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Research Article

Evaluation of the Physicochemical and Micromeritic Properties of Exudate Gum of *Cussonia arborea* Stem Bark in Conventional Tablet Formulation

Samuel Lugrie Kipo, Noble Kuntworbe, Mariam El Boakye-Gyasi, Yaa Asantewaa Osei, Frederick William Akuffo Owusu, Raphael Johnson, Kwabena Ofori-Kwakye, and Marcel Tunkumgnen Bayor

Department of Pharmaceutics, Faculty of Pharmacy and Pharmaceutical Sciences, College of Health Sciences, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

Correspondence should be addressed to Samuel Lugrie Kipo; slkipo@yahoo.com

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Pharmaceutical excipients are classified based on the function(s) in the processing and/or finished product. However, functionality evaluations, procedures, and related acceptance criteria for excipients tend to depend on the dosage form, and assessment is usually done on a case-by-case basis. This means that any useful and reliable evaluation of the overall functionality-related properties is only possible within the context of the specific formulation method. This study evaluated the physicochemical, functional, and related properties of purified gum obtained from the stem bark of the *Cussonia arborea* tree. The purified gum was acidic (pH 5.32–5.50) with percentage (%) moisture content and insoluble matter of 13.33 ± 0.33 and 0.47 ± 0.01, respectively. Moreover, it was soluble in all the aqueous-based solvents but insoluble in all the organic solvents. The total ash of the gum was higher than that of international standard gum Arabic. Micromeritic properties indicated the need for a flow aid to improve flowability. Six formulated batches of tablets containing 0.5–5%w/w of gum, respectively, were generally soft with none passing the USP T_{80} standard of drug dissolution indicating poor tablet binding and drug-releasing properties. The disintegration action of CAPG was poor (only batches containing 0.5 and 1% CAPG passed) and was not comparable to that of the standard corn starch. The gum was therefore considered a poor disintegrant and binder in the formulation of conventional release tablets.

1. Introduction

The physical and chemical properties of natural gums are broad and unique. These properties are dictated by the major significant diversity of structural features derived from differences in monosaccharide constituents and linkage types, shapes of primary chain, charge, and water solubility [1, 2]. Gums are characterized by diverse physicochemical properties, and these are the basis for their wide application [3]. These diverse physicochemical properties warrant the standardization of gums as a pharmaceutical excipient, cosmetic excipient, and food additive where they have drawn significant favourable attention [4].

Physicochemical properties worth evaluating for a natural gum intended to be used as a pharmaceutical excipient in tablet dosage forms include organoleptic, water solubility, pH, moisture content/loss on drying, water sorption capacity/hygroscopicity, swelling capacity, hydration capacity, micromeritic parameters (bulk and consolidated densities, Hausner's ratio, compressibility index, and angle of repose), and ash values. Microbial quality and toxicity of the gum should also be studied and specified, respectively [5, 6].

Cussonia arborea Hochst. ex A. Rich with the common name "Octopus cabbage tree" because of the cabbage-like branches is a gum exudate tree of the kingdom—*Plantae*; phylum—*Tracheophyta*; class—*Magnoliopsida*; order—Apiales;

family—Araliaceae and of genus *Cussonia* of the *Cussonia arborea* species. It is widely distributed as an indigenous plant in tropical African countries. The local name of this plant depends on the people living there and sometimes how they see it in each season. In Ghana, it is called "saaborfere" (Twi) by Asantis, "gangulagu" (Dagbani) by Dagobas, and "samadoro" by Gonjas. In Nigeria, the Hausas call it "gwabsa hannium kutunuu" (leper's hand) or "takanar giiwaa" (elephant sugar cane), and Yorubas call it "ako-sigo," "bolokoloni" meaning "stump of an amputated limb" by the people of Manding-Bambara (Mali), and the same tribe in Burkina Faso calls it bolo-kununi meaning "cut hand." Different parts of the plant are harvested from the wild for local use, mainly as medicine. Its folkloric uses as medicine are very broad and seem to depend on the inhabitants of the area [7, 8]. Leaves and stem bark decoction of *Cussonia arborea* are used to treat several microbial infections, and research has revealed the presence of antimicrobial activity against *Staphylococcus aureus*, *E. coli*, *Enterococcus faecalis*, *Pseudomonas aeruginosa*, *Trichomonas vaginalis*, *Neisseria gonorrhoea,* and *A. flavus* [9, 10].

Cussonia arborea and other species of *Cussonia* have benefited from a lot of scientific research for medicinal purposes. However, to the best of our knowledge, there is no scientific research about the physicochemical and tablet formulation properties of the gum that oozes out freely when the tree is wounded. In this study, the physicochemical properties of this gum as an excipient for tablet formulation were evaluated, and the potential use of the gum in tablet formulations as a binder and a disintegrating agent was assessed.

2. Materials and Methods

2.1. Materials. A crude gum sample was collected from the incised trunks of the *Cussonia arborea* tree at Miaso Kwahu in the Eastern region of Ghana as previously reported [11]. Chemicals used included conc. sulfuric and hydrochloric acids (Philip Harris plc., Shenstone, England), sodium hydroxide pellets (VWR PROLABO BDH), acetone (Sigma-Aldrich Laborchemikalien GmbH, Germany), chloroform (Fisher Scientific, U.K.), potassium dihydrogen orthophosphate crystals (B.D.H. Laboratory Chemicals Division, Poole England), and all the required laboratory grade reagents obtained from the chemical stores of Departments of Pharmaceutics and Pharmaceutical Chemistry, KNUST, Kumasi. Lactose (Prolabo Leuven, Belgium) and corn starch (Alpha Chemicals, India) were gifts from Aspee Pharmaceuticals, Kumasi. The model drugs, paracetamol powder (Tianjin Bofa Pharmaceutical Co., Ltd., Tianjin, China), polyvinylpyrrolidone (PVP) (Fisher Scientific, U.K.), and magnesium stearate (Prolabo, Leuven, Belgium) were also gifts from Pokupharma industry, Kumasi.

2.2. Methods

2.2.1. Purification of Crude Gum. The purification of *Cussonia arborea* crude gum was undertaken as previously reported [11] and labelled as CAPG. The purification percentage yield was calculated as

$$\frac{\text{Weight of purified gum}}{\text{Weight of crude gum}} \times 100. \quad (1)$$

2.2.2. Phytochemical Screening of CAPG. The authenticity of CAPG as a gum was confirmed by the Ruthenium red test [12, 13].

The presence of carbohydrates was tested by Molisch's reagent and conc. H_2SO_4 [14], starch by iodine test [15], and reducing sugars by Benedict's test solution [16].

Secondary metabolites tested for were alkaloids with Dragendorff's reagent [17, 18], glycosides by bromine water test [19] and Keller-Kiliani test [20], tannins by lead acetate dilute solution test [21], and ferric chloride solution test [22]. The detection of saponins was by the froth test [23]; free amino acids by the ninhydrin test [12]; and protein, steroids, and flavonoids by procedures of Thakur et al. [24]. Other secondary metabolites that were tested for were terpenoids by Salkowski's test [20] and coumarins by the fluorescence test [25].

2.2.3. Physicochemical Properties of CAPG for Tablet Formulation

(1) Organoleptic characteristics of CAPG powder sieved through an aperture of 180 μm were evaluated for colour, shape, size, odour, and taste using the natural sensory organs of sight, touching with fingers, smell, and taste [26].

(2) Weight loss on drying (moisture content) and insoluble matter was determined in triplicate using the BP (2018) procedure for acacia gum.

(3) The solubility profile of powder was determined in distilled water, 0.1N HCl, phosphate buffers pH 6.8 and 7.4, chloroform, ethanol (96%), and acetone at room temperature (25°C). That of distilled water was repeated at 80°C. The solubility of CAPG in each solvent was expressed as stated in the BP 2018 [27].

Other physicochemical properties that were determined included pH of 1%w/v dispersion, water-absorptive profile (hydration, swelling, and water retention capacities), moisture sorption/desorption capacity of powder, total organic carbon in gum, and ash contents (total ash, water-insoluble ash, and acid-insoluble ash).

Triplicate determinations were carried out for each test, and the blank and mean were calculated.

2.2.4. Tablet Formulation Properties of CAPG

(1) Flow Parameters of CAPG Powder Were Characterized Using the Parameters Outlined below

(1) Bulk density, Hausner's ratio, and % compressibility index measurements were sequentially determined using a dried 100 ml of measuring cylinder and 30 g of CAPG powder.

The bulk density was determined using method 1 of the BP 2018. The powder was carefully transferred into the cylinder tilted at about 60°. The cylinder was straightened to cautiously level the powder without disturbing the packing of the entire powder, and the volume (unsettled apparent volume) in millilitres was recorded as V_o. The initial (fluff or poured) bulk density, D_o, was then determined as a ratio of the powder mass (m) to the unsettled apparent volume (V_o):

$$D_o = \frac{\text{m}}{V_o} = \frac{30\,\text{g}}{V_O}. \quad (2)$$

The cylinder and content were manually tapped by raising it through a distance of about 5 cm and allowing it to drop under its mass on a hard pad (200 times) until constant volume V_f (ml) was obtained.

The final (equilibrium/tapped/consolidated) density, D_f, was determined as $\text{m}/V_f = 30\,\text{g}/V_f$.

Hausner's ratio was evaluated as quotient of tapped density, D_f, and initial bulk density, D_o (D_f/D_o), or quotient of unsettled apparent volume (V_o), and final tapped volume (V_f).

The compressibility index was calculated as $\{(D_f - D_o)/D_f)\} \times 100$ or $(V_o - V_f)/V_o \times 100$.

(2) Angle of repose was evaluated by the fixed height cone method, which involves allowing the powder to free-flow through a clamped funnel fixed at a height (2 cm) to form a heap [27].

(2) Tablet Binding and Disintegrating Potential of CAPG

(1) Gum-drug (paracetamol) compatibility and stability testing was done using fresh and stored blends of paracetamol and CAPG powders. Samples of CAPG and paracetamol powders were individually scanned through a midwave number of 400–4000 cm^{-1} on Bruker IR-ATR (infrared-attenuated total reflectance) spectrophotometer (Model: Bruker Alpha Platinum ATR). This process was repeated for a sample of the mortar and pestle blend of paracetamol-CAPG powder in a ratio of 1 : 1. The blend was assayed for paracetamol using the BP (2018) procedure of assaying paracetamol tablets. The rest of the powder mixture was stored at 40 ± 2°C and 75% relative humidity in a stability chamber for 30 days [28, 29]. The determination of percent drug content was repeated, and the IR spectrum was generated again. Spectra were compared for any possible interaction(s) after mixing and/or storage.

(2) Tablet formulation using CAPG dispersions as a binder.

Six different batches of granules each containing the equivalent % concentration of CAPG powder labelled CA0.5–CA5.0 (Table 1) were prepared using the wet granulation method with 12/20 sieves.

Flow properties of all the batches of granules were determined by the procedure used in "Flow parameters of CAPG powder were characterized using the parameters outlined below." Granules of batch CA0.5 were powdery and showed passable flow behavior. Batches of granules CA1–CA5 were mixed with 0.35% w/w of magnesium stearate and manually compressed with Hanseaten E_1 (Wilhelm Fette) single punch tableting machine set within the compaction force of approximately 75–80 N (7.5–8.0 kgF).

The compressed tablets were subjected to various quality control tests and dissolution profiles under sink conditions using BP (2018) and USP 30-NF 25 (2007) apparatus II, the paddle method. The setup of the dissolution equipment and medium was as stated in the USP 30-NF 25 (2007). Aliquots of 10 ml of the dissolution medium and drug mixture were withdrawn and immediately filtered at 2.5, 5, 10, 15, 30, 45, and 60 min. Each volume that was withdrawn was replaced with a fresh dissolution medium at the same temperature (37 ± 0.5°C). Each filtrate was assayed for drug concentration using the USP 30-NF 25 (2007) procedure.

The USP 30-NF 25 (2007) tolerance of 80% of labelled paracetamol content to dissolve within 30 min [T_{80}(min)] and the model-independent parameter, and dissolution efficiency (DE) were estimated from the dissolution plots of the batches for effective comparison [27].

(3) Evaluation of tablet disintegrating ability of CAPG powder.

The dry gum powder was added to the other ingredients as a disintegrating agent for the formulation of 100 tablets, each containing 500 mg of paracetamol powder (Table 2). These were labelled as batches CA6, CA8, and CA10 (Cussonia arborea). The procedure was repeated for another set of batches containing reference maize starch as ST6, ST8, and ST10. The numbers 6, 8, and 10 attached to the tablet formulation batches represented the %w/w of disintegrant per tablet (paracetamol, lactose, and the disintegrant).

An appropriate volume of 20% w/v PVP solution was used as a binder solution to granulate each formulation such that the concentration of dry PVP powder was 2.5% w/w per tablet. Granules were assessed, lubricated with 0.35% w/w of magnesium stearate, and compressed into tablets as in "Tablet formulation using CAPG dispersions as a binder." The quality properties of these compressed tablets and dissolution parameters were determined in "Tablet formulation using CAPG dispersions as a binder."

3. Results and Discussion

3.1. Percentage Yield, Purity, and Authenticity of Extracted Gum. The percentage yield of CAPG was 69.32. This was a good yield. However, the pharmaceutical acceptability of

Table 1: Formula for 100 tablets of paracetamol (500 mg per batch).

Batch (100 tablets)	Powder ingredient (g)/batch				
	Paracetamol	Lactose	Starch	CAPG	*Mg. stearate
CA0.5	50.00	3.7	3.6	0.29	0.20
CA1.0	50.00	3.7	3.6	0.58	0.20
CA2.0	50.00	3.7	3.6	1.17	0.20
CA3.0	50.00	3.7	3.6	1.77	0.21
CA4.0	50.00	3.7	3.6	2.36	0.21
CA5.0	50.00	3.7	3.6	2.98	0.21

*Values were theoretical. CA—formulation batches containing the various concentrations (%) of CAPG as a binder.

Table 2: The formula for 100 tablets of paracetamol containing CAPG or corn starch powders as disintegrant.

Ingredient/g	Formulation batch (100 tablets)					
	CA (6)	CA (8)	CA (10)	ST (6)	ST (8)	ST (10)
Paracetamol	50.00	50.00	50.00	50.00	50.00	50.00
Lactose	3.70	3.70	3.70	3.70	3.70	3.70
CAPG	3.43	4.67	5.97	—	—	—
Corn starch	—	—	—	3.43	4.67	5.97
PVP (2.5% w/w)	1.46	1.50	1.53	1.46	1.50	1.53

CA/ST—formulation batches containing the attached numerical value as the concentration (%) of CAPG or ST (standard corn starch) as disintegrant.

this gum may not depend on only this yield but also the physicochemical, toxicological, and formulation properties. Furthermore, the cost-effectiveness of the use of this gum in pharmaceutics depends on its application. CAPG obtained by this purification procedure had been confirmed as nontoxic with acceptable microbiological quality and safe for use as a pharmaceutical excipient [11].

The confirmation of CAPG as plant gum and phytochemicals present or absent is presented in Table 3. Phytochemicals are compounds of primary and secondary metabolites of plants and, although gums are generally considered extracellular materials [1, 30, 31], crude gums sometimes (due to the method of collection or extraction) contain some of these compounds, which are usually removed completely or partially during purification. Depending on the method of purification and its efficiency, compounds that may be present in the crude gum may be removed either partially or completely [32]. From Table 3, the positive result (pink) of the Ruthenium red test confirmed CAPG as a plant gum [12, 14]. The positive result for Molisch's test indicated the presence of carbohydrates and reducing sugars (hydrolysed constituents). Gums are nonstarch complex polysaccharide polymers of monosaccharide units, hence the detection of reducing sugars and carbohydrates. The absence of the tested secondary metabolites may indicate an efficient purification procedure adopted and also confirms the fact that gums are not products of metabolism [15]. The absence of these secondary metabolites in the purified gum (CAPG) is very necessary for its use as a pharmaceutical excipient.

3.2. Physicochemical Properties of CAPG. All the organoleptic characteristics of CAPG may enhance its application as a pharmaceutical excipient, except the colour (Table 4). Using this gum as an excipient (in relatively higher concentrations) in colourless formulations may be difficult.

Considering the procedure of purification of CAPG, any volatile matter or essence (resins) and oils (fats) could have been removed completely. Therefore, the weight loss recorded for CAPG could not be due to any other substance than water as the gum sample was heated above water-vapour transition temperature and the gum was dried at 50°C after purification. The moisture content of CAPG was within the international specification range of 13–15% for gum Arabic [5]. CAPG may not be too difficult to store at fluctuating temperatures. Gums with high moisture content tend to depend so much on temperature control during storage, and at relatively high temperatures, any otherwise inactive enzyme present could be activated [33]. Furthermore, at high temperatures, high moisture content gums are prone to the proliferation of any latent microorganisms that may be present. Both processes may lead to spoilage of the gum.

Moisture content determination for potential pharmaceutical excipient(s) is a useful decisive formulation factor for the formulation, storage, and shelf life of pharmaceuticals, especially water-sensitive active pharmaceutical ingredients (APIs) [34, 35]. Considering the moisture content value of the gum (Table 4), it may be good for formulation with moisture-sensitive APIs. Also with knowledge of moisture content, the formulation scientist can calculate the exact dry weight of the substance(s) to be used.

3.3. Solubility of CAPG in Common Solvents/Solutions. The solubility profile of a potential excipient is very necessary as it suggests the type of dosage form appropriate for its use in a formulation. For gums, this knowledge can be applied to manipulate the solubility of APIs during formulation (improve the solubility of poorly soluble or retard

Table 3: Phytochemical screening of purified gums.

Chemical test	Observation	Inference
Ruthenium red	Pink colour	Plant gum/mucilage
Molisch's reagent	Purple colour at the interface	Carbohydrate present
Iodine 0.2N solution	No colour change	Starch absent
Lead acetate dilute solution	No visible precipitate	Tannins absent
Ferric chloride solution	Brown precipitate	Tannins absent
Benedict's solution	Brick red ppt	Reducing sugar present
Froth test	Froth was present and disappeared after the addition of two drops of olive oil	Saponins absent
Ninhydrin (0.2%w/v) solution	No visible colour change	Free amino acids absent
Biuret test	No visible colour change	Protein absent
Dragendorff reagent	No precipitate formed	Alkaloids absent
NaOH (10%w/v) solution	No visible colour change	Flavonoids absent
Ferric chloride (5%w/v) solution	No visible colour change	Flavonoids absent
Bromine water	No precipitate formed	Glycosides absent
Keller–Kiliani test	No clear layer and colour change	Cardiac glycosides absent
Salkowski's test	Colourless layer on top of black layer	Terpenoid absent
Ethanol and conc. H_2SO_4 test	Black solution	Steroids absent

Table 4: Organoleptic and some physicochemical properties of CAPG.

Parameter/critical quality attribute	Result
Organoleptic/sensory	
(i) Colour	Pinkish brown
(ii) Odour	Odourless
(iii) Taste	Bland/tasteless
(iv) Touch (powder #80)	Smooth and slippery
Mean weight loss on drying (LOD)	13.33 ± 0.33
Insoluble matter (%)	0.4712 ± 0.0143
pH (1% solution)	5.41 ± 0.09
Inorganic constituents (ash values)	
(i) Total ash	4.58 ± 0.04
(ii) Water-insoluble ash	1.07 ± 0.03
(iii) Acid-insoluble ash	2.02 ± 0.01
Organic carbon (%)	55.66 ± 0.37

The insoluble matter for CAPG was below the maximum official standard for acacia gum of 0.5% (BP 2018).

the solubility of freely soluble APIs) [4]. Generally, gums exert their optimum functionality when sufficiently dissolved or hydrated in water [36].

Solvents used for this evaluation were carefully selected to represent gum's solubility and temperature effect during drug formulation (distilled water at room temperatures 25°C and 80°C) and gum's solubility in the upper GIT: the stomach (0.1N HCl), small intestine (buffer solution pH 7.4), the colon (buffer solution pH 6.8) [37], and in organic solvents (ethanol 96%, acetone, and chloroform).

CAPG was generally soluble in all the aqueous-based solvents/solutions, and solubility was not significantly affected by temperature and pH (Table 5). CAPG was slightly more soluble in distilled water than the rest of the aqueous solutions. It was practically insoluble in acetone, chloroform, and ethanol (96%). These are organic solvents of which natural polysaccharide gums such as CAPG are insoluble [38].

3.4. Water Absorption Properties of CAPG. The aqueous absorptive properties of CAPG determined were hydration capacity (HC), swelling index (SI), and water retention capacity (WRC) (all in per cent) in distilled water (DW) (formulation medium), 0.1N HCl (stomach), and phosphate buffer solutions of pH 6.8 (rectum) and 7.4 (small intestine) (Table 6).

HC is the maximum quantity of total water gum material that can be absorbed and held under defined conditions [39]. It indicates the hydrophilic strength of the gum under formulation and administration conditions. The HC was low in all the solvents used. This suggests the dispersions of this gum will be less viscous and may likely be a highly branched gum [15]. For pharmaceutical excipient applications, CAPG may be a good tablet binder but a poor tablet disintegrant and suspending agent.

The swelling index (SI) (volume of gum increased) of CAPG demonstrated the increasing pattern in distilled water, phosphate buffer 6.8, 0.1N HCl, and phosphate buffer pH 7.4 (Table 6). This means medicines containing this gum will swell in the stomach and more so in the descending colon than in the rectum. Hence, the release of drugs from solid dosage forms containing this gum will be poorer in the stomach and small intestine than in any other parts of the GIT. This is an indication that CAPG can be manipulated in formulation to protect acid-sensitive drugs in the stomach and small intestine for it to be released in the colon. So, this gum may be a good excipient when colon-targeting preparation is required as the solid dosage form may swell and not easily release the API in the stomach and small intestine [15, 38]. CAPG will be a poor suspending agent, as well as its swelling in distilled water, which was just 1.1 times.

The water retention capacity (WRC) of the gum followed the same pattern as HC. This was expected as both give the water-holding ability of the gum. WRC of the gum was poor as it was not able to retain any significant quantity (not even half) of the added amount of solvent at any given pH. Combining the results of all the water-absorptive properties of CAPG, it could be said that it is not a viscous gum and, hence, will produce low-consistency suspension [38].

3.5. Moisture Sorption/Desorption Capacity of CAPG. The influence of extreme variation of moisture (storage condition) on solid-state stability of CAPG powder is demonstrated in Figure 1. During preformulation studies, this is necessary for recommending the appropriate packaging material for and storage conditions for the excipient and product(s) containing such excipient so that their stability will remain intact [40].

At high humidity [100% relative humidity (RH)] environment at room temperature (25°C), the gum steadily adsorbed (sorption) a significant quantity of moisture to reach its saturation point in 7 days. Even though sorption was rapid, gum took 7 days to reach hydration equilibrium. This conforms with the general observation that hydration equilibrium time increases with % RH [41]. When the receptacles containing this same moisture-saturated gum were transferred into the desiccator containing an activated silica gel (extremely low humidity) on the 8^{th} day, there was a drastic loss of moisture within the 1^{st} day (24 hr), and then, moisture loss became gradual and all its sorption moisture was lost by the 10^{th} day. The moisture that was lost after the 10^{th} day was part of the moisture content (desorption) of the gum. From Figure 1, moisture loss was more gradual from days 10 to 14 depicting a long hydrous equilibrium time indicating high water activity in the gum [42]. Since the interaction of pharmaceutical excipients with water can affect some of their physicochemical and mechanical properties, CAPG and solid products that contain it should not be exposed to extreme humidity fluctuation as loss or absorption of moisture may lead to excessive dryness or dampness that may affect their properties [43].

3.6. pH of 1% w/v Dispersion of CAPG. The pH of 1% w/v solution of CAPG was in the range of 5.321–5.505 (5.413 ± 0.092) (Table 4), indicating weak acidic behavior, a characteristic of exudate gums [44, 45].

Table 5: Solubility profile of CAPG (BP, 2018).

Solvent medium	Gram solvent/gram solute	Solubility consideration
Distilled water (25°C)	27.3379	Soluble
Hot distilled water (80°C)	27.2988	Soluble
0.1N HCl	29.8929	Soluble
Buffer pH 6.8	28.7880	Soluble
Buffer pH 7.4	29.9494	Soluble
Acetone	Infinity	Practically insoluble
Chloroform	Infinity	Practically insoluble
Ethanol (96%)	Infinity	Practically insoluble

Water absorption properties of CAPG.

Table 6: Water-absorptive parameters of CAPG.

Aqueous medium	Parameters		
	Hydration capacity (HC) (%)	Swelling index (SI) (%)	Water retention capacity (WRC) (%)
Distilled water	131.8 ± 0.19	110.9 ± 2.89	17.67 ± 1.45
0.1 N HCl sol	204.3 ± 9.78	156.4 ± 6.41	22.33 ± 1.45
PO_4 buffer pH 6.8	205.6 ± 11.39	149.1 ± 10.37	27.33 ± 1.33
PO_4 buffer pH 7.4	259.0 ± 9.17	213.2 ± 17.66	31.67 ± 2.19

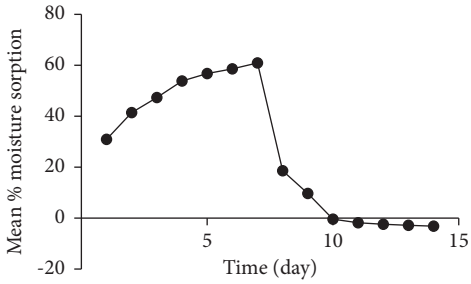


Figure 1: Moisture sorption capacity of CAPG powder.

The pH of a potential excipient such as gum is among the important formulation critical parameters that decide its suitability in pharmaceutical formulations since it directly affects stability, application, and physiological characteristics of preparations [35]. CAPG will be an ideal excipient for formulating acidic, neutral, and weak basic drugs, such as Paracetamol [46] (Maswadeh, 2017), Diclofenac [47, 48], Aspirin [49], Allopurinol [50], and Ibuprofen [51].

3.7. The Organic and Inorganic Composition of CAPG. The various definitions of plant gum as naturally occurring polysaccharides composed partly of carbon, hydrogen, oxygen, and sometimes nitrogen with a high organic carbon content [52] were also observed in CAPG (Table 4).

From the basic chemical composition of natural gums as indicated above, any ash that remains after complete combustion represents the inorganic portion of the gum and it is the total ash value. It is an applied parameter of quality and detection of the inorganic composition of natural gums [4]. Ash values determine levels of contamination of samples of natural origin and the quality of general handling processes to the level of use. With standardized natural materials having monographs, ash values are used to ascertain identity, authenticity, and purity so that adulterated and substituted natural products may be identified.

The total ash of CAPG (Table 4) is higher than that of the accepted international standard of 2–4% w/w for gum Arabic [5]. However, this value is lower than that of *Khaya senegalensis* gum of 5.25 ± 0.14% as determined by Ozoude et al. [53]. This high value of total ash for CAPG may be due to the entire handling processes involved and the geographical area where the crude gum was harvested.

Part of the total ash that could not dissolve when boiled in distilled water is the water-insoluble ash and measures the number of carbonates, silicates, and silica in the gum. The rest of the total ash that dissolved in the water (water-soluble ash) is partly the phosphates, alkaline, and other metals that oxidized to soluble oxides during the incineration [54]. The acid-insoluble ash constituted the residues left after the total ash was boiled in an HCl-water solution. Acid-insoluble ash of plant materials such as gum usually constitutes silica and silicates and suggests the presence of soil contaminants [4]. Acid-insoluble ash value, therefore, demonstrates the quality of the handling processes, especially during harvesting of the gum and geographical variations in the sourcing of the gum [55]. The acid-insoluble ash value of the gum was unexpectedly too high considering the water-insoluble ash value (Table 4). This may be attributable to the presence of high water-soluble phosphates, which did not dissolve in the acid or form a buffer solution with it, thereby reducing the solubility of some of the otherwise water-soluble components that dissolved when the total ash was boiled in water alone. Usually, the presence of high amounts of silica and/or silicates in the excipient of the tablet can cause abrasions on punches and dies during compression.

3.8. Micromeritic Properties of CAPG Powder. From the BP (2018) scale of flowability, all the flow properties of the powder were good (Table 7). This means that if CAPG powder is included in tablet formulation, the granules may require a glidant to obtain good flow during compression.

Table 7: Flow parameters of CAPG powder.

Parameter	Result	Scale of flowability*
Fluff bulk density (D_o) (g/ml)	0.664–0.670	Not applicable
Consolidated density (D_f) (g/ml)	0.824–0.830	Not applicable
Hausner's ratio	1.228–1.252	1.19–1.25 (Fair)
Compressibility index (CI) (%)	18.72–19.98	16–20 (Fair)
Angle of repose (°)	32.017–32.823	31–35 (good)

*BP (2018).

3.9. Tablet Formulation Properties of CAPG. In the performance evaluation of CAPG in the formulation of pharmaceutical tablets as binder and disintegrant, paracetamol (acetaminophen) was used as a sample drug. The compatibility and stability of their combination were studied using FTIR spectra of CAPG powder (Figure 2), paracetamol powder (Figure 3), and freshly blended (Figure 4) and stored blend (Figure 5) of these two ingredients.

3.10. Drug and CAPG Compatibility Studies. The spectrum of CAPG (Figure 2) had two principal absorption peaks and only two peaks as a fingerprint; an indication of the simple spectrum (less than five absorption bands, including absorptive peaks in the fingerprint region) and that of paracetamol (Figure 3) had four principal absorption peaks and a bunch of fingerprints [56–58].

The spectrum of the freshly blended paracetamol and CAPG (1 : 1) produced four PAPs (Figure 4 and Table 5) of which were numerically almost the same as that of pure paracetamol spectrum, indicating no change or generation of functional groups and, therefore, no chemical interaction after mixing [59]. Four PAPs were detected from a spectrum of part of the blend that was stored at 40 ± 2°C at 75% relative humidity for 30 days (Figure 5 and Table 8). These PAPs were as that for the freshly blended mixture, demonstrating no change or addition of functional groups, proof of the stability of this mixture. Furthermore, paracetamol assayed was quantitatively the same percentage (Table 9), confirming no loss of drug as a result of instability.

3.11. Use of CAPG as a Tablet Binder. The % fines in all batches of granules were high suggesting poor adhesive (tackiness) properties or low concentration of CAPG (Table 10). The pattern of the result of the % fines suggests more concentration dependency than adhesiveness. Using the scale of flowability of the BP (2018), Hausner's ratio (HR), compressibility index % (CI), and angle of repose of all batches of granules except CA0.5 demonstrated fair flow behavior. Granules of CA0.5 were passable for HR and CI% and powdery for the angle of repose. These results agreed well with the flow behavior of CAPG alone (Table 7) and, hence, the inclusion of magnesium stearate before the compression was necessary.

3.12. Quality Assessment of Paracetamol-CAPG Compressed Tablets. From the BP (2018) standards for uncoated compressed tablets, all batches passed the % content of the drug test but were generally soft and failed the friability test with disordered disintegration results (Table 11). This is an indication that even though CAPG was considered as soluble gum, it resisted water penetration and, therefore, may not be useful as a tablet binder as even the softest tablets failed to disintegrate within the permissible time and only tablets of batch CA2.0 containing 2% w/w of CAPG passed the weight uniformity test. This inconsistency in weight may partly be due to the generally poor flow properties of the granules.

3.13. Dissolution Profile of Compressed Paracetamol Tablets with CAPG as Binder. The drug release pattern of batches demonstrated clear dependency on CAPG concentration but not on the hardness of the tablets (Figure 6). Generally, drug (paracetamol) release from tablets was poor and decreased as "%" CAPG concentration increased. Apart from batch CA1, the other batches could not achieve 80% paracetamol release within the experimental time of 60 min of dissolution.

For meaningful and effective characterization of the dissolution profiles in Figure 6, the model-independent approach, the percent dissolution efficiency (DE%), and USP 30-NF 25 (2007) T_{80} (Table 12) were used to reduce the curves to numerical values [60, 61]. From DE% values, drug release was in the order of CA1.0 > CA4.0 > CA3.0 > CA2.0 > CA5.0. Tablets of all the batches failed the T_{80} standard, and none achieved 80% drug release within 60 min of dissolution time except for tablets of the CA1.0 batch.

3.14. Comparative Use of CAPG as Tablet Disintegrant. Using the BP (2018), the flow properties of all the batches were comparable and needed flow aid (Table 13).

Tablets of all batches of CAPG and ST6 tablets passed the BP (2013) uniformity of weight test, sufficiently hard, and all except CA8 failed the friability test. Tablets of all CAPG batches failed the BP (2018) disintegration test for uncoated tablets, and all batches of corn starch passed (Table 14). Comparing batches of the same composition, RC values for CA6 and ST6 were 51.20 and 67.81 N with their friability values of 1.30 and 1.36%, respectively, yet CA6 with a lower RC value failed the disintegration test, while the standard ST6 passed. Considering batches of 8% disintegrant composition, the RC of CA8 was 90.00 N with friability of 0.5% and RC of ST8 was 90.53 N and friability of 3.86 had a DT value of 3.78 min, while the DT of the former was 36.67 min. Critical examination of batches of the same composition, in terms of RC values, percentage disintegrant, and DT values, revealed that DT increased with increasing percentage of disintegrant for CAPG batches and vice versa for batches of corn starch suggesting a poor disintegrant effect of CAPG.

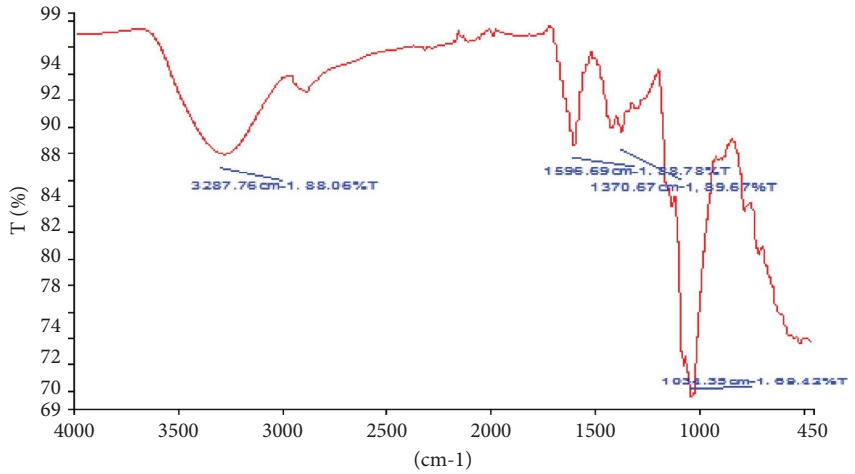


Figure 2: FTIR spectrum of CAPG powder.

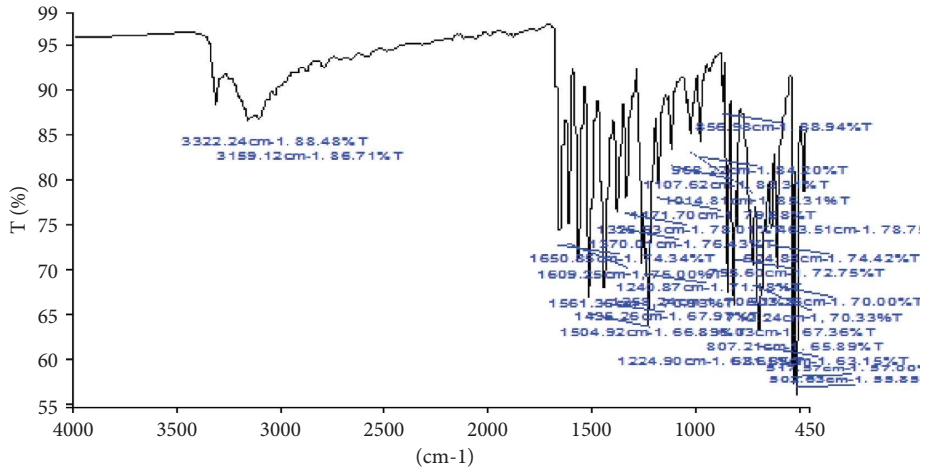


Figure 3: FTIR spectrum of paracetamol powder.

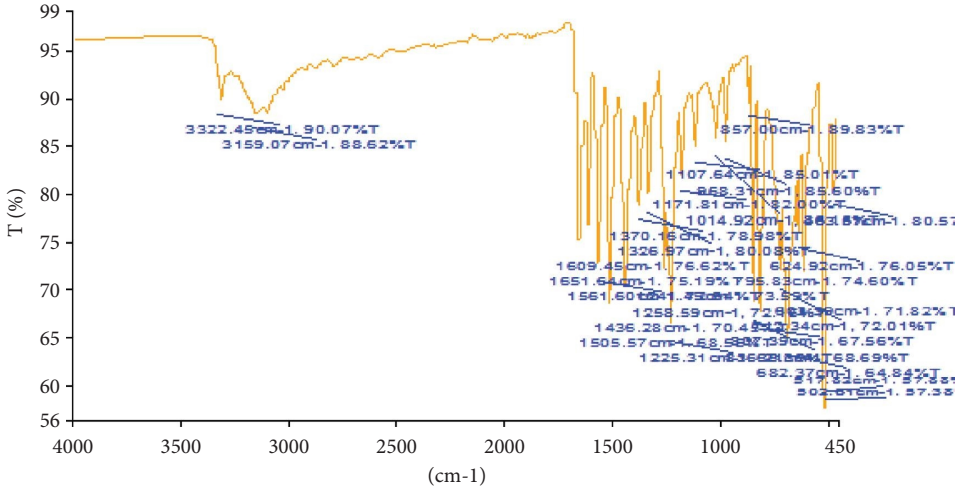


Figure 4: FTIR spectrum of CAPG-paracetamol freshly blend.

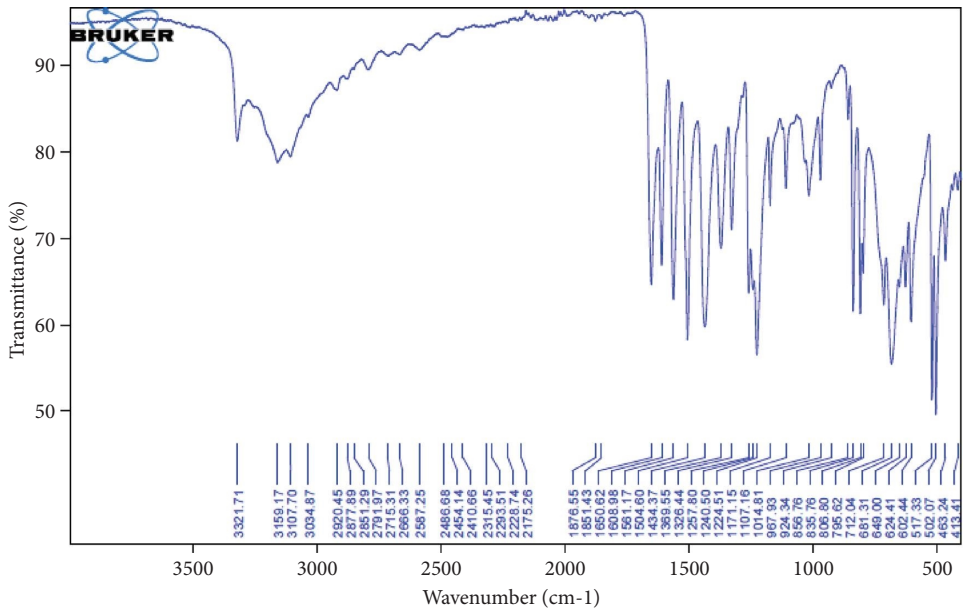


Figure 5: FTIR spectrum of CAPG-paracetamol stored blend.

Table 8: Data of FTIR spectroscopy of paracetamol, CAPG, and their blended mixture.

PAP of paracetamol	PAP of CAPG	SFG	Standard (cm^{-1})	PAP of I	PAP of II
3322.24	3287.76	Single bonds	3600–2700	3322.49	3321.71
3159.12		Aromatic C-H	3150–3070	3159.07	3159.17
1650.85		C=O	1655–1645	1651.64	1650.62
1609.25	1596.69	C=C	1610–1550	1609.49	1608.98

PAP, principal absorption peak; SFG, suspected functional group. I—paracetamol + CAPG fresh blend. II—paracetamol + CAPG mixture after 30 days of storage.

Table 9: % Content of paracetamol in CAPG-paracetamol blend.

Time (Day) of blend	Paracetamol content (%)
1 (fresh)	100.56
30	100.59

Table 10: Flow parameters of total granules of paracetamol and CAPG formulations.

Formulation	% fines	Hausner's ratio (HR)	CI %	Angle of repose (°)
CA0.5	32.87	1.28	21.74	38.99 ± 0.06
CA1.0	31.34	1.24	19.40	40.07 ± 0.05
CA2.0	30.37	1.25	19.99	35.95 ± 0.13
CA3.0	28.64	1.24	19.36	39.20 ± 0.33
CA4.0	28.27	1.23	18.47	37.44 ± 0.22
CA5.0	23.93	1.24	19.35	37.02 ± 0.57

(°)—degrees. CI %—compressibility index %.

3.15. Dissolution Profile of Compressed Tablets with CAPG and Corn Starch as Disintegrants. The disintegration of a solid dosage form such as a tablet may proceed to granules before deaggregating to primary drug particles depending on the ingredients. The process of tablet dissolution can occur from any or all of these at different rates. Depending on the efficiency of a disintegrating agent, dissolution may occur at a slow rate from intact tablets, at a moderate rate from granules, and/or at a relatively rapid rate from primary drug particles [62]. Therefore, tablets with effective disintegrants will have a faster rate of drug dissolution than tablets containing the same drug but with poor disintegrant. Corn starch as a standard tablet disintegrating agent demonstrated better drug release in increasing order of its concentration, while tablets of CAPG batches showed the opposite at the end of the 60 min of dissolution (Figure 7).

The DE % and T_{80} values revealed the effect of the hardness of CA8 and ST8 on the dissolution of the tablet. None of the CAPG batches of tablets released 80% of drug within the 30 min of dissolution (Table 15).

Matching the DE% values of batches, it was suggested that the disintegration action and drug release profile of CAPG and corn starch were not comparable, and as the mean minimum of 85% drug dissolution of CAPG batches could not be estimated on the dissolution plots, the model-independent approach using a mathematical method to evaluate the extent of similarity or difference was not necessary [63].

Table 11: Quality of the compressed tablets containing varying quantities of CAPG in solution.

Batch	Mean tablet weight (g)	Weight deviation Tablet(s) deviated >5%	>10%	RC (N)	Friability (%)	DT (Min.)*	Content (%) of drug
CA0.5	0.5487	5	3	20.15 ± 7.84	12.60	3.25	101.54
CA1.0	0.5763	4	1	25.89 ± 6.70	10.27	9.75	101.12
CA2.0	0.5882	2	0	24.18 ± 2.91	4.67	27.48	101.09
CA3.0	0.5844	4	2	44.03 ± 10.83	7.89	36.70	100.32
CA4.0	0.5915	3	1	31.24 ± 10.42	3.18	20.63	102.00
CA5.0	0.5840	3	0	29.00 ± 9.72	5.53	32.67	102.01

*$N = 6$. RC = resistance to crushing. DT = disintegration time.

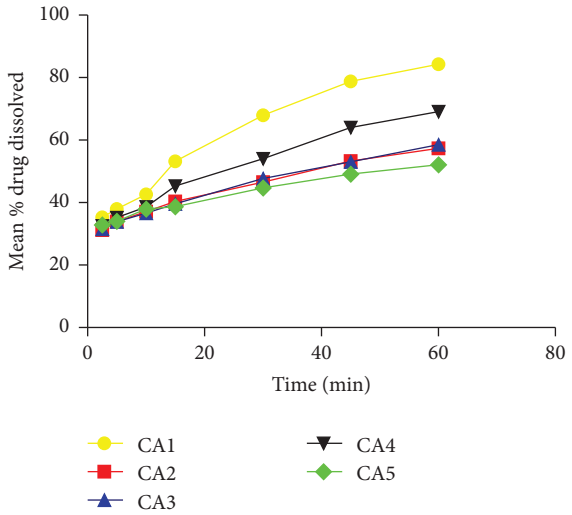


Figure 6: Mean cumulative % drug dissolved against time (min).

Table 12: Mean dissolution parameters of compressed tablets.

Formulation batch	Parameter Mean $T_{(80)}$ (min)	Mean DE (%)
CA1.0	47.47 ± 0.23	65.47 ± 0.12
CA2.0	—	46.67 ± 0.15
CA3.0	—	46.87 ± 0.13
CA4.0	—	54.05 ± 0.12
CA5.0	—	44.26 ± 0.11

Considering DT, DE%, and T_{80} values is sufficient to suggest that CAPG will not be a good tablet binder.

Table 13: Flow parameters of total granules of CAPG and starch as disintegrants.

Batch (%)	% Fines	HR	CI%	Angle of repose (°)
CA5	24.16	1.22	17.90	38.51 ± 0.46
CA8	21.58	1.21	17.18	34.29 ± 0.13
CA10	25.38	1.21	17.46	33.92 ± 0.52
ST5	21.32	1.21	17.14	37.47 ± 0.19
ST8	21.38	1.23	18.58	33.06 ± 0.12
ST10	24.40	1.23	18.57	35.48 ± 0.50

CA/ST—Formulation batches containing the attached numerical values as the concentration (%) of CAPG or ST (standard corn starch) as disintegrant.

Table 14: Quality of the compressed tablets containing CAPG and corn starch.

Batch	Mean tablet weight (g)	Weight deviation Tablet(s) deviated		RC (newton) ±SD*	Friability (%)	DT (min)
		>5%	>10%			
CA6	0.5810	2	0	51.20 ± 11.25	1.30	15.67
CA8	0.5977	1	0	90.00 ± 15.78	0.53	36.37
CA10	0.6430	2	0	68.98 ± 12.51	1.13	36.18
ST6	0.6122	2	0	67.81 ± 17.02	1.36	4.95
ST8	0.6609	4	0	90.53 ± 10.58	3.86	3.78
ST10	0.6567	4	0	67.37 ± 14.66	1.10	5.40

*$N = 6$.

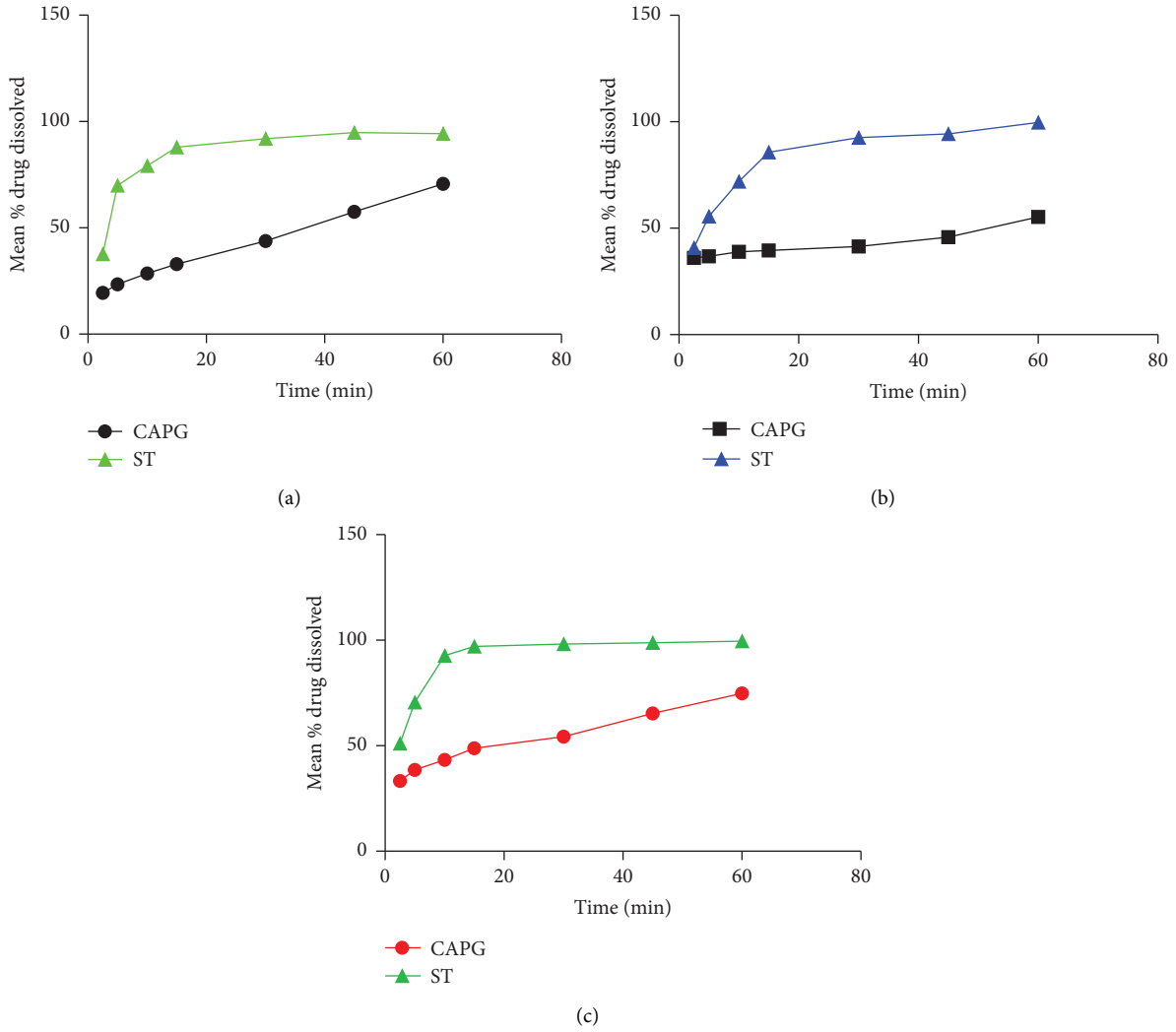


Figure 7: (a) Mean cumulative % drug dissolved to time (min) for tablets containing 6% w/w disintegrating agent. (b) Mean cumulative % drug dissolved to time (min) for tablets containing 8% w/w disintegrating agent. (c) Mean cumulative % drug dissolved to time (min) for tablets containing 10% w/w disintegrating agent.

Table 15: Mean dissolution parameters of tablets containing CAPG and corn starch as disintegrants.

Formulation batch	Parameter	
	Mean $T_{(80)}$ (min)	Mean DE (%)
CA6	—	45.83 ± 0.64
ST6	14.94 ± 0.23	88.56 ± 0.45
CA8	—	43.41 ± 0.04
ST8	17.41 ± 0.07	87.42 ± 0.04
CA10	—	56.48 ± 0.53
ST10	9.9 ± 0.0	95.05 ± 0.06

4. Conclusion

The purified *Cussonia arborea* stem exudate was confirmed as gum (CAPG) and was free from all phytochemicals evaluated. Micromeritic properties of the gum powder were generally fair, and these had an impact on the granules requiring an antiadhesive agent. The gum was compatible with the sample drug but demonstrated poor tablet binding and disintegrant properties at the concentrations used (0.5–5% w/w) and is not comparable to the standard disintegrant used (starch). Furthermore, GS-MS studies are recommended to be done in other studies of *Cussonia arborea* gum to ascertain the chemical composition/structures present in the gum.

Data Availability

The data used to support the findings of this study are included in the article and can be made available upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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