

Studies of Co-Processed Hydrophilic Polymer Composites of Cissus Gum With Acacia, Tragacanth or Guar Gums: Processing and Characterization

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ABSTRACT

New hydrophilic polymers were developed by co-processing of Cissus gum (CG) with acacia (AG), tragacanth (TG) or guar (GG) gums. Batches of the new hydrophilic polymers were co-processed using the CG obtained from the stem of *Cissus populnea* with AG in the respective proportions of 5(%w/w)CG + 95(%w/w)AG, 10(%w/w)CG+90(%w/w)AG, 15(%w/w)CG +85(%w/w)AG and 20(%w/w)CG +80(%w/w)AG. Similar co-processed hydrophilic polymers were developed with CG and TG or GG respectively. A 50.0ml aqueous based slurry was made with each set of ingredients, precipitated with acetone, dried (desiccator), pulverized (180 μ m) and assessed for densities, flowability, moisture characteristics, pH and viscosities. The bulk and tapped densities varied statistically within the starting and the co-processed polymers ($P<0.05$), indicating that the co-processed powders may be compressible light bulk powders with low flowability due to high interparticulate interactions confirmed from the results of the flow rate, angle of repose, Carr's index and Hausner's ratio. Moisture contents of the starting materials appeared similar ($P>0.05$), but increased in the co-processed powders as CG+GG>CG+TG>CG+AG ($P>0.05$). Hydration capacity of the initial polymers ranked as CG>TG>GG>AG ($P<0.05$), increased with the increment of CG in the co-processed powders, as CG+TG>CG+GG>CG+AG ($P<0.05$). The swelling index of the initial materials presented as CG>GG>AG>TG ($P<0.05$), increased in the co-processed powders with increasing CG as CG+TG>CG+GG>CG+AG ($P<0.05$). The viscosities of the initial polymers ranked as GG>TG>CG>AG ($P<0.05$) and in the co-processed powders as CG+GG>CG+TG>CG+AG ($P<0.05$). Therefore, the study resulted in new co-processed hydrophilic polymers with improved hydration and swelling capabilities and viscosities advantageously essential in the adjuvants exploited as binders, disintegrants, emulsifiers, especially in the formulation of in-diffusible drugs in the liquid disperse systems necessitating the uniform and stable dispersion of the API coupled with enhanced viscosities and pH stability.

Keywords: Excipient, gum, hydrophilic polymer, co-processed, cissus, guar, tragacanth, acacia.

1 INTRODUCTION

Pharmaceutical excipients have commonly been derived from natural (animal, vegetable and mineral) and synthetic sources [1]. The excipients acquired from natural bases remains incomparable for the manufacturing of pharmaceutical dosage forms due to their reduced toxicity, low cost, local availability, soothing action, non-irritant nature, relative abundance, biocompatibility, improved patient tolerance, and public acceptance compared to synthetic excipients [2-4]. Meanwhile, there has been a consistent rise in the need for new pharmaceutical excipients in line with the technical formulation requirements for certain drugs, especially the ones possessing distinct pharmacological active compounds or active pharmaceutical ingredients (APIs) with multifaceted physico-chemical properties as well as comprising elaborate approaches in their manufacture [5]. An excipient is

a material that is employed in the formulation of pharmaceutical dosage forms, usually incorporated in conjunction with the active pharmaceutical ingredient(s) in the medication [6]. Excipients may accomplish a diversity of practical functions in the pharmaceutical dosage form. In the immense widely held view, and in most settings, excipients are expected to retain limited (if any) pharmacological influence when compared with the active pharmaceutical ingredient (API). Due to this variance in the anticipated bioactivity and the risks/benefits association amid excipients and the API, the approaches for the safety evaluation of excipients and API varies [7]. Excipients are generally selected to impart stability to the final dosage form with each playing a definite role in a dosage formulation, acting either as a binder, diluent, disintegrant, for pH regulation, control of drug release dynamics, conferment of a therapeutic boost on the API in the finished dosage form such as facilitating drug release, absorption, [8,9][4, 5], reducing viscosity [10][6], enhancing viscosity [7, 8][11, 12] or improving solubility [13, 14] [9, 10]. Excipients are relevant in the industrial procedures to sustainance the control of the active ingredient such as enabling powder flowability or reduction of particle adherence in addition to supporting *in vitro* stability such as the prevention of denaturation or aggregation over the expected shelf life. The selection of appropriate excipients also depends upon the route of administration of the intended dosage formula as well as the active ingredient and other factors [15, 16] [11, 12]. Pharmaceutical guidelines and standards necessitate that all the constituents in medications, including the products of their chemical decomposition remain identifiable and established to be safe [13] [17]. Most of the time, excipient(s) may be in a higher proportion in a pharmaceutical dosage form than the active ingredient and in practice, all marketed drug products comprise excipients [6, 17, 18] [2, 13].

Quite a lot of natural products are polymers [19][14] and have served as excipients, having been applied in the pharmaceutical sector as binding, disintegrants, sustaining, suspending, thickening, gelling agents, etc. Currently, there are numerous pharmaceutical excipients derived from plants such as starch, guar gum, cellulose and acacia [20-23] [15-18]. Polymers are macromolecules comprising numbers of recurrent monomers linked by polymerization. They could be either natural or synthetic. Polymers obtainable from plant sources are derivable from plant stem, seed, root or tubers and include the polysaccharides which are complex carbohydrates such as gums, starches, celluloses, etc. The investigation into the natural polymeric materials has been inundated with increasing attention attributable to several factors such as their relative abundance, low cost, biodegradability and eco-friendly profiles. **Polymers derived from beans or plant seeds are described as galactomannans or gums and includes the guar, tara, cassia, locust bean gums, etc. [19, 24-26] [14, 19, 20].** Gums generally are plant-based exudates arising as a response to pathological damage, unfavourable settings, etc. to the cell walls of a plant, a process termed gummosis. On the other hand, mucilage is principally a normal product of metabolism formed inside the cell of plants. Its formation does not reflect any damage to the plant. Gums easily dissolve in water, while, mucilage forms slimy masses. Acacia, tragacanth and guar gums are examples of gums while mucilage could be found in diverse parts of a plant. Gums and mucilages appear alike and could generally be referred to as plant hydrocolloids or hydrophilic polymers [27-29] [21-23]. Essentially, polymers have been applied in the formulation of medicinal preparations utilizing their functionalities as diluents, binders, disintegrants, films or enteric coatings of solid dosage forms, drug

release enhancers/retardants, viscosity enhancers in suspensions, emulsions, production of encapsulation devices, preparation of micro-beads, micro-particles, pharmaceutical packaging, etc.[19, 23, 30, 31] [14, 18, 24, 25]. Hydrocolloids are high molecular weight hydrophilic polymers retaining polar or charged functional groups which enable their aqueous solubility [32]. They are also employed in product formulations to regulate the functional characteristics of aqueous-based dosage forms, especially in cases where enhanced viscosity is desirable to maintain product stability as in pharmaceutical disperse systems [33]. Hydrocolloids may be hot or cold-water-soluble. Examples of cold-water-soluble hydrocolloids are guar gum and gum arabic (acacia). Once dispersed, the cold-water hydrocolloids are wholly hydrated with mild or sufficient agitation at ambient temperatures. The hot-soluble hydrocolloids may hydrate basically in hot water and require subsequent heat treatment (80-90 °C) for complete hydration. The more water available in the system, the faster and more efficient the hydration of the hydrocolloid [34]. Hydrocolloids are extensively applied in various foods and pharmaceutical formulations to improve quality characteristics and shelf-life. They are mainly employed as thickening and gelling agents to enhance or regulate the rheology of liquids or semi-solid dispersions [34, 35].

One of the polymers considered in this study, guar gum is an easily hydrated galactomannan derived from the seeds of *Cyamopsis tetragonolobus*, a leguminous plant. It is essentially utilized in the form of guar gum powder in the formulations of food, pharmaceuticals, etc. It is capable of forming hydrogen bonding with water molecule enabling it to easily get hydrated in cold water, making its key application as thickener and stabilizer possible [36, 37].

Acacia, another polymer employed in the present study is the air-hardened natural gummy exudate derived from the trunk and branches of *Acacia senegal* (L) Willdenow. It is soluble in cold water (up to 43–48% v/v) but not soluble in ethanol. Acacia is employed as a pharmaceutical ingredient in drug formulations for the throat, etc. and as a film-forming agent in peel-off skin masks [38].

Tragacanth also utilized in the current study is a natural gum derived from the dried sap of some species of Middle Eastern legumes of the genus *Astragalus*. It is a viscous, odourless, tasteless, water-soluble mixture of polysaccharides. Tragacanth provides thixotropy to a solution (forms pseudoplastic solutions). The maximum viscosity of the solution is achieved after several days, due to the time taken to hydrate fully. It is stable at a pH range of 4-8 and it is an improved thickening agent compared to acacia. It is employed in pharmaceutical dosage formulations as a suspending agent, emulsifier, thickener and stabilizer [39]. *Cissus populnea* Guill & Perr belong to the family of Vitaceae and the genus, *Cissus* [40]. The gum obtained from *Cissus populnea* has been evaluated for its prospective application as a dispersant in pharmaceutical liquid dispersion systems. *Cissus populnea* is a rich source polymer as all parts of the plant are mucilaginous. Being rich in adhesive exudates and retaining some of the essential qualities such as availability and relative cost-effectiveness, is considered relevant for exploration in the manufacture of pharmaceutical dosage forms. *Cissus* gum has been employed in several other industries such as the food industry and it is yet to be maximally exploited in the pharmaceutical industry [41-43].

Novel pharmaceutical excipients retaining value-added functionalities could be developed by co-processing. Co-processing is an innovative model introduced to modify excipient functionality by retaining complimentary characteristics and augmenting with novel properties. This is achievable by treating the parent excipient with another excipient. The high functionality excipients derived by the technique enhances such desirable properties as flow properties, compressibility, disintegration and dissolution of solid dosage forms, enhancement of gelling or viscosity regulation characteristics due to improved hydration and swelling capacity of the new excipient, etc. These and lots more have been the purposes of co-processing in pharmaceutical technology [22-24, 44-48]. The purpose of this study was to develop and characterize new hydrophilic polymers by co-processing of Cissus gum (CG) with acacia (ACA), guar (GG) or tragacanth (TG) gums.

2 MATERIALS AND METHODS

2.1 Materials

The following materials were used as procured and included: Acetone, *n*-hexane (JHD, China), acacia gum (J.T Baker, USA), tragacanth gum (Lobachem, Germany), guar gum (Qualikems, India) and silica gel (JHD, China).

2.2 Collection and identification of the sample

The fresh matured stem of *Cissus populnea* was procured from *Ukwo-Ogbo* market, *Ogbadibo* Local Government Area, Benue State, Nigeria. The sample was identified by a Taxonomist in the Department of Plant Science and Biotechnology, University of Port Harcourt, Nigeria as *Cissus populnea* (Guill & Perr) (Family: Vitaceae). It was assigned an e-herbarium number EH/ABC/067 and deposited in Ecoland herbarium (EH), Port Harcourt, Nigeria.

2.3 Processing of sample

A 12.665 kg of the fresh matured stem of *Cissus populnea* was weighed, scraped, washed using clean water and cut into minute pieces. The tiny bits of the sample was soaked in sufficient deionised water freshly boiled to 100 °C and allowed to stand for 24 h. The mucilage formed from the macerated sample was expressed out using a clean muslin cloth. The mucilage was precipitated using acetone in a ratio of 1:2. The precipitated mass was dried to constant weight in a desiccator loaded with silica gel. The dried sample was pulverized in a porcelain mortar and classified with an 180µm sieve (Retch, Germany) and designated as cissus gum (CG).

2.4 Preparation of co-processed hydrophilic polymers

Using the formula in Table 1, batches of co-processed hydrophilic polymers containing 5.0, 10.0, 15.0 or 20.0 % w/w of cissus gum (CG) with 95.0, 90.0, 85.0 or 80.0% w/w of either acacia gum (AG) or tragacanth gum (TG) or guar gum (GG) were developed. The respective proportions totalling 100.0 % in each batch was homogenized and dispersed in 55.0 ml of deionized water into a smooth slurry. It was precipitated with acetone, dried to constant weight in a desiccator loaded with silica gel, pulverized and classified with 180µm sieve.

Table 1: Preparation of co-processed hydrophilic polymer containing various amounts of cissus gum with proportions of either acacia gum or tragacanth gum or guar gum.

Polymers	Concentration (% w/w)			
CG	5.0	10.0	15.0	20.0
AG	95.0	90.0	85.0	80.0
CG	5.0	10.0	15.0	20.0
TG	95.0	90.0	85.0	80.0
CG	5.0	10.0	15.0	20.0
GG	95.0	90.0	85.0	80.0

2.5 Determination of physico-chemical properties of the co-processed hydrophilic polymers

All the experiments for the determination of the physico-chemical properties were performed on the co-processed powders and the original powders of cissus, acacia, tragacanth and guar gums. Each procedure was executed in triplicate.

2.5.1 Densities

2.5.1.1 Bulk density, tapped and particle densities

A 20 g amounts of the individual powders was engaged in the evaluation of bulk and tapped densities using the Stampfvolumeter (STAV 2003JEF, Germany). The bulk and tapped densities were worked out by the equations below:

$$\text{Bulk density} = \text{Weight of powder} / \text{Bulk volume of powder} \dots\dots\dots (1)$$

$$\text{Tapped density} = \text{Weight of powder} / \text{Tapped volume of powder} \dots\dots\dots (2)$$

The particle density of the individual powders was accessed using the solvent displacement approach and employing *n*-hexane as non-solvent [23, 24, 49]. A void density glass bottle of 25.0 ml capacity was balanced (W). It was packed full of *n*-hexane and balanced again (W1). The variation in weight amid this (W1) and W was considered as W2. A 0.5g measure of the respective powders was taken up (W3) and cautiously let into the glass density bottle, wiping off the surplus *n*-hexane and establishing the new weight (W4). The particle density of each of the powders was calculated as follows:

$$\text{Particle density, } P_t \text{ (g/ml)} = W2 \times W3 / V (W3 - W4 + W2 + W) \dots\dots\dots (3)$$

Where: *v* is the capacity of glass density bottle = 25.0 ml.

2.5.2 Flow Properties

2.5.2.1 Flow Rate and Angle of Repose

A 50.0 g of each powder was utilized in the determination of the flow rate making use of the funnel method reported by Carstensen and Chan [23, 24, 50]. The flow rate was calculated from the formula below.

$$\text{Flow rate} = \text{Mass of powder} / \text{Time} \dots\dots\dots (4)$$

The angle of repose of the individual powders of cissus, acacia, tragacanth and guar gums was established by pouring 50.0 g of each powder into a cylindrical plastic tube of measurable diameter stationed on a flat base. The cylindrical plastic tube was gradually drawn up to discharge the powder and thereby creating a cone of powder on the base. The height of the powder heap was estimated. This is an amendment of the approached documented by Jones and Pilpel [51] while those of the respective co-processed powders was determined as follows. A glass funnel was clamped to a retort stand with the funnel orifice tip leaving a permanent space of 3.0 cm from the horizontal base on plain paper. Each of the co-processed powders was individually dispensed into the funnel till the powder heap constituted reached the tip of the funnel thereby hindering further outflow of powder through the funnel outlet [23, 24, 52]. The diameter of the edge of the heap of powder was estimated and angle of repose was calculated as follows.

$$\text{Angle of repose, } \theta = \tan^{-1} (2h/d) \dots\dots\dots (5)$$

Where θ is the angle of repose, h is the height of powder heap, d is the diameter of the powder heap.

The derived properties of the respective powders were calculated as follows.

2.5.2.2 Hausner's Ratio

Hausner's ratio (HR) is an index that relates to the flowability of a powder or granular material [53]. It was calculated as the ratio of tapped density to bulk density of the individual powders.

$$\text{Hausner ratio} = \text{Tapped density of powder} / \text{Bulk density of powder} \dots\dots\dots (6)$$

2.5.2.3 Carr's index

Carr index (CI) or Carr's compressibility index is an indication of the compressibility of a powder [54]. It was calculated using the data for the bulk and tap densities in an equation as follows.

$$\text{Carr's index} = [\text{Tapped density} - \text{Bulk density} / \text{Tapped density}] \times 100 \dots (7).$$

2.5.3 Assessment of the moisture properties of the powders

2.5.3.1 Hydration Capacity

The hydration (water retention) capability of the separate powders was assessed by the procedure documented by Ring [55]. A 1.0 g quantity of powder was retained in a 15.0 ml plastic centrifuge tube and 10.0 ml of water was introduced, shaking the tube occasionally within a space of 2 h and rested for 30 min. The set up was centrifuged for 10 min at 3000 revolutions per minute (rpm). The supernatant was poured out while the weight of the wet powder due to water uptake and centrifugation, x was evaluated using the equation as follows.

$$\text{Hydration capacity} = \left[\frac{x}{y} \right] 100 \dots\dots\dots (8)$$

Where x is the weight of moist powder after centrifugation, y is the weight of dry powder.

2.5.3.2 Swelling Capacity

The extent to which the respective powders would swell when exposed to water was assessed using an adjusted approach reported Bowen and Vadino [56]. The tapped capacity engaged by 5.0 g of each powder V_x , was recorded while the powder was dispersed in 85.0 ml of water, adjusting the volume to 100.0 ml using water and kept still for 24 h when the size of the sediment, V_v , was assessed. The swelling capacity was calculated as follows.

$$\text{Swelling capacity} = \left[\frac{V_v}{V_x} \right] 100 \dots\dots\dots (9)$$

Where V_v is the volume of sediment and V_x is the tapped volume engaged by the powder.

2.5.3.3 Moisture content

The moisture content of the various powders were evaluated as follows. The weight of an empty crucible recorded. A 0.5 g of each powder was dispensed into each crucible, labelled and the current weight was noted. The various crucibles were positioned in an oven (Mettler, England) at $105.0^\circ\text{C} \pm 1.0$ with occasional weighing until a persistent weight was attained. The new weight of each crucible was recorded while the moisture content was calculated.

$$\text{Moisture content} = \left[\frac{\text{Initial weight} - \text{Final weight}}{\text{Final weight}} \right] \times 100 \dots\dots\dots (10)$$

2.5.4 Assessment of the viscosity of the powders

The viscosity of 0.5 % of the respective powders was evaluated using a Brookfield Viscometer (DV2T, Brookfield engineering laboratories, Massachusetts, USA) using a spindle of #61 for 30 s at a temperature of 25.7°C .

2.5.5 pH measurement

The pH of 2.0 % w/v aqueous dispersion of each powder was evaluated with a pH meter (Ultrameter II, 6PFC E; Myron L, UK).

2.5.6 Statistical analysis

The figures were presented as a mean $\pm$ standard deviation (SD). One-way analysis of variance (ANOVA) was performed followed by Fisher's Least Significant Difference (LSD) post hoc test to determine the level of significance.

3 RESULTS AND DISCUSSION

3.1 Organoleptic properties of cissus gum powder

The cissus gum powder was a brownish fine and light powder without a characteristic odour.

3.2 Densities

The results of the assessments of the bulk, tapped and particle densities of cissus, acacia, tragacanth, guar gums and the co-processed powders containing various

proportions of the above polymers are presented in Table 2. Cissus gum powder exhibited a low particle density which seemed to cause similar low particle densities observed in the corresponding co-processed powders containing it. The results of the densities of the original polymeric powders (cissus, acacia, tragacanth and guar gums) and their corresponding co-processed powders indicate that they are generally bulk powders and have low densities. There was consistent variations in the bulk and tapped densities of the respective starting polymers and the co-processed powders ($P < 0.05$). The statistical differences computed between the respective bulk and tapped densities were significant ($P < 0.05$) indicating that though, the co-processed powders could be compressible, but, exhibits poor flowability [46].

Table 2: Showing bulk, tapped and particle densities

Polymers/ Co-processed polymers	Bulk density (g/ml)	Tapped density (g/ml)	Particle density (g/ml)
CG	0.57±0.01	0.67±0.00	0.69±0.00
AG	0.63±0.05	0.80±0.03	1.33±0.01
TG	0.66±0.02	0.82±0.02	1.28±0.06
GG	0.51±0.01	0.63±0.03	0.99±0.11
CG5%AG95%	0.69±0.01	0.88±0.02	0.69±0.00
CG10%AG90%	0.72±0.01	0.90±0.02	0.69±0.00
CG15%AG85%	0.74±0.00	0.95±0.01	0.78±0.15
CG20%AG80%	0.75±0.01	0.96±0.01	0.69±0.00
CG5%TG95%	0.56±0.01	0.70±0.01	0.69±0.00
CG10%TG90%	0.59±0.01	0.75±0.01	0.69±0.00
CG15%TG85%	0.60±0.01	0.75±0.01	0.69±0.00
CG20%TG80%	0.63±0.01	0.67±0.01	0.69±0.00
CG5%GG95%	0.53±0.00	0.67±0.01	0.69±0.00
CG10%GG90%	0.54±0.00	0.69±0.01	0.69±0.00
CG15%GG85%	0.55±0.00	0.72±0.01	0.69±0.00
CG20%GG80%	0.55±0.00	0.73±0.01	0.69±0.00

3.3 Flow properties of the powders

The results of the flow parameters (flow rate, angle of repose, Carr's index and Hausner's ratio) are displayed in Table 3. It is known that the interactions existing within the particles in a bulk powder determine the key properties of the powder, especially its flow characteristics [46, 57]. The assessment using the Carr's index (CI) or the Hausner's ratio (HR) frequently offers a guide to the flowability and compressibility of a powder. They indicate the extent a powder could be consolidated [53, 54]. It has been documented that the CI < 10 % and HR of 1.00-1.11 depicts a powder with excellent flow. A CI of 11-15% and HR of 1.12-1.18 defines a powder retaining good flow properties. Further, values of CI of 16-20 % and HR of 1.19 -1.25 designates a powder showing fair flow characteristics. In conclusion, a value of CI >21% with HR > 1.26-1.34 points to a powder with poor flow properties.

In addition to Carr's index and Hausner's ratio, the angle of repose has equally been useful in the assessment of powder flowability as regards their interparticulate barriers to flow. It is a common observation extreme reduction of solid material

leads to irregularities in particle size and thereby increasing the value of its angle of repose. By the ordering of Carr, solid particles demonstrating an angle of repose of 25-30° are measured to have excellent flow property while those retaining values of 31-35° are seen to retain good flow characteristics. However, the ones with values of 36-40° are considered to display fair flow properties [53, 54, 58, 59]. It has been documented that the angle of repose above 40° for a powder indicates that it is very cohesive [60]. There is also a report indicating that the angle of repose less than or equal to 40° indicate a poorly flowing powder [61]. The general results of the flow rate, angle of repose, Carr's index and Hausner's ratio indicate that the cissus, acacia, tragacanth and guar gum powders and their derivative co-processed powders retain poor flow characteristics, an indication of high interparticle interaction depicted by the statistical variations in their respective bulk and tapped densities and low particle densities.

Table 3: Flow properties of powders

Polymers/ Co-processed polymers	Flow rate (g/s)	Angle of repose (deg.)	Carr's index (%)	Hausner's ratio
CG	2.78±0.33	24.52±3.31	15.08±1.37	1.18±0.01
AG	6.32±1.02	33.54±5.46	21.30±4.87	1.27±0.08
TG	5.65±2.02	28.72±6.28	19.04±4.58	1.24±0.07
GG	2.78±0.33	22.42±0.20	20.15±4.21	1.25±0.07
CG5%AG95%	4.10±0.68	15.87±1.66	21.39±1.22	1.27±0.02
CG10%AG90%	4.20±0.80	16.71±3.22	20.36±0.95	1.26±0.02
CG15%AG85%	3.83±0.18	14.29±2.81	21.61±1.07	1.28±0.02
CG20%AG80%	4.08±0.71	20.23±3.06	21.88±0.99	1.28±0.01
CG5%TG95%	4.31±0.59	24.52±1.64	19.72±0.28	1.25±0.00
CG10%TG90%	5.13±0.69	24.77±2.04	21.46±0.77	1.27±0.01
CG15%TG85%	4.61±0.38	23.69±1.85	19.59±1.36	1.24±0.02
CG20%TG80%	4.80±0.53	24.38±2.22	18.05±0.69	1.22±0.01
CG5%GG95%	4.42±0.47	19.33±2.01	21.25±0.16	1.28±0.02
CG10%GG90%	4.87±0.35	18.02±1.90	21.63±1.35	1.28±0.02
CG15GG85	5.47±1.01	17.72±0.53	24.54±1.21	1.33±0.02
CG20%GG80%	5.40±0.43	18.72±0.25	24.41±0.72	1.32±0.01

3.4 Moisture properties, pH and Viscosities

The results of the moisture studies, pH and viscosities of cissus, acacia, tragacanth, guar gum powders and their derivative co-processed powders are presented in Table 4.

3.4.1 Moisture content

There is considerable high moisture content within the starting polymeric powders and their derivative co-processed powders. This is indicative of their amorphous and hydrophilic polymeric nature, showing their ability to take up moisture easily and retaining the same. Hydrophilic polymers are known to retain the ability to absorb water comparable to hundreds of times their weight [62]. The results showed that the moisture contents of the original starting polymers were similar ($P>0.05$) but an increase in moisture contents were observed within the co-processed powders ($P<0.05$). All the co-processed powders containing cissus and

guar gums exhibited the highest moisture contents when compared to the starting materials and other co-processed powders ($P<0.05$).

3.4.2 Hydration capacity and swelling index

The results showed that the hydration capacity exhibited by the starting polymers ranks as $CG>TG>GG>AG$ ($P<0.05$). A low hydration capacity was recorded for the co-processed powders derived from CG and AG compared to all the starting polymers and their derivative co-processed powders even though hydration capacity was observed to increase as the proportion of CG increased ($P<0.05$). Very high values of hydration capacity were recorded for the co-processed powders developed from CG and TG, followed by those of CG and GG, then CG and AG. In each setting, hydration capacity increased commensurately with the increasing percentage of CG in the co-processed powders compared to the respective starting materials ($P<0.05$).

In considering the swelling index of the respective starting polymers and their respective derived co-processed powders, the lowest values of swelling index resulted from co-processing CG and AG, their values appearing much lower than their starting single materials ($P<0.05$). The co-processed powders derived from CG and TG exhibited the highest values of swelling index followed by those of CG and GG, with a corresponding boost in swelling index following increasing proportion of CG ($P<0.05$).

In terms of viscosity, enhanced viscosities were recorded with the co-processed powders derived with CG and TG as well as those containing CG and GG, with the latter ranking highest and those containing CG and AG ranking lowest ($P<0.05$).

The pH of the various co-processed powders varied with those of the respective starting materials ($P<0.05$), with those developed from CG and GG exhibiting high pH in the alkaline region.

The general results of high moisture content, hydration capacity and swelling index recorded with the various polymers employed as starting materials as well as their corresponding co-processed products are indications that the hydrophilic nature of the polymers used in the study are to a greater extent, amorphous. Stamm has recognized that the amorphous portion of cellulosic or polymeric substance is liable for their uptake of moisture and swelling [63]. The results presented above showed that the co-processing of CG with AG, TG or GG gave rise to products with new properties which could be useful in various aspect of formulation of pharmaceutical dosage forms ranging from solid, semi-solid or liquid dosage forms as binders, disintegrants or viscosity enhancers. The high hydration capacity recorded with the co-processed powders got with CG and TG or CG and GG are indications that the new powders will be useful in the formulation of drugs that are poorly hydrated or indiffusible, especially as disperse systems. The high values of swelling index recorded with the co-processed powders containing CG and TG or CG and GG exposed them as valuable materials for tablet disintegration as well as pharmaceutical suspension or use in low concentrations in dry syrups. The co-processed powders got from CG and AG at all ranges exhibited poor hydration capacities and swelling index. Their materials may be applied in the formulation of

dosage forms where diffusible drugs are involved or as tablet disintegrants, especially in immediate release conventional tablets.

4 CONCLUSION

The co-processing of CG with AG, TG or GG resulted in new co-processed hydrophilic polymers exhibiting improved hydration and swelling capabilities with viscosities that are advantageously essential in the adjuvants exploited as binders, disintegrants, emulsifiers and in the formulation of in-diffusible drugs, especially in the liquid disperse systems necessitating the uniform and stable dispersion of the API coupled with enhanced viscosities and pH stability.

Table 4: Moisture properties, pH and Viscosities

Polymers/Co-processed polymers	Moisture content (%)	Hydration capacity (%)	Swelling index (%)	pH	Viscosity (cP)
CG	18.70±0.12	834.79±3.44	493.61±2.25	6.17±0.49	19.50±1.5
AG	17.96±0.24	493.67±2.02	464.33±3.02	4.53±0.21	19.10±0.20
TG	18.23±0.29	527.67±2.51	422.33±3.01	5.57±0.32	22.67±0.48
GG	18.15±0.22	521.00±3.81	475.00±2.57	7.03±0.27	23.55±0.39
CG5%AG95%	16.75±0.26	106.79±2.60	143.38±2.50	5.53±0.05	14.50±1.50
CG10%AG90%	16.87±0.04	121.15±2.34	147.15±2.96	5.13±0.05	15.50±3.50
CG15%AG85%	20.73±3.56	156.34±3.87	184.98±3.72	5.27±0.06	18.50±3.61
CG20%AG80%	16.85±0.57	163.57±2.79	201.11±4.03	5.27±0.06	20.00±4.50
CG5%TG95%	20.55±0.05	880.28±3.96	607.14±4.71	4.90±0.10	19.50±1.50
CG10%TG90%	20.8±0.63	929.84±2.83	665.53±3.18	5.00±0.00	20.50±2.00
CG15%TG85%	17.88±1.34	960.72±2.42	675.00±4.00	4.97±0.06	23.50±0.50
CG20%TG80%	21.19±0.52	999.19±3.26	711.03±5.02	5.07±0.06	25.00±1.50
CG5%GG95%	21.43±0.41	552.59±4.34	377.78±4.33	9.23±0.05	31.67±1.50
CG10%GG90%	22.19±0.37	570.74±3.93	405.76±4.39	9.23±0.06	35.00±2.08
CG15GG85	21.36±0.47	579.74±4.54	440.12±2.68	9.30±0.00	39.50±1.53
CG20%GG80%	20.15±0.09	601.10±3.92	491.60±4.24	9.20±0.00	43.67±1.00

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