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Preliminary Characterization of Co-processed Excipients of Okra (*Abelmoschus esculentus*) Mucilage and Pregelatinized Potato Starch

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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 article.

Abstract

Background: Okra mucilage is highly viscous with good binding properties in tablets. Pregelatinized starches have significantly improved flow properties but produce tablets of poor mechanical strength.
Objective: Preliminary evaluation of co-processed excipients of Okra mucilage and pregelatinized potato starch as directly-compressible excipients.
Methods: Polymers were characterized for morphology (SEM), crystallinity (FT-IR) and flow properties. Co-processed excipients were developed with Okra mucilage and pregelatinized potato starch at different ratios of starch: mucilage (95:5, 90:10, 85:15, 80:20, 70:30), using the co-fusion method. The flow, packing and compaction properties of the co-processed excipients were evaluated using density measurements, angle of repose, angle of internal friction, Kawakita model, consolidation index (C) and consolidation rate (K).
Results: Larger agglomerates of the co-processed excipients indicated formation of a new polymer. FT-IR spectra showed retention of all the major peaks of individual polymers. Okra mucilage imparted swelling while starch improved flow in the co-processed excipients (Hausner's ratio 1.12-1.20). Values from Kawakita plots revealed cohesiveness and compressibility were imparted to the co-processed excipients ($a = 0.300–0.329$; $b = 0.078–0.361$) suggesting good compactibility. Consolidation index and rate were observed to increase with Okra mucilage content, implying improved rate of packing as well as enhanced flow ($C = 0.566-1.389$; $K = 0.123-0.424$). The batch containing starch: mucilage 70:30 gave the best properties of good flow, cohesiveness and compactibility, essential parameters required in directly-compressible excipients.
Conclusion: The co-processed excipients of Okra mucilage and pregelatinized potato starch could therefore be used as excipients for direct compression in tablet formulations.
Keywords: Co-processing, Compaction properties, Flow properties, Okra mucilage, Pre-gelatinized potato starch.

INTRODUCTION

In the formulation of pharmaceutical dosage forms, there are four major types of excipients that have been used and these include single entity excipients, mixtures or blends of multiple excipients, novel excipients or new chemical entities and co-processed excipients (Allamnen and Suresh, 2014). In tableting, the direct compression process is influenced by powder characteristics like compressibility, flow ability and dilution potential (Brniak *et al*, 2013). No single excipient is likely to possess all these characteristics. Novel combinations of existing excipients would be an interesting option for improving excipient functionality in tablet formulations.

Co-processed excipient is a combination of two or more excipients to produce a material that possesses improved functionality and superior performance that cannot be achieved using a physical admixture of the same combination of excipients (Ogunjimi and Alebiowu, 2013). Co-processing is of interest because the products are physically modified without altering their chemical structure. A fixed and homogenous distribution of the components is achieved by embedding them within mini-granules. Excipient mixtures in co-processing are produced to make use of the advantages of each component and to overcome specific limitations. Most important characteristics are the binding and blending properties of the co-processed excipients, which must be better than those of a physical mixture of the starting materials. The synergistic effect should improve the quality of the tablet formulations made with the co-processed excipient. Owing to their combining properties, co-processed excipients fulfil the increasing demand for excipients for direct compression tableting (Nachaegari and Bansal, 2004; Uma and Naheed, 2014; Parfati *et al*,, 2018).

Pregelatinized starches are pre-cooked starches that are processed to permit swelling in cold water as compared to natural starches which require heating. Pregelatinized starches possess thickening and flow properties designed for easy application in pharmaceutical tablet formulations. Other advantages of pregelatinized starch include improved flowability, ease of tablet preparation, the potential of a constant release rate (zero-order) for an extended period of time and the possibility to incorporate high percentage of drugs with different physicochemical properties (Peerapattana *et al*, 2010). However, pregelatinized starches form tablets of low crushing strength-friability ratio, indicating poor mechanical strength. Mechanical and release properties of tablets containing pregelatinized starch tablets can be enhanced to the desired profile by different parameters, like geometries of the tablet, compaction force and the incorporation of additional excipients. Okra (*Abelmoschus esculentus L.* Moench) belongs to the Malvaceae plant family (Eshiet and Brisibe, 2015). Okra mucilage derived from the wall of tender pods has been found to have a good alkaline pH with high viscosity at low concentration and good solubility in cold water. In previous studies, Okra mucilage was evaluated for its safety and found to be suitable as excipients in several pharmaceutical formulations (Bakre and Jaiyeoba, 2009; Ilango *et al*, 2010; Chodavarapu *et al*, 2011; Okunlola *et al*, 2020). Thus, the aim of this study is to co process Okra mucilage with pregelatinized potato starch using the co-fusion method with a view to producing a novel excipient with improved properties. The flow and compaction properties of the co-processed excipients would be evaluated for its directly compressible properties.

METHODOLOGY

Materials

Okra fruits were obtained from a local market in Oyo state, Nigeria. Pregelatinized potato starch, Prejel™ PA 5 PH, was a gift from DFE Pharma, USA. Ethanol was obtained from Sigma- Aldrich GmbH, Germany). All the other reagents were of analytical grades.

Methods

Extraction of Okra Mucilage

Okra fruits were carefully washed and dried inside a desiccator at room temperature for 24 hours until constant weight was obtained. The dried fruits were blended into powder and passed through a sieve. A 400 g sample of powdered Okra was dispersed in 2 litres of demineralised water, allowed to stand for 24 hours and extracted with 96 % ethanol to obtain the mucilage. The mucilage obtained was filtered through muslin cloth and then dried at 50°C for 24 hours. The dried mucilage was blended into powder and screened through a sieve 125 µm (Okunlola *et al*, 2020).

Preparation of the co-processed excipients

A 100 g batch of co-processed excipients of pregelatinised potato starch and Okra mucilage at varying ratios (95:5, 90:10, 85:15, 80:20, 70:30, 100:0, 0:100), were prepared using the co-fusion method. Okra mucilage powder was dispersed in sufficient quantity of distilled water to form a viscous, homogenous dispersion while heating over a water bath. Distilled water was added to pregelatinized potato starch in a beaker to form a slurry. The dispersion of Okra mucilage was added to the starch slurry whilst stirring for 20 min at low heat. The resulting homogenous mass was dried in a GallenKamp hot air oven (Model*:* BS 250, UK) at 60°C for 48 hours (Olowosulu *et al*, 2011). The dried mass was then milled, sieved with a 250 µm mesh and stored in well - sealed containers.

Powder characterization

Morphology

The morphology of the sample was determined using a scanning electron microscope (Hitachi SU8030 FE-SEM Tokyo, Japan) at an accelerating potential of 5.0kV. All samples were super coated with Au/Pd prior to examination. The particle size was determined using a light microscope (Olympus Research microscope CH20i, Olympus Optical Co, Shinjuku, Japan).

Fourier Transform Infra-red (FT-IR) analysis

The samples were analysed by FT-IR (FT-IR-Thermo Nicolet Nexus 870 Madison, WI, USA) in transmission mode. Transmission spectra were recorded using at least 64 scans with 8 cm^{-1} resolution in the spectra range 4000 – 400 cm^{-1}.

pH

The pH of 1% w/v suspension of the samples was measured using a pH meter (Model 720 A, Thermo Electron Corporation, MA, USA) at 25°C.

Swelling index

Each samples (5g) was weighed and transferred into a 100-ml measuring cylinder and the volume occupied was determined (V_1). Distilled water (90 ml) was added, the dispersion was shaken for two minutes and then made up to volume. The slurry was allowed to stand for 24 hours before the sedimentation volume was read (V_2). The swelling index was calculated as V_2/V_1 (Okunlola *et al*, 2020).

Density

A 50-ml pycnometer was weighed empty, filled with the non-solvent (xylene) and the excess wiped off. The weight of the pycnometer with the non-solvent was determined. A 2 g quantity of the sample was weighed and transferred into the pycnometer bottle. The excess non-solvent was wiped out off the pycnometer and weighed again. The particle density was calculated from the equation:

$$\frac{W2W3}{50(W3 - W4 + W2 + W\ )} gcm - 3 \qquad (1)$$

where W = weight of empty pycnometer; W2 = weight of the pycnometer + non-solvent; W3 = weight of powder sample; W4 = weight of pycnometer + non-solvent + powder sample

The bulk density of each excipient at zero pressure (loose density) was determined by pouring 10 g of the powder sample at an angle of 45° through a funnel into a 5-ml glass measuring cylinder with an internal diameter of 22 mm. The bulk density was measured at the ratio of mass to volume occupied by the mucilage. The tapped density was measured by applying 100 taps to 10g of mucilage sample in a granulated cylinder at a standardized rate of 38 taps per minute (British standard 1460**)** .

Flowability

The flowability of the powders was evaluated using the Hausner's ratio and Carr's Index:

$$Carr's\ index = \frac{tapped\ density - bulk\ density}{tapped\ density} x\ 100 \qquad (2)$$

$$Hausner's\ ratio = \frac{Tapped\ density}{Bulk\ density} \qquad (3)$$

Angle of Repose

An open- ended cylinder was placed on a base and 10g of each powder was allowed to flow freely through a funnel to form a conical heap. The angle of repose (θ) was calculated from:

$$Tan\ \theta = \frac{h}{r} \qquad (4)$$

where *h* is the height of the powder and *r* is the radius of the base of the cone.

Angle of internal friction.

The particle and bulk densities were determined and the relative density of the samples were obtained. Porosity of the powder bed was determined using the equation below:

$$\epsilon\ =\ 1 -\ Pb\ /\ Pt \qquad (5)$$

where P_b and P_t are the bulk and particle densities respectively.

The angle of internal friction was obtained from the of plots of ϵ^2 N / (1- ϵ) (porosity factor) versus N, where N refers to the number of taps. The angle was measured as that made between the ordinate line and the abscissa.

Flow Rate.

The flow rate of the sample powders was obtained by determining the time ''t'' it took 10g of the powder to pass through the orifice of a 10-ml pipette. The flow rate was calculated as mean of four determinations according to:

$$10\ g\ /t \qquad (6)$$

Compaction properties

Each powder sample (10g) was allowed to flow freely through a funnel into a measuring cylinder. The volume occupied by the powder was noted. One hundred taps were applied to the powder and the volume occupied after each set of 10 taps was determined. The volume reduction of the powder due to the applied pressure (tapping) was evaluated using the Kawakita equation (Kawakita and Ludde, 1971):

$$\frac{N}{C} = \frac{N}{a} + \frac{1}{ab} \qquad (7)$$

where N is the number of taps and both 'a' and 'b' are constants obtained from the slope and intercept, respectively. Constant 'a 'describes the compressibility while the reciprocal of the constant 'b'(i.e. 1/b) describes cohesiveness of powders or the time of onset of final packing. 'C' describes volume reduction during the tapping and can be calculated from the equation:

$$C = \ Vo - V))\,/\,(Vo \qquad (8)$$

where Vo is the loose volume of the powder before tapping and V is the volume of the powder after a certain number of taps.

The data obtained was also used to assess the consolidation behaviour of the excipients using the method described by Neumann *et al*. (1967) to study the relative decrease in powder volume and density as a function of applied load according to the equation below:

$$Log\ (PT - PB)/PT = K\ Log\ N + C \qquad (9)$$

where P_T and P_B are the tapped and bulk densities respectively. N is the number of taps.
C is the consolidation index and K is the rate of consolidation.

RESULTS AND DISCUSSION

Okra mucilage yield.

The yield of Okra mucilage was found to be 7.85 %w/w on a dry weight basis. This is comparable to the yield reported in the literature (Archanaa *et al*, 2013; Gemede *et al*, 2018).

Material Properties

The material properties of the co-processed excipients are presented in Table 1.

Table 1: Material properties of Okra mucilage, pregelatinized potato starch and the formulations of co-processed excipients

	Starch: mucilage	pH	Particle size µm	Swelling index	Particle density gcm-3	Bulk density gcm-3	Tapped density gcm-3	Hausner's ratio	Carr's index %	Angle of repose °	Angle of internal friction °	Flow rate /s
B_1	95:05	6.60±0.46	271.25±10.39	5.90±0.06	1.433±0.010	0.619±0.011	0.761±0.043	1.20±0.09	16.43±5.88	27.33±1.90	34.99±2.30	1.46±0.04
B_2	90:10	6.70±0.24	364.10±9.51	6.40±0.05	1.724±0.002	0.572±0.016	0.684±0.050	1.18±0.06	14.91±3.78	25.60±2.94	36.09±3.55	1.48±0.07
B_3	85:15	6.75±0.47	378.22±11.03	7.97±0.15	1.445±0.010	0.619±0.011	0.732±0.015	1.16±0.04	14.07±2.89	24.14±1.19	37.16±2.98	1.55±0.09
B_4	80:20	6.76±0.54	457.45±10.73	9.10±0.20	1.440±0.007	0.627±0.039	0.715±0.026	1.14±0.06	12.31±4.93	22.62±1.83	39.48±4.04	1.62±0.05
B_5	70: 30	6.77±0.65	464.30± 9.70	9.83±0.11	1.716±0.005	0.600±0.021	0.674±0.013	1.12±0.05	10.98±4.88	22.11±2.14	44.68±3.65	1.72±0.04
B_6	potato	7.05±0.33	54.90 ± 11.55	6.00±0.22	1.509±0.011	0.578±0.016	0.769±0.010	1.18±0.03	15.60±2.53	27.84±1.42	33.02±4.18	1.40 ±0.02
B_7	Okra	6.48±0.14	233.50±15.10	13.00±1.1	1.415±0.009	0.508±0.016	0.594 ± 0.04	1.17±0.07	14.48 ±2.90	31.00±0.42	34.21±4.22	1.81±0.02

Morphology

Scanning Electron Microscope (SEM) micrographs are shown in Figure 1. The morphology as characterized by particle shape and size can be used as an important feature for the identification and distinction of different polymers. Particle size and shape are considered critical parameters in powder characterization particularly in direct compression formulations affecting powder performance, packing consideration, flowability and compaction (Nidal, 2010). The Okra mucilage and pre-gelatinised potato starch were irregular and oval shaped granules with mean particle sizes of 233.50±15.10µm and 54.90±11.5 µm, respectively. It is generally accepted that powder flow increases with an increase in particle size (Liu *et al*, 2008). The particle size of Okra mucilage was found to be larger than that of pre-gelatinized starch but the mucilage granules were more irregular in shape. The ranking of particle size was $B_6 < B_7 < B_1 < B_2 < B_3 < B_4 < B_5$.

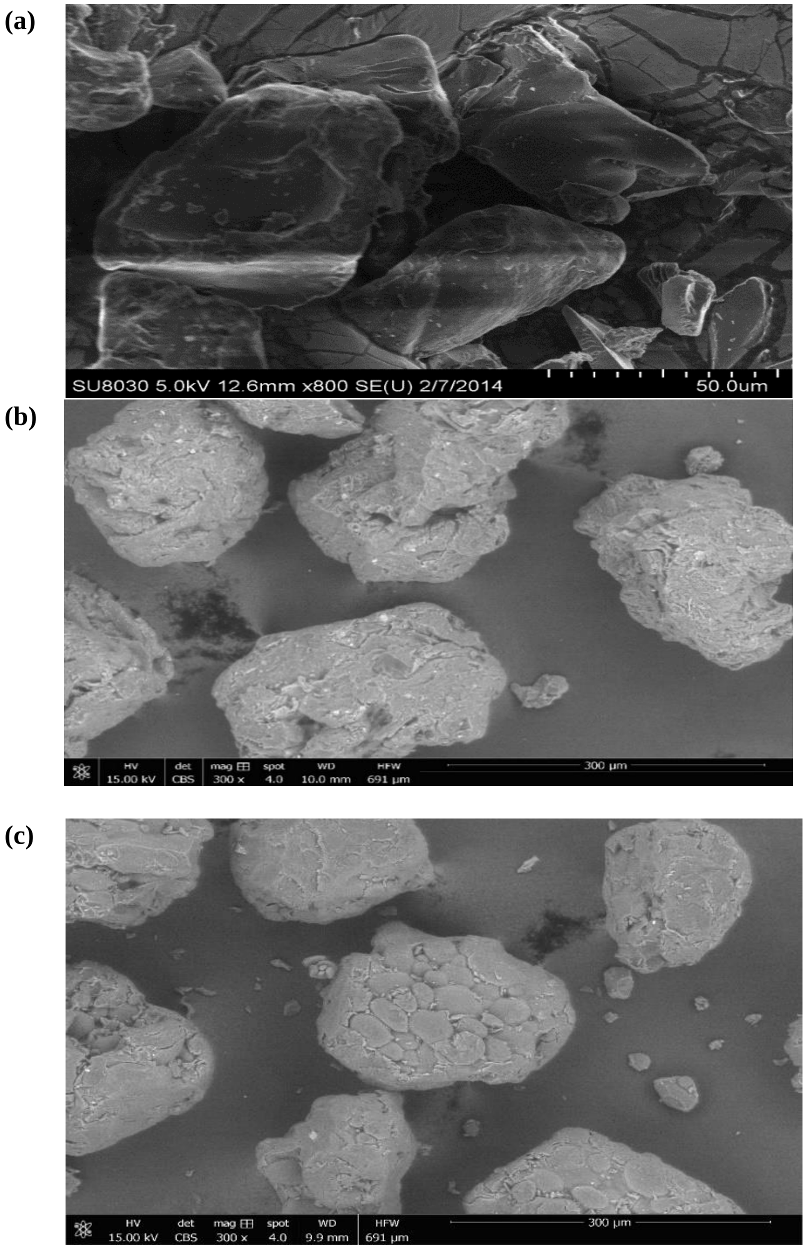

Figure 1: Scanning electron micrographs (SEM) of: (a) Pregelatinized potato starch; (b) Okra mucilage and (c) Co-processed excipient

Comparison of the morphology of the co-processed excipients with the individual polymers showed co-processing resulted in larger agglomerates, which had less irregular, near spherical shape when compared to the particles of Okro mucilage. The particle agglomerates of the co-processed excipients showed mechanical interlocking of the particles of mucilage and starch, indicating formation of completely new types of polymers. The geometry of particles is another factor that affects the flow properties of a powder. The larger, less-irregular agglomerates of the co-processed excipients were observed to possess interparticulate pores which is expected to contribute to the improved flow of the new excipient when compared to individual starting materials. However, a complex interplay may exist between particle size, particle shape, particle size distribution as well as the intra- and inter-particulate forces within the particles, making it difficult to predict how these parameters may individually affect flowability of the powders

(Adeoye and Alebiowu, 2013). Co-processed batch B$_5$, with ratio of starch: mucilage 70:30, had the largest particle size

Fourier Transform Infra-red (FTIR) analysis

The FT-IR spectra of the samples are shown in Figure 2. Figure 2a showed the formation of amorphous structure of the pre-gelatinized potato starch with disruption in the ordered structure of starch as shown by the reduction in the band intensity at 1042 cm^{-}1. The absorption bands at 3300 and 1610 cm−1 were due to bound water, while that at 1350 cm−1 was due to the bending vibrational modes of O –C- H, C –C- H, and C- O- H. In the region between 1200 and 900 cm−1 several strong absorption peaks were assigned to C- C and C -O stretching modes. In Figure 2b, a broad peak at 3438 cm^{-1} was found in the spectrum of Okra gum, indicating the presence of aromatic sugar groups with O–H as the main functional group. The O–H groups are able to bind with water molecules and produce bound moisture to the polymer components. The existence of O–H groups represents the hydrophilic characteristic that is present in the polysaccharide. The medium peak that was visible at 2938.69 cm^{-1} represents C–H stretches that exist in galactose and rhaminose. The stretching peak at 1200–1000 cm^{-1} indicates C–O stretch bonds which are present in the aromatic compounds of galactose, rhamnose, and galacturonic acid. The methyl, carbonyl, and hydroxyl functional groups that are present in the chemical structure of Okra are constituents of carbohydrate molecule, which is the main backbone of the polymer. FT-IR spectra of co-processed excipients still retained majority of the major peaks of individual polymers, suggesting the absence of chemical interaction between polymers during co-processing.

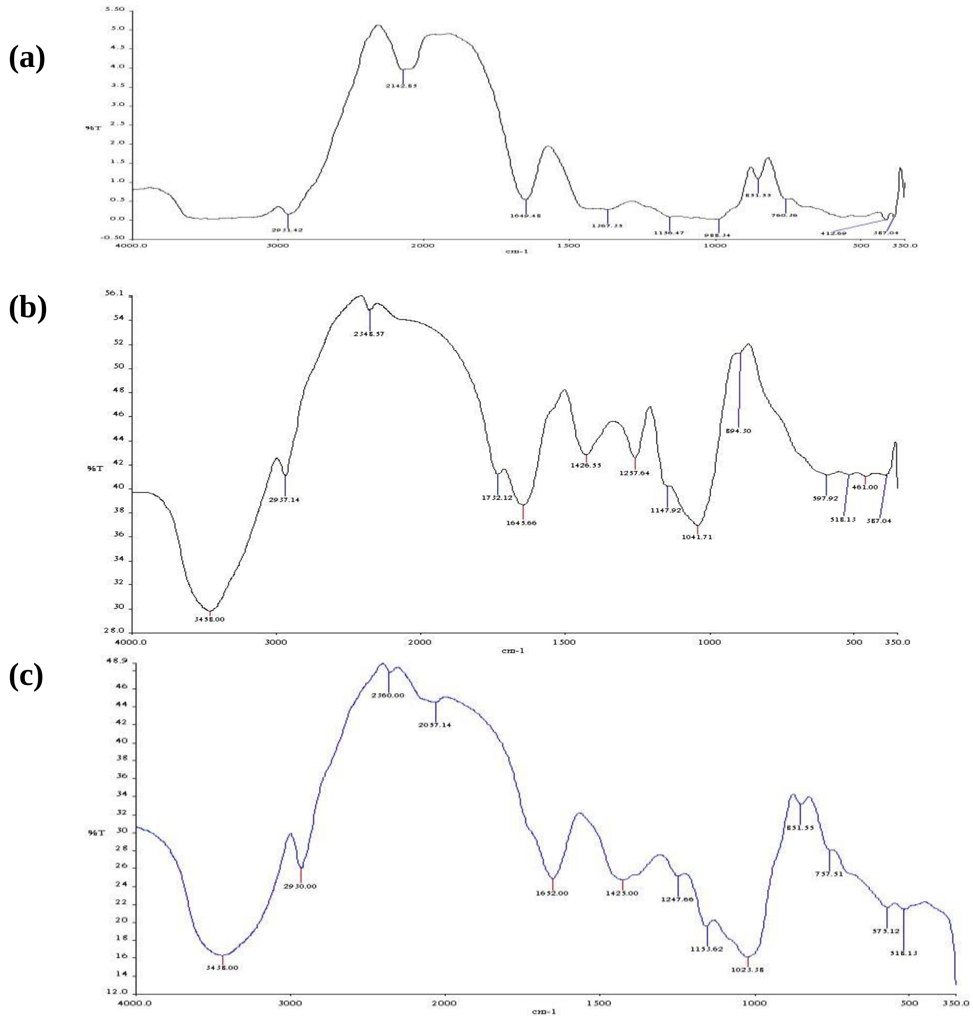

Figure 2: FTIR Spectra of: (a) Pregelatinized potato starch; (b) Okra mucilage and (c) Co-processed excipients

pH

The pH of a powder can affect the release properties of the formulation in which it is used. The pH (determined at room temperature) was 7.05 for pregelatinized potato starch while that of Okra mucilage at the same temperature was 6.57. The pH of the co-processed excipients was also near neutral, suggesting these polymers would minimize irritation to the gastro-intestinal tract (git), making them suitable as an excipient (Malviya, 2011)

Swelling index

The swelling index of a powder is defined as an increase in volume (and/or weight) when allowed to swell freely in water (Akin-Ajani *et al*, 2014). Swelling index is an analytical test to measure water uptake. In starch, amylopectin is considered as the sole contributor to water absorption and subsequent swelling and pasting of starch granules, whereas, amylose tend to retard this phenomenon (Samutsi and Suphantharika, 2012). The swelling index of starch powder is of great importance in tablet formulations because the disintegrating properties of starches have been said to be influenced by their swelling and wicking action (Musa *et al.*, 2008). The ranking of the swelling index was in the order: $B_7>B_5>B_4>B_3>B_2>B_6>B_1$.The result showed that Okra mucilage had higher swelling than pregelatinized potato starch and imparted its swelling property on the co-processed excipients. The swelling index increased with increase in amount of mucilage in the batches of co-processed excipients. This is in line with a previous study by Mandala and Bayas (2004), where it was observed that the addition of xanthan (0.09%) gum to wheat starch enhanced swelling of starch dispersion (2%w/v). The mucilage must have promoted adhesive interaction and entrapped the gelatinized granules by keeping them close, thereby facilitating swelling and amylose solubilisation. Batch $B_{5,}$ with ratio of starch: mucilage 70:30, had the highest swelling out of all the batches of co-processed excipients produced.

Densities

Particle density has been observed to affect the compaction behaviour of powders and is one of the major contributors to the packing behaviour of formulation materials during various operations of tabletting such as granulation, mixing, filling into die as well as on their compressibility, especially at the initial phase prior to the phase where elasto-plastic flow is being carried out (Riley and Adebayo, 2010; Van den Ban and Goodwin, 2017). Bulk density of a material is the ratio of the mass to volume (including all the inter-particulate void volume) of an untapped powderA higher bulk density is advantageous in tabletting because of a reduction in powder fill volume of the die (Nidal *et al*, 2015). The ranking of the values of particle density was $B_7 < B_1 < B_4 < B_3 < B_6 <B_5 < B_2$ while that of bulk density was $B_7 < B_2 < B_5 < B_6 < B_1 = B_3 < B_4$. Tapped density on the other hand, refers to the bulk density of powder after a specified compaction which usually involves the vibration of the container. During tapping, particles gradually pack more efficiently, the powder volume decreases while the tapped density increases. The ranking of tapped density was in the order of $B_7 < B_3<B_2<B_5<B_4<B_1<B_6$. Particle sizes can affect bulk and tapped densities of a powder. Small particle size leads to high bulk density and higher packing ability. The decrease in densities observed after coprocessing may be closely related to a decrease in cohesivity of the powders.

Flow properties

The flow properties of a powder are essential in determining its suitability as direct compression excipients. The flow properties of a powder can be determined by using Hausner's ratio, Carr's Index, angle of repose, angle of internal friction and flow rate. Hausner's ratio is an indirect index of the ease of powder flow (Okunlola and Gbadamosi, 2020). It gives an indication of densification that could result from vibration of the feed hopper during tabletting operations. Higher values of Hausner’s ratio predict a significant densification of powders while lower values suggest better flow (Hausner, 1967). Generally, lower Carr's index and Hausner's ratio values represent better flow. Okra mucilage gave lower values of both Hausner's ratio and Carr's index than pregelatinized potato starch, indicating that Okra mucilage has better flow properties (Carr, 1965). To a large extent, as the amount of Okra mucilage in the batches of the co-processed excipients increased, the values of both parameters decreased showing good flow. The decrease in densities observed after coprocessing is closely related to a decrease in cohesivity of the powder which translates to a greater tendency for improved flow of the powder.

The angle of repose (θ) could be used as a qualitative measure of cohesiveness or the tendency of powdered or granulated materials to flow. It is the steep angle of descent or deep relative to the horizontal plane to which a material can be piled without slumping. The angle of repose is affected by the particle size distribution and is also related to the density, surface area and particle shape of a powder.. Most free-flowing materials have angle of repose of less than or equal to 30° (Adeoye and Alebiowu, 2013. Powders with angle of repose of 40° have flow problems and are regarded as poorly flowing powders. Okra mucilage gave the highest value of angle of repose in comparison to pregelatinized potato starch and the co-processed excipients. The complex interplay between particle size, particle shape, particle size distribution, and intra and inter particulate forces at work within the particles makes it difficult to predict how these parameters individually affect the flowability of powders (Vasilenko, *et al* 2011). The values of angle of repose of the co-processed excipient indicate that powder flow improved after co-processing Okro mucilage with potato starch as a result of the reduction in the interparticulate friction. Such uniformity of flow is expected to minimize weight variations in tablets produced when the co-processed excipients are used as directly-compressible excipients. Batch B_5 containing starch: mucilage 70:30 had the lowest value of angle of repose (22.11 ± 2.14^0). Varthalis and Pilpel (1976) showed that the angle of internal friction would be more indicative of flow pattern than angle of repose. The angles of internal friction were obtained using the relationship between porosity and the number of taps and the plots are presented in Figure 3. The angle made between the ordinate line and the abscissa is known as angle of internal friction (Podczeck and Miah, 1996). Higher values of angle of internal friction indicate greater cohesiveness and higher formation of bridges and arches in the powder which can therefore impairs the flow of the powders. The results showed that co-processing improved the angle of internal friction in comparison to the individual excipients.

Flow rate of a powder is another parameter in demonstrating the flow properties of a powder. Flow rate is the rate of flow (i.e. inversely proportional to time of flow). The higher the flow rate, the better the flow. Hence, Okra mucilage with higher flow rate showed better flow than pregelatinized potato starch. The improved flow rate resulted from the formation of particles of less irregular shape during the co-processing. As the amount of Okra mucilage in the co-processed excipients increased, the flow rate increased. Co-fusion method was effective in producing novel co-process excipients with enhanced flowability. Batch $B_{5,}$ with ratio of starch: mucilage 70:30, had the fastest flow rate of all the new batches of co-processed excipients produced.

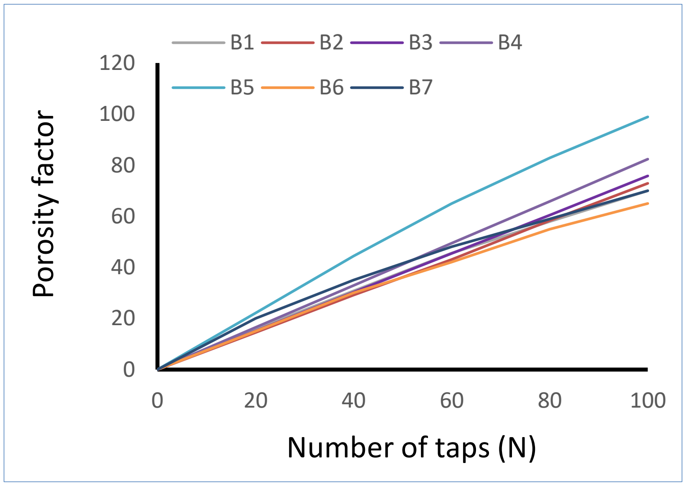

Figure 3: Plots of Porosity factor as a function of number of taps (N) for Okra mucilage, pregelatinized potato starch and co-processed excipients

Compaction properties

Compressibility is the ability of a material to reduce in mass or volume by the application of pressure.The Kawakita plots of N/C versus number of taps (N) for the co-processed excipients and the starting materials are shown in Figure 4. A linear relationship was obtained with the constants 'a' and **'b'** determined from the slope and intercept of the plots respectively and the values are presented in Table 2. The constant 'a' is equal to the minimum porosity of the material before compression while the constant 'b' is related to the plasticity of the material after compression. The lower the 'a' value of a powder, the better the flowability. Lower value of 'b', which is an inverse measure of cohesiveness, shows that the powder is more cohesive with less flowability. The combination of the two parameters may therefore be used as an indicator of particle re-arrangement during compression (Nordström *et al*, 2008). Okra mucilage gave larger 'a' but lower 'b' values lower than those of pregelatinized potato starch and the co-processed excipients, indicating that Okra mucilage had a better compressibility and cohesiveness. The presence of Okra mucilage appeared to improve the cohesiveness and compressibility of the co-processed excipient, implying that including the co-processed excipients in tablet formulations would impart higher mechanical strength to such tablets. Batch B_5 with pregelatinized potato starch: Okro mucilage ratio of 70:30 can be considered to be the optimum formulation in terms of balance between adequate flow properties, cohesiveness and compressibility.

The consolidation behaviour of the excipients were determined using the method described by Neumann *et al* (1967) to study the relative decrease in powder volume and density as a function of applied load. The plots of Log ($Ƥ_T$- $Ƥ_B$)/$Ƥ_T$ versus number of taps (N) are shown in Figure 5. From the plots, the values of C and K were obtained for each batch and are also presented in Table 2. The value of C is a measure of the effect of packing on flow. The higher the index, the higher is the effect on flow. The value of K is a measure of the rate of packing of powder/granulation. The ranking of C was $B_5 > B_6 > B_4 > B_7 > B_3 > B_2 > B_1$ while that of K was in the order: $B_5 > B_6 > B_7 > B_4 > B_3 > B_2 > B_1$. The values of C and K increased with increase in ratio of Okra mucilage with Batch B_5 containing starch: mucilage 70:30 having the highest values. The results show that the presence of okro mucilage imparted greater effect on flow and rate of packing on the co-processed excipients when compared to the individual starting materials (Ogunjimi and Alebiowu, 2013).

Characterization of the batches of co-processed potato starch and Okro mucilage has been carried out in order to have a comprehensive understanding of their behaviour and show their potential as useful, cheap and locally available excipients in direct compression of tablets. The two important properties necessary for making good compacts are compressibility and fluidity. The co-processed excipients have shown high fluidity or flowability that will enable uniform fill of the dies during tableting. In addition, they have shown sufficient compaction properties that can guarantee the formation of firm, strong tablets under adequate compression force. In further studies, evaluation of selected batches of the co-processed excipients would be done by including them in tablet formulations of drugs using direct compression and determining their influence on tablet properties. The final acceptability of these excipients would be their ability to comply with pharmacopoeia requirements, relating to purity, inertness and compatibility.

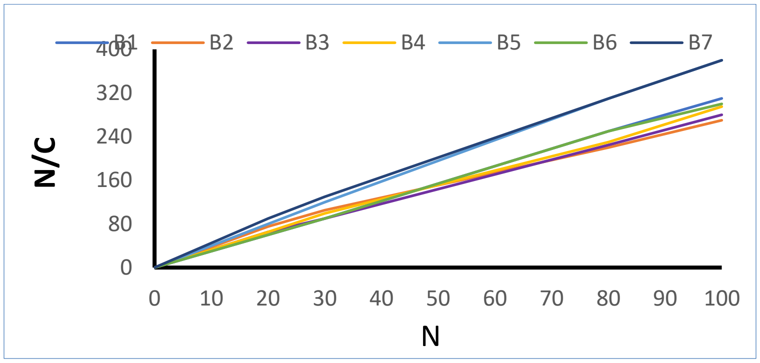

Figure 4: Kawakita plots for Okra mucilage, pregelatinized potato starch and co-processed excipients

Table 2: Compaction properties of Okra mucilage, pregelatinized potato starch and the formulations of co-processed excipients

Formulation	Starch: mucilage	Kawakita Compressibility a	Kawakita cohesiveness b	Consolidation Index C	Consolidation rate K
B_1	95:5	0.300	0.371	0.566	0.123
B_2	90:10	0.309	0.349	0.741	0.153
B_3	85:15	0.324	0.259	0.885	0.194
B_4	80:20	0.316	0.199	0.961	0.222
B_5	70:30	0.329	0.078	1.389	0.424
B_6	100:0	0.287	0.077	1.036	0.270
B_7	0:100	0.360	0.059	0.925	0.236

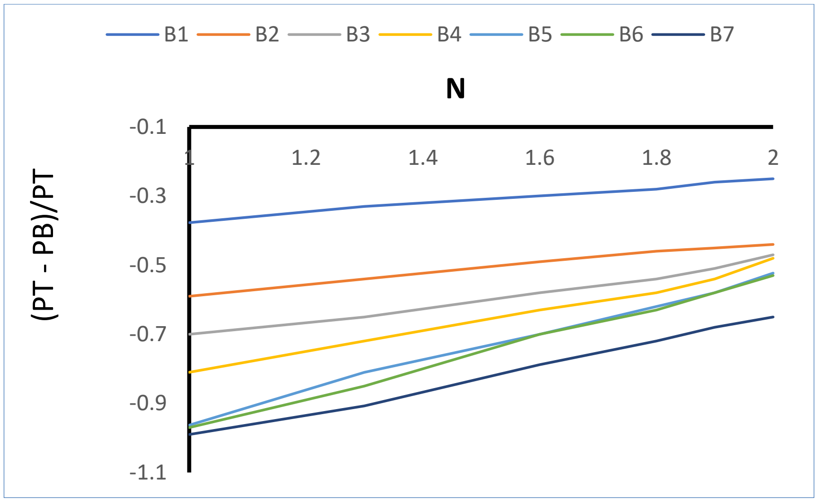

Figure 5: Plot of Log (Ƥ$_T$- Ƥ$_B$) / Ƥ$_T$ Vs N for Okra mucilage, pregelatinized potato starch and co-processed excipients

CONCLUSION

Co-processing of Okra mucilage with pregelatinized potato starch resulted in improved flow, cohesiveness and compaction properties. Formulation B$_5$ with starch: Okra mucilage ratio 70:30 appeared to be the optimum formulation in terms of adequate flow properties, cohesiveness and compressibility which would impart good flow and mechanical strength into tablets; essential parameters required in directly compressible excipients. Co-processed excipients of Okra mucilage combined with pregelatinized potato starch could be suitable for use as directly-compressible excipients. Future studies would involve the evaluation of selected batches of the co-processed excipients in tablet formulations of drugs.

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