 mL conical flask (W) and 15 mL of distilled water was added. It was shaken for 5 min and placed in a water bath prior to heating it between $80 \pm 2.5^\circ\text{C}$ for 40 min with constant stirring. The slurry was then transferred into a pre-weighed centrifuge tube (W_1) and 7.5 mL of distilled water was added and then centrifuged at 2200 rpm for 20 min. The supernatant was carefully decanted into a tarred dish (W_2), dried at 100°C to constant weight (W_3) and then cooled in a desiccator. The solubility was calculated using the equation below.

$$\text{Solubility \%} = \frac{\text{Weight of Soluble}}{\text{Weight of Sample}} \times 100 \quad (2)$$

Fourier Transformed Infrared (FTIR) Spectroscopy

Spectra were obtained for each of COG, PS and MCC, and the various mixtures of COG : PS and COG : MCC using a Spectrum BX 273, Perkin-Elmer, USA [10]. Exactly 5 mg each of the completely dried powdered samples was weighed and then dispersed in 200 mg KBr (pellet procedure). Signal averages were obtained at a resolution of 4 cm^{-1} and a scanning range of $350\text{--}4400\text{ cm}^{-1}$.

Density and Flow Properties

Particle Density

The particle density of each COG, PS and MCC, and the various mixtures of COG : PS and COG : MCC was determined by the liquid pycnometer method using xylene as the displacement fluid. An empty 50 mL capacity pycnometer was weighed (W). It was then filled with xylene and the excess liquid was wiped off. The weight of the pycnometer with xylene was determined (W_1). The difference in weight was calculated as W_2 . A 2 g quantity of the sample was weighed (W_3) and quantitatively transferred into the pycnometer bottle. The excess xylene was wiped off and the pycnometer was weighed again (W_4). The particle density (ℓ_s) was calculated from the equation below:

$$\ell_s = \frac{W_2 \times W_3}{50 (W_3 - W_4 + W_2 + W)} \quad (3)$$

Bulk Density Determination

The loose bulk density, ℓ_s , of each sample of the COG, PS and MCC, and the various mixtures of COG : PS and COG : MCC was determined at zero pressure by pouring 10 g of the powdered sample at an angle of 45° through a funnel into a 50 mL glass measuring cylinder. The bulk density was measured as the ratio of mass to the volume occupied by the sample. Determinations were carried out in quadruplicate and the loose bulk density values (ℓ_0) were calculated using the following equation:

$$\ell_0 = m/\pi r^2 h \text{ (g/cm)} \quad (4)$$

where:

m = weight of the sample in the cylinder,

r = radius of the cylinder,

h = height of the sample in the cylinder.

The relative density of each sample at zero pressure, D_0 , was obtained from the ratio of the loose bulk density to the particle density.

Tapped Density Determination

The tapped density was measured by applying 100 taps to 10 g of the sample in a graduated cylinder at a rate of 100 taps per minute.

The Hausner Ratio

The Hausner ratio was determined as the ratio of the initial bulk volume to the tapped volume.

Compressibility Index

Compressibility index was calculated from the results obtained from the bulk and tapped densities by applying the equation:

$$\text{Compressibility Index} = \frac{\text{Tapped density} - \text{Bulk density}}{\text{Tapped density}} \quad (5)$$

Porosity

Porosity was evaluated based on the apparent density and the true density of the powdered material. True density is the density of the powdered materials excluding the volume of any open and closed pores, while the apparent density is similar to the true density except the volume of closed pores is also included. The porosity was determined based on the mathematical equation:

$$1 - (\text{Apparent Density/True Density}) \quad (6)$$

Viscosity

Viscosity of the various samples of the COG, PS and MCC, and the various mixtures of COG : PS and COG : MCC was determined using the Brookfield Model

–DV-11+pro viscometer (spindle 03) at 20, 50 and 100 revolutions per minute. Samples (3 g) were weighed into a canister, 25 mL of distilled water was added and the viscosity determined.

Results and Discussion

The morphological and material properties of the excipients are presented in Table 1, while the photomicrographs are presented in Fig. 1. The studies carried out by Rahmati et al. [11] indicated that the methods employed in the processing of particles affect the morphological characteristics of the resulting excipients. The photomicrographs presented in Fig. 1 showed that the co-processed excipients produced varying degrees of sphericity identified as oval, cylindrical or irregular. Particle shape can influence compaction characteristics, as it affects the packing behavior of powder samples. This is because there is a tendency for particle rearrangement to occur in the initial stage of the compaction process [12]. Generally, there was a decrease in both the mean particle size and degree of agglomeration with a corresponding increase in the sphericity as a result of co-processing. Particle size also has significant effect on the densification of powders during die filling, particle rearrangement, fragmentation propensity and elastic/plastic deformation [13]. The ranking of the mean particle size was in the order COG > COG : PS (1 : 4) > COG : PS (1 : 1) > COG : PS (1 : 2) > COG : MS (1 : 2) > COG : PS (1 : 1) > PS > COG : OS (1 : 2) > COG : MS (1 : 4) > MCC

The results obtained for the solubility, water absorption capacity and swelling index tests are also presented in Table 1. There was a decrease in the percentage solubility of the co-processed excipients with the highest and lowest solubility observed in COG ($54.1 \pm 0.07\%$) and PS ($3.7 \pm 0.16\%$), respectively. Gonzalez et al. [14] reported that high water solubility of a natural gum can be attributed to the presence of glucuronic acid units

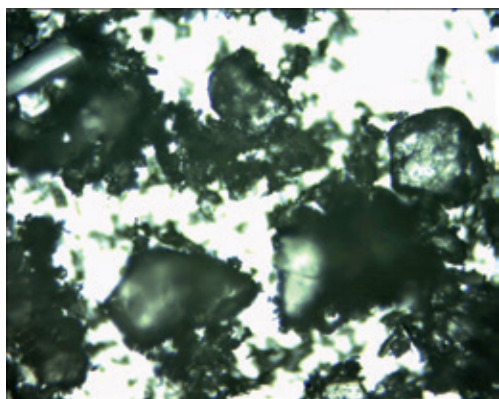
and the methyl derivative. The disruptive effect of the sugar units on co-processing could be responsible for the decrease in the solubility of the COG. The water absorption capacity of an excipient has been reported as a measure of predicting the disintegration of tablets formulated using such excipients [15]. The water absorption capacity of the component excipients improved with co-processing with COG : MCC increasing from 171.8 ± 1.54 (1 : 1) to 214.8 ± 1.07 (1 : 2), while COG : PS increased from 95.2 ± 0.08 (1 : 1) to 206.2 ± 0.13 . The swelling index provides evidence of the magnitude of interaction between the chains present in the samples within the amorphous and crystalline domains. Amylose/amylopectin ratio has been reported to influence the extent of this interaction in terms of molecular weight distribution, degree and length of branching and conformation [16]. The degree of swelling depends on the species of the sample [17]. The ranking of swelling capacity at room temperature (27°C) was MCC > P > S > G_1M_2 > G_1P_4 > G_1M_1 > G_1M_4 > COG > G_1P_1 > G_1P . The intrinsic swelling power has been recognized as a qualitative assessment of potential disintegrant effects of starches [18]. The MCC showed the highest degree of swelling and thus can be said to possess good disintegrant properties. The COG, on the other hand, showed a relatively low swelling index, which could be inferred from the high solubility of COG in water.

Table 2 shows the interpretation of the FTIR spectra. The FTIR spectra of COG indicated the presence of characteristic peaks at 2933.30 cm^{-1} and 2369.74 cm^{-1} , which can be attributed to C-H stretching due to the aliphatic and asymmetric methyl groups respectively. In addition, the prominent absorption peaks at 1622.36 cm^{-1} , 1427.13 cm^{-1} and 1254.49 cm^{-1} can be attributed to deformation vibration due to unsaturated –CH₂ and –CH₃ skeletal vibration due to isopropyl chains and t-butyl groups. The FTIR spectra of the COG/PS mixture showed a slight change on co-processing in relation to the characteristic peaks that were observed in that of COG. Characteristic peaks were observed

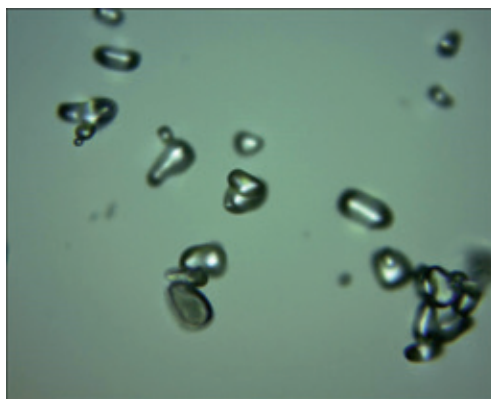
Table 1. Morphology and material properties of native and co-processed excipients (mean \pm SD, n = 3)

Excipients	Mean particle size (mm)	Swelling power	Water absorption capacity	Solubility (%)
COG	317.66 ± 158.73	0.53 ± 2.09	98.3	54.1
MCC	34.44 ± 11.78	1.66 ± 0.21	125.6	12.1
PS	39.55 ± 15.58	1.44 ± 0.38	82.0	3.7
COG : MCC (1 : 1)	53.15 ± 24.22	0.88 ± 1.54	171.8	37.3
COG : MCC (1 : 2)	44.00 ± 20.71	1.14 ± 0.11	214.8	23.5
COG : MCC (1 : 4)	34.64 ± 13.53	0.60 ± 0.73	87.7	20.5
COG : PS (1 : 1)	41.82 ± 18.73	0.50 ± 0.04	95.2	33.8
COG : PS (1 : 2)	38.69 ± 13.89	0.44 ± 0.16	97.4	25.3
COG : PS (1 : 4)	76.28 ± 35.10	1.08 ± 0.07	206.2	20.5

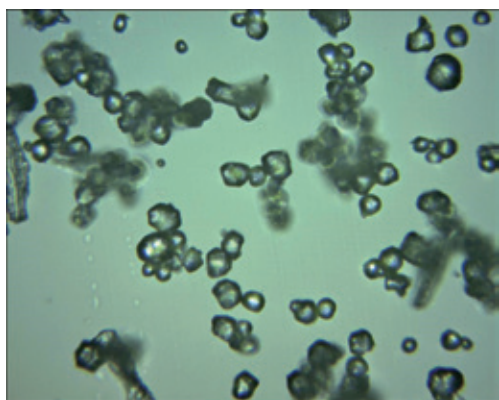
COG – *Cedrela odorata* gum, PS – plantain starch, MCC – microcrystalline cellulose.



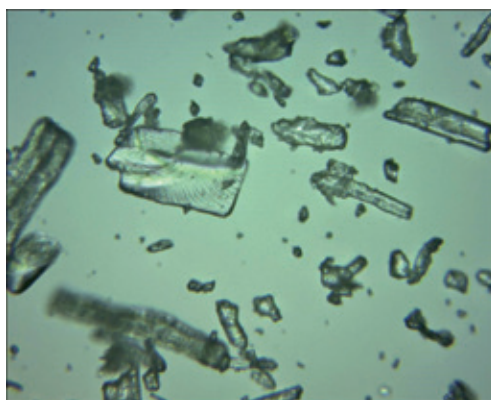
A: Photomicrograph of COG



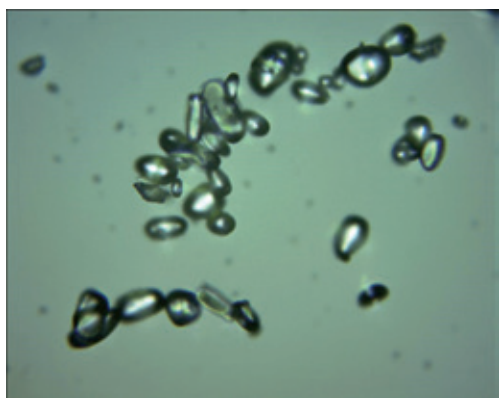
B: Photomicrograph of PS



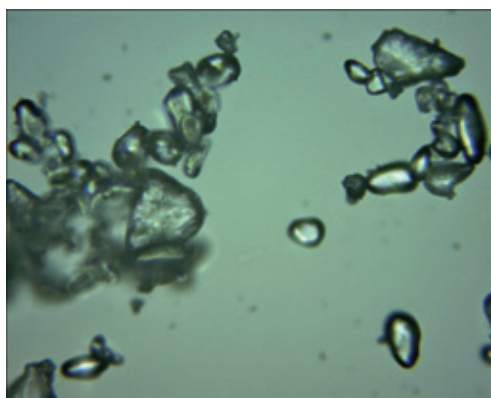
C: Photomicrograph of MCC



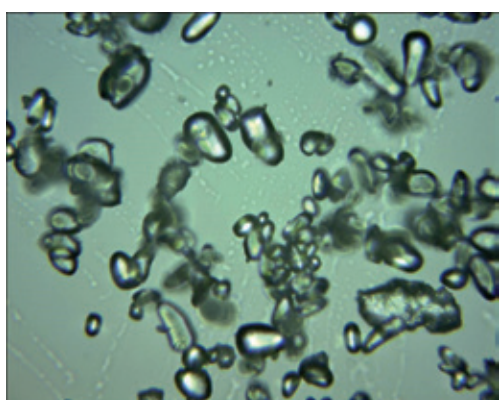
D: Photomicrograph of COG : MCC (1 : 1)



E: Photomicrograph of COG : MCC (1 : 2)



F: Photomicrograph of COG : PS (1 : 1)



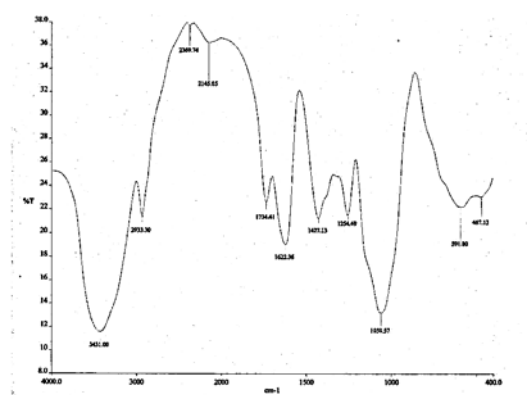
G: Photomicrograph of COG : PS (1 : 2)

COG – Cedrela odorata gum, PS – plantain starch,
MCC – microcrystalline cellulose.

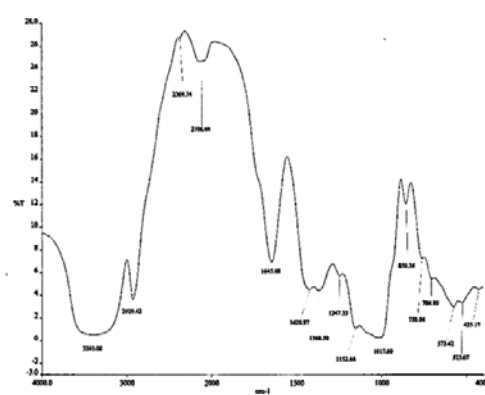
Fig. 1. Photomicrographs of excipients
at a magnification of 100

Table 2. Table showing interpretation of FTIR Spectra

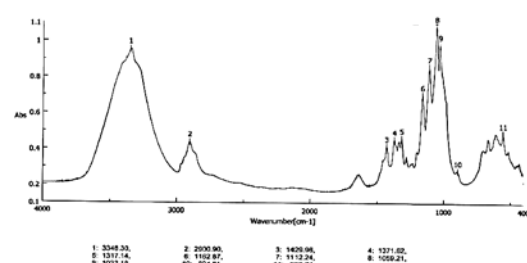
Characteristic Peaks observed for COG	
2933.30 cm^{-1}	C-H stretching due to aliphatic groups
2369.74 cm^{-1}	C-H stretching due to asymmetric methyl groups
1622.36 cm^{-1} 1427.13 cm^{-1} 1254.49 cm^{-1}	deformation vibration due to unsaturated $-\text{CH}_2$ and $-\text{CH}_3$ skeletal vibration due to isopropyl chains and t-butyl groups.
Characteristic Peaks observed for COG : PS mixture	
2929.42 cm^{-1}	C-H stretching due to aliphatic groups
2369.74 cm^{-1}	C-H stretching due to asymmetric methyl groups
1645.88 cm^{-1} 1420.97 cm^{-1} 1247.55 cm^{-1}	deformation vibration due to unsaturated $-\text{CH}_2$ and $-\text{CH}_3$ skeletal vibration due to isopropyl chains and t-butyl groups.
Characteristic Peaks observed for MCC retained in the COG : MCC mixture	
1033.18 cm^{-1}	$-\text{CH}_2$ twisting vibration
1162.87 cm^{-1}	rocking vibrations due to C-C bond
1371.62 cm^{-1}	$-\text{CH}_3$ stretching due to aliphatic groups
3348.30 cm^{-1}	$-\text{CH}$ stretching due to aliphatic $-\text{C}=\text{CH}$ groups



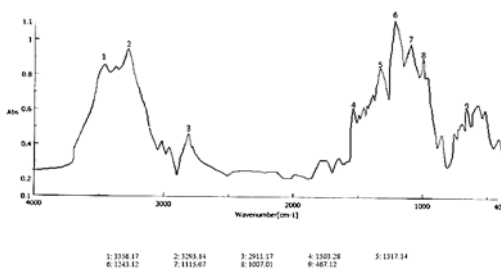
FTIR Plot for COG powder



FTIR Plot for the physical mixture of COG and PS



FTIR Plot for MCC powder



FTIR Plot for the physical mixture of COG and MCC

COG – *Cedrela odorata* gum, PS – plantain starch, MCC – microcrystalline cellulose.

Fig 2. FTIR Plots

at 2933.30 cm^{-1} , 1622.36 cm^{-1} , 1427.13 cm^{-1} and 1254.49 cm^{-1} were noted to have shifted to 2929.42 cm^{-1} , 1645.88 cm^{-1} , 1420.97 cm^{-1} and 1247.55 cm^{-1} , respectively. This shift, though small, could be referred to as a reduction in the degree of hydrogen bonding in the co-processed COG : PS ratios [19]. The peak observed

at 2369.74 cm^{-1} was completely retained in the FTIR plot of the co-processed COG/PS mixture. The FTIR plot for the COG/MCC mixture was observed to retain the characteristic peaks observed for the MCC alone at 1033.18 cm^{-1} , 1162.87 cm^{-1} , 1371.62 cm^{-1} and 3348.30. Representative FTIR plots are shown in Figure 2.

Table 3. Density and flow properties of native and co-processed excipients (mean \pm SD, n = 3)

Excipients	Bulk density (g/cm)	Tapped density (g/cm)	Particle density (g/cm)	Porosity	Angle of repose	Hausner's ratio	Carr's index
COG	0.33 \pm 0.10	0.43 \pm 1.02	1.476 \pm 0.02	0.706	57.5	1.3030	23.25
MCC	0.28 \pm 0.06	0.42 \pm 0.31	1.528 \pm 0.03	0.817	61.7	1.5000	33.33
PS	0.43 \pm 0.21	0.53 \pm 1.15	1.462 \pm 0.01	0.776	55.0	1.2326	18.90
COG : MCC (1 : 1)	0.41 \pm 0.10	0.60 \pm 0.66	1.493 \pm 0.14	0.725	63.4	1.4634	26.47
COG : MCC (1 : 2)	0.40 \pm 0.15	0.54 \pm 0.39	1.544 \pm 0.09	0.741	63.4	1.3500	23.10
COG : MCC (1 : 4)	0.56 \pm 0.32	0.70 \pm 0.19	1.317 \pm 0.01	0.575	60.8	1.2500	24.11
COG : PS (1 : 1)	0.63 \pm 0.25	0.85 \pm 0.20	1.441 \pm 0.02	0.563	60.8	1.3600	31.70
COG : PS (1 : 2)	0.60 \pm 0.22	0.78 \pm 0.05	1.428 \pm 0.05	0.580	65.0	1.3000	25.86
COG : PS (1 : 4)	0.41 \pm 0.02	0.54 \pm 0.36	1.536 \pm 0.13	0.733	64.2	1.3170	24.31

COG – *Cedrela odorata* gum, PS – plantain starch, MCC – microcrystalline cellulose.

The particle density, bulk density and tapped density of the excipients are presented in Table 3. The ranking of the loose bulk densities was COG : PS (1 : 1) > COG : PS (1 : 2) > COG : MCC (1 : 4) > PS > COG : MCC (1 : 4) = COG : PS (1 : 4) > COG : MCC (1 : 2) > COG > MCC, while the ranking for the tapped densities was COG : PS (1 : 1) > COG : PS (1 : 2) > COG : MCC (1 : 4) > COG : MCC (1 : 1) > COG : MCC (1 : 2) = COG : PS (1 : 4) > PS > COG > MCC. The bulk density of a powder describes its packing behavior. Higher bulk density is advantageous in tableting because of a reduction in the fill volume of the die [12]. The tapped density indicates the rate and extent of packing that would be experienced by the material during the various unit operations of tableting [12]. The difference observed in the tapped density values could be due to the difference in the particle shape and particle size distribution, both of which affect the packing arrangement of particles. The value of the compressibility index is a measure of the flowability and compressibility of a powder [12]. Thus, COG would be expected to have better flow properties, but lower compressibility than COG : MCC (1 : 2) and PS based on the result shown in Table 3. The compressibility index of 5–10, 12–16, 18–21, and 23–28 represents excellent, good, fair and poor flow properties respectively [20, 21]. The ranking of the compressibility index was MCC > COG : PS (1 : 1) > COG : MCC (1 : 1) > COG : PS (1 : 2) > COG : PS (1 : 4) > COG : MCC (1 : 4) > COG > COG : MCC (1 : 2) > PS, thus indicating that PS had the lowest flow properties with the highest compressibility.

The Hausner ratio (tapped to bulk density) provides an indication of the degree of densification which could result from the vibration of the feed hopper, for example, during tableting. Higher values of the Hausner ratio predict significant densification of powders. The ranking of the Hausner ratio was MCC > COG : MCC (1 : 1) > COG : PS (1 : 1) > COG : MCC (1 : 2) > COG : PS (1 : 4) > COG > COG : PS (1 : 2) > COG : MCC (1 : 4)

> PS. The packing and cohesive properties of powdered materials influence the various aspects of their processing, such as milling, blending, flow from hoppers, compression and packing into capsule shells or containers. These properties depend to a large extent on the particle size distribution and shape of the granules made from such powdered materials.

The angle of repose, θ , has been used as a qualitative measure of the cohesiveness or the tendency of the powdered or granulated materials to flow, for instance, from hoppers through the feed frame into the tableting machine [21]. Such uniformity of flow will minimize weight variations in tablets produced. Angles of 30° or below is usually an indication that the powder is free flowing, while an angle of 40° or above indicates poor flow characteristics [21]. The angle of repose is affected by the particle size distribution and usually increases with a decrease in particle size. In general, the smaller the particle size, the more cohesive the materials studied. The ranking of the angle of repose was COG : PS (1 : 2) > COG : PS (1 : 4) > COG : MCC (1 : 1) = COG : MCC (1 : 2) > MCC > COG : MCC (1 : 4) = COG : PS (1 : 1) > COG > PS.

The viscosity of a fluid is the measure of its resistance to gradual deformation by shear stress or tensile stress. It corresponds to the informal concept of liquid thickness [22, 23]. The values obtained from the viscosity measurements are shown in Table 4. At 20 rpm, the viscosity of MCC and PS was lower compared to that of COG. With increased shear, MCC and PS showed an increase in viscosity, while COG showed a decrease. After co-processing COG with MCC and PS, there was generally a significant increase in viscosity, thus suggesting that co-processed COG, MCC and PS may be useful as a suspending agent or in matrix formulations for sustained release.

The porosity of pharmaceutical excipients can influence tablet compression. Tablet properties such as mechanical strength and disintegration are in turn af-

Table 4. Parameters obtained from the viscosity determination of native and co-processed excipients

Excipients	Viscosity (poise) at 20 rpm	Viscosity (poise) at 50 rpm	Viscosity (poise) at 100 rpm
COG	7.30	6.80	6.25
MCC	0.05	0.08	0.14
PS	0.05	0.08	0.12
COG : MCC (1 : 1)	2.60	2.40	2.28
COG : MCC (1 : 2)	0.18	0.49	2.55
COG : MCC (1 : 4)	0.15	0.24	0.31
COG : P (1 : 1)	1.60	2.06	2.15
COG : PS (1 : 2)	0.40	0.44	0.51
COG : PS (1 : 4)	0.17	0.26	0.30

COG – *Cedrela odorata* gum, PS – plantain starch, MCC – microcrystalline cellulose.

ected by the pore structure. It has been shown that, irrespective of the composition of a compacted formulation, the initial porosity influences the rate at which the disintegration fluid penetrates its matrix, which, in turn, may exert a significant influence on the disintegration and dissolution rate of drug substances [24]. The ranking of the porosity of the excipients (Table 3) is in the order MCC > PS > COG : MCC (1 : 2) > COG : PS (1 : 4) > COG:MCC(1:1)> COG>COG:PS(1:2)> COG:MCC (1 : 4) > COG : PS (1 : 1). The COG shows a low porosity

level relative to MCC and PS. This may be accounted for by the irregularly shaped particles of COG, causing a high degree of interlocking of the particles. Thus, COG is likely to cause a slower rate of drug release due to its high viscosity.

Co-processing *Cedrela odorata* gum with microcrystalline cellulose or native plantain starch enhanced the characteristics of the component excipients without altering their chemical nature, thus making the co-processed excipients suitable for direct compression of tablets.

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