ORIGINAL ARTICLE

Development and Evaluation of Isolated *Garcinia xanthochymus* Mucilage as a Pharmaceutical Binder for Solid Oral Dosage Forms

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Abstract

Background: In the pharmaceutical industry, natural excipients are being increasingly considered as substitutes for synthetic binders due to their safety, sustainability, and cost-effectiveness. Plant-derived mucilages have shown promise as binding agents. This study focused on isolating and characterizing mucilage from Tamala fruits (*Garcinia xanthochymus*) and assessing its binding efficiency in paracetamol (PCM) tablet formulations compared to gum acacia. **Materials and Methods:** Mucilage was extracted using the hot maceration technique and underwent physicochemical characterization. Its morphology was examined through scanning electron microscopy (SEM), its crystalline or amorphous nature was determined by powder X-ray diffraction (PXRD) and differential scanning calorimetry (DSC), and its structure was confirmed by Fourier transform-infrared spectroscopy (FTIR). PCM tablets were produced through wet granulation with varying mucilage concentrations (3%, 5%, 10%, and 15% w/v), labelled as GF1–GF4. Control tablets were made with gum acacia at the same concentrations. Standard evaluation parameters for uncoated tablets were conducted, followed by *in vitro* dissolution tests. **Results:** SEM showed the mucilage had irregular particle shapes and sizes, PXRD and DSC suggested an amorphous nature, and FTIR confirmed the presence of polysaccharides. Among the formulations, GF1 (3%) and GF2 (5%) exhibited optimal binding efficiency, releasing 98–99% of the drug within 25–30 min. These results were superior to those of tablets made with gum acacia at the same concentrations. **Conclusion:** Mucilage from *G. xanthochymus* demonstrated excellent binding efficiency and favorable physicochemical properties, indicating its potential as a promising natural excipient in conventional uncoated tablet dosage forms.

Key words: Garcinia Xanthochymous, mucilage, natural binder, tablet formulation, paracetamol, excipient

INTRODUCTION

In the realm of pharmaceutical drug development, excipients, which are inactive ingredients, hold a significance equal to that of active drug components. These excipients enhance stability, ease of administration, and mask unpleasant tastes or odors, thereby improving patient adherence. They also regulate drug release, boost absorption, and maintain product quality. Although both synthetic and natural excipients are utilized, natural ones have garnered attention for their biodegradability, safety, and cost-effectiveness. Natural polymers, such as gums and mucilages, are particularly valuable due to their abundance and versatility. They function as thickeners, suspending agents, and emulsifiers in liquid formulations, as well as bases in semisolid preparations, and serve as binders, diluents, or agents that modify release in solid dosage forms.[1,2]

Mucilages, which are plant-based polysaccharides with hydrophilic properties, are utilized in cosmetics, packaging, and edible films due to their ability to swell and form gels. Their biodegradable and non-toxic nature makes them

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promising candidates for both traditional and innovative drug delivery systems. *Garcinia xanthochymus* known as Tamala fruits, belongs to the Fabaceae family and is widely distributed. It has been traditionally used for its antibacterial, antifungal, anti-inflammatory, antioxidant, and wound-healing benefits. This research involved isolating mucilage from *G. xanthochymus* and characterizing it through scanning electron microscopy (SEM), powder X-ray diffraction (PXRD), differential scanning calorimetry (DSC), Fourier transform-infrared spectroscopy (FTIR), swelling index, and phytochemical analysis. Its binding capabilities were assessed by formulating paracetamol (PCM) tablets and comparing them with those made using gum acacia. The study investigates the potential of *G. xanthochymus* mucilage as a natural excipient in solid oral dosage forms.[3,4]

Isolation of mucilage

Fresh *G. xanthochymus* fruits were gathered, thoroughly rinsed with water to remove any dust and debris, and left to dry in the shade. Once dried, they were ground into a fine powder using a grinder. This powdered substance was then soaked in water, using a ratio of 4 times the powder's volume, for 2–3 h to ensure proper mixing. The mixture was subsequently heated to 70°C for about 20–25 min to aid in the release of mucilage into the water.[5,6]

After boiling, the mixture was allowed to cool and sit for 1 h to ensure complete extraction. The mass was then filtered through an eight-layer muslin cloth to remove the solid residue, and the liquid was collected. Acetone was added to the liquid in a 1:3 ratio (liquid: Acetone) to precipitate the mucilage. The precipitated mucilage was separated and dried in an oven at a controlled temperature not exceeding 50°C. The dried material was then ground, passed through mesh #80 to achieve a fine powder, and stored in a desiccator for future use. The percentage yield of mucilage extracted from *G. xanthochymus* was 11.3%.[7,8]

SEM

SEM was used to examine the surface morphology of mucilage powder from *G. xanthochymus*. The dried sample was gold-coated for conductivity, adhered to an aluminium stub with adhesive tape, and examined under a JEOL JSM-6100 microscope to see surface characteristics and particle shape.[9,10]

PXRD

An X-ray diffractometer was used to determine whether the isolated *G. xanthochymus* mucilage was crystalline. Under operating conditions of 45 kV voltage and 40 mA current, the sample was tested at 25°C. Using a scan length of 50° and a step scan time of 50.16 s, the diffraction pattern was captured by scanning in the range of $2\theta = 10°$.[11,12]

DSC

A DSC 60 was used to examine the thermal behavior of the isolated *G. xanthochymus* mucilage. An aluminium pan with a pinhole cover was used to precisely weigh and seal a 6.1 mg sample. The analysis was conducted in a nitrogen atmosphere at a flow rate of 40 mL/min over a temperature range of 10–300°C, with a heating rate of 10°C/min.[13,14]

FTIR

A Shimadzu infrared affinity spectrometer was used to get the FTIR spectra of *G. xanthochymus* mucilage. To identify functional groups, the sample was combined with KBr, crushed into a pellet, and scanned across 4000–400 cm^{-1}.[15]

Phytochemical examination of mucilage

Initial phytochemical screening was performed on the isolated mucilage from *G. xanthochymus* to detect the presence of various classes of compounds. Carbs, mucilage, proteins, flavonoids, alkaloids, glycosides, resins, saponins, steroids, and tannins were all tested.[16,17]

Microbiological properties

By measuring bacterial and fungal growth, the separated mucilage's microbiological quality was evaluated. Fungal growth was facilitated by Sabouraud's dextrose agar medium, whereas bacterial growth was facilitated by nutrient agar media. After autoclaving both media for 15 min at 121°C to sterilise them, they were transferred into Petri dishes under aseptic conditions. The streak method was used to inoculate pre-incubated samples of the isolated mucilage onto the media plates. After that, the plates were incubated for 72 h at 27°C to track fungal growth and 37°C to track bacterial growth.[18]

Physicochemical characterization of crude mucilage

The crude mucilage's physicochemical characteristics, such as pH, solubility, total Ash value, water-soluble ash, acid-insoluble ash, viscosity, and drying loss, were assessed. These characteristics shed light on mucilage's appropriateness, quality, and purity as a medicinal excipient.[19]

Drug-excipient compatibilitystudy

To guarantee the safety and stability of the isolated *G. xanthochymus* mucilage as a binder, its compatibility with the model medication was evaluated. FTIR spectroscopy was used to conduct interaction experiments. To achieve this, a 1:1 physical mixture of pure drug and mucilage was

made and kept in a desiccator for 3 months before analysis. These investigations assisted in assessing any potential physicochemical interactions between the mucilage and the medication.[20]

Preparation of tablets

PCM tablets were developed through the wet granulation method, utilizing *G. xanthochymus* mucilage as a natural binding agent. PCM served as the model drug, with corn starch acting as the disintegrant, lactose as the filler, magnesium stearate as the lubricant, and talc as the glidant. Four different batches were created, each with varying concentrations of *G. xanthochymus* mucilage: 3%, 5%, 10%, and 15% (w/w). The active pharmaceutical ingredient (API) and excipients were measured, as shown in Table 1, mixed thoroughly, granulated with a binder solution, dried, and sieved.

The granules were then lubricated with magnesium stearate and talc before being compressed into tablets. The necessary amounts of PCM and lactose were combined in a mortar, and the mucilage solution was added gradually to form a wet mass.[21,22] Half of the corn starch was added, and the mixture was passed through a #22 mesh to form granules. These granules were dried at 60°C until they reached a constant weight and then rescreened through a #44 mesh. The remaining corn starch, talc, and magnesium stearate were mixed with the dried granules before being compressed into 650 mg tablets using a 12 mm concave round die. For comparison, four batches of PCM tablets were also prepared using acacia gum as the standard binder at concentrations of 3%, 5%, 10%, and 15%, following the same procedures and proportions of excipients. The formulations with *G. xanthochymus* mucilage were labelled GF1–GF4, while those with acacia gum were designated GA1–GA4, allowing for the evaluation of binding efficiency under consistent conditions, as detailed in Table 1.[23,24]

Micromeritics studies of prepared dried granules

Micromeritics investigations were carried out on dried granules made with acacia gum and mucilage from *G. xanthochymus* (Tamala fruits) as binders. The purpose of these investigations was to assess and contrast the granules' micromeritic characteristics, which have a direct impact on their compressibility, flow behavior, and general suitability for tablet formulation.[25]

Particle size distribution (PSD)

The mechanical sieving method was used to determine the dried granules' PSD. 35 g of granules from each batch were carefully placed on the top sieve of a stack of sieves (#60, #80, and #100) that were set up on a motorized shaker. The granules that remained on each sieve were gathered and weighed after the shaker was run for 10 min. The granules' PSD was examined based on the weight distribution across the various sieve diameters.[26]

Flow properties of granules

For tablet compatibility, the flow behavior of dried granules was assessed. A ROLEX device was used to measure the bulk density (BD) and tapped density (TD) of 10 g granules in a 50 mL cylinder. The flowability and compressibility were then evaluated using Hausner's ratio and Carr's index.[27]

$$\text{Hausner's ratio} = TD/BD$$

$$\text{Carr's compressibility index} = (TD–BD/TD) \times 100$$

BD = Mass of granules taken/bulk volume
TD = Mass of granules taken/tapped volume

The funnel method was used to measure the angle of repose of granules from each batch that were made using both acacia gum and *G. xanthochymus* mucilage. This method created a

Table 1: Composition table of prepared uncoated conventional tablet (All values in %, total weight of each tablet 650 mg)

Ingredients	Application in formulation	3% GF1	5% GF2	10% GF3	15% GF4	3% GA1	5% GA2	10% GA3	15% GA4
Paracetamol	Active pharmaceutical ingredient	76.9	76.9	76.9	76.9	76.9	76.9	76.9	76.9
Lactose	Diluents	13.1	11.1	6.1	1.1	13.1	11.1	6.1	1.1
Garcinia xanthochymus	Binder	3.0	5.0	10.0	15.0	-	-	-	-
Acacia gum	Binder	-	-	-	-	3.0	5.0	10.0	15.0
Corn starch	Disintegrants	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Talc	Glidant	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Magnesium stearate	Lubricant	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

heap by letting grains fall freely through a fixed funnel. After measuring the heap's height and radius, the angle of repose (θ) was computed using the following formula:

Angle of repose = Tan (Height of pile/Radius of pile)

Evaluation of prepared tablets

The quality of the produced pills was assessed using both standard and extra tests. The Indian Pharmacopoeia (IP) norms were followed when conducting the standard tests. These included measuring the tablets' width and thickness, verifying that their weight was consistent, evaluating the hardness of the tablets, conducting friability tests, calculating the disintegration time (DT), and verifying that the medication content was consistent.[28,29]

In vitro release study

The medication release profile was examined by testing tablets from each batch that were made with both binders (isolated mucilage and acacia). To find out how the medication is released from the tablets over time, this was done *in vitro* using a USP Type II (paddle) dissolution device.[30,31]

MATERIALS AND METHODS

Garcinia Xanthochymus (Family: Clusiaceae) fruits used in the present study were authenticated by Prof. Nawal Kishore Dubey, Centre of Advanced Study in Botany, Banaras Hindu University (BHU), Varanasi, India, using standard taxonomic methods. A voucher specimen (Asteraceae: 2024/01) was deposited in the BHU Herbarium. Lactose, starch, magnesium stearate, and talc were used as excipients. All chemicals and reagents were of analytical grade and obtained from GLA University, Mathura. Fresh fruits were cleaned, air-dried, and powdered using a mechanical grinder. The powder was soaked in deionized water (1:4 w/v) for 2–3 h with continuous stirring to form a slurry. The slurry was heated at 70 °C for 15–20 min and allowed to stand. The mixture was filtered through muslin cloth to remove residue. Acetone (1:3) was added to the filtrate to precipitate the mucilage. The precipitate was filtered and dried below 50 °C in a hot air oven. The dried mucilage was powdered, sieved (#80), and stored in a desiccator for further use.

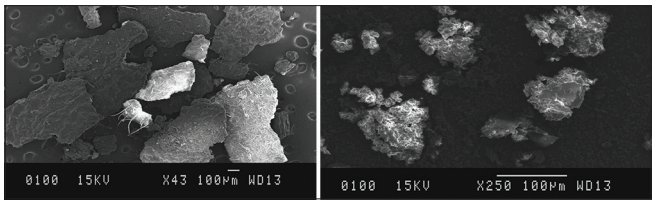

Figure 1: Scanning electron microscopy images of *Garcinia xanthochymus* mucilage

RESULTS

SEM

SEM was used to analyze the surface morphology of the mucilage that was separated from *G. xanthochymus* [Figure 1]. Suggests that the micrographs demonstrate that mucilage is amorphous in form, with aggregated and asymmetrical particles. It is crucial to comprehend surface morphology since it directly affects the mucilage's ability to retain water.[32]

PXRD

The amorphous nature of the mucilage of *G. xanthochymus* (Tamala fruits) was confirmed by the PXRD pattern, which showed a broad halo with maximum intensity at 2θ = 21.4°. The mucilage's amorphous nature is further supported by the lack of strong crystalline reflections, although a few faint peaks were found in the 30–40° range [Figure 2].[33]

DSC

The loss of bound water and thermal softening of the polymer matrix were indicated by a strong endothermic peak in the DSC thermogram of the mucilage of *G. xanthochymus* (Tamala fruits) at 125.6°C, with a beginning at 113.4°C and an end set at 150.0°C. The observed enthalpy change was −450.40 mJ, or −74.88 J/g. The amorphous character of the mucilage was confirmed by the lack of any distinct melting transition [Figure 3].[34]

FTIR

The extracted *G. xanthochymus* (Tamala fruits) mucilage was subjected to FTIR analysis; the spectra are displayed in Figure 4. The mucilage sample's FTIR spectra showed a wide O–H stretching band at about 3275 cm^{-1}, indicating a high concentration of hydroxyl groups typical of polysaccharide

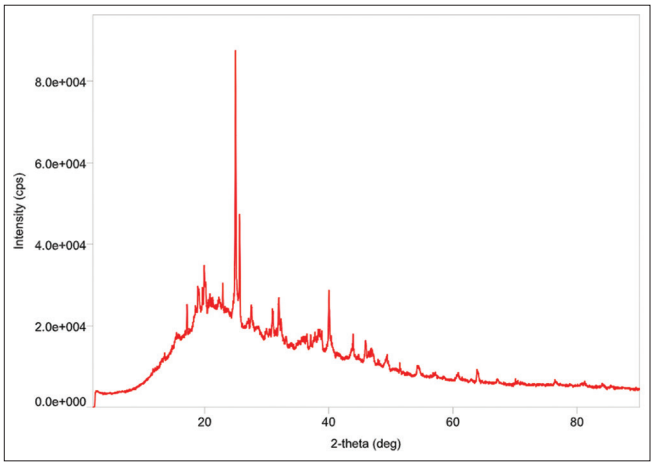

Figure 2: Powder X-ray diffraction image of *Garcinia xanthochymus* mucilage

Table 2: Phytochemical properties of *Garcinia xanthochymus* isolated mucilage

Active constituents	Test	Statement	Results
Carbohydrate	Molisch's test, Iodine test	Rusty-brown shade	Positive
Proteins	Biuret test	It was a dark purple color	Positive
Resin	Resin test	No pink color developed when using HCl. FeCl3 did not produce any greenish-blue tint	Negative
Tannins	Ferric chloride test	A bright yellow tint remained the same deep purple color for the+ve outcome.	Negative
Mucilage	Ruthenium red test	The color pink emerged.	Positive
Glycosides	Baljet's test	A yellow to orange tone was visible.	Positive
Saponin	Fourth formation test	There was no foam present.	Negative
Alkaloids	Mayer's reagent test	There was no evidence of cream precipitate.	Negative
Flavonoid	Shinoda test	Red to pink tone	Positive

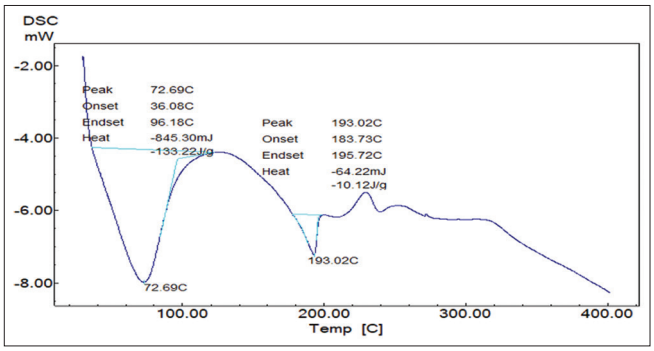

Figure 3: Differential scanning calorimetry thermogram of isolated *Garcinia xanthochymus* mucilage

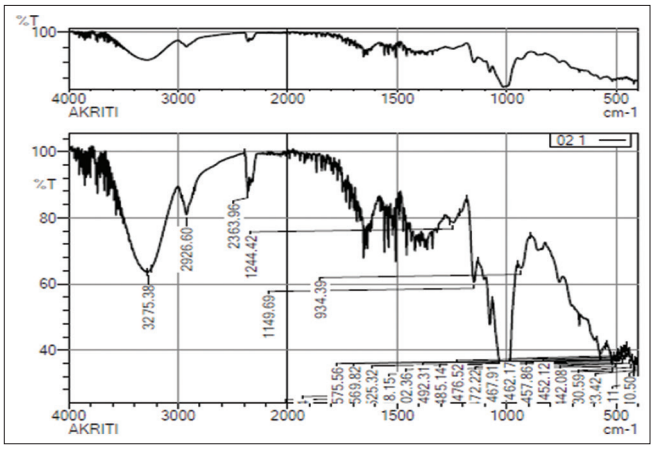

Figure 4: Fourier transform-infrared spectroscopy spectra of mucilage isolated from *Garcinia xanthochymus* mucilage

structures. Strong absorptions in the 1242–932 cm^{-1} range were indicative of C–O and C–C stretching vibrations from the mucilage polymer backbone, while peaks near 2926 cm^{-1} showed aliphatic C–H stretching. In line with natural plant mucilage, the evidence confirms the presence of complex polysaccharides with a high degree of hydrogen bonding. Overall, the FTIR analysis verifies that polysaccharides make up most of the isolated mucilage from *Helianthus annuus*.[35]

Phytochemical examination of mucilage

Polysaccharide-rich hydrocolloids generated from plants that influence medication release are called mucilages. *G. xanthochymus* powder's hydrocolloid nature was validated by phytochemical screening, which revealed the presence of mucilage and polysaccharides [Table 2].[36]

Microbiological properties

Microbiological contamination of the isolated *G. xanthochymus* mucilage was examined. Its microbiological safety and stability for pharmaceutical application are confirmed by Table 3, which shows that no bacterial or fungal growth was found after 72 h.[37]

Physicochemical characterization of mucilage

The physicochemical characteristics of *G. xanthochymus* mucilage were assessed in accordance with pharmacopoeial standards [Table 4]. It exhibited hydrocolloid behavior in cold water and was freely soluble in hot water, but it was insoluble in organic solvents such as acetone, ethanol, and chloroform. Good thickening capacity was indicated by the mucilage's measured viscosity of 1145 cP for a 3% w/v solution and 1368 cP for a 5% w/v solution. A 1% w/v solution's pH of 6.8 was found to be within the permissible range for uncoated traditional tablets, making it appropriate for use in pharmaceutical applications.[38]

Drug excipient compatibility study

Because natural polymers may interact with APIs to impact formulation stability and efficacy, compatibility studies are crucial. To guarantee its safe use in tablets, the drug-excipient compatibility of the isolated *G. xanthochymus* mucilage was assessed. No incompatibility observed.[39]

Table 3: Microbial examination of the mucilage of *Garcinia xanthochymus*

Parameters	Fungal	Bacterial
Growth media	Sabouroud's dextrose agar media	Nutrient agar media
Temperature during incubation	27°C	37°C
Observed after 24 h	No growth	No growth
Observed after 72 h	No growth	No growth

Table 4: Physicochemical characterization of isolated mucilage from *Garcinia xanthochymus* (The values are mean±S.D. for *n*=3)

Parameters (Tamala fruits)	Observation
Solubility in water	Freely soluble in hot water, a colloidal solution is formed in cold water. Insoluble in acetone, ethanol, and chloroform
pH (1% w/v solution)	6.8
Total Ash value (%)±S.D.	7.5±0.30
Acid insoluble ash (%)±S.D.	1.25±0.20
Water soluble ash (%)±S.D.	7.36±0.26
Viscosity (3% and 5% w/v solution)	1145 cP and 1368 cP respectively
Loss on drying (%)	2.85
Swelling index	7

SD: Standard deviation

These conclusions were further corroborated by DSC analysis, which showed no significant differences between the thermogram of the 1:1 combination and pure PCM. All these findings demonstrated that the isolated mucilage of *G. xanthochymus* is a good excipient for tablet formulations since it is chemically and physically compatible with PCM.[40]

Micromeritics studies of prepared dried granules

The PSD and flow characteristics of dried granules made with *G. xanthochymus* mucilage, important variables affecting tablet compression, hardness, and drug release, were assessed. For granules with 3–15% mucilage, PSD rose with increasing binder content, and flow characteristics (BD/TD, Hausner's ratio, Carr's index, and angle of repose) showed excellent compressibility and flow [Table 5]. With very slight variations in Carr's index at 15%, comparisons with gum acacia revealed comparable outcomes, indicating that *G. xanthochymus* mucilage is a useful natural binder appropriate for tablet production.[41]

Evaluation of prepared tablets

To evaluate the produced pills' overall quality and performance, both compendial and non-compendial evaluation tests were administered. Tablet thickness and diameter, weight variation, hardness, friability, disintegration duration, consistency of drug content, and in vitro dissolving behavior were among the evaluation criteria. The comparative results of all batches made with gum acacia and *G. xanthochymus* (Tamala fruits) mucilage as binders are shown in Table 6.[42]

The physical and mechanical characteristics of the tablets made with gum acacia (GA1–GA4) and *G. xanthochymus* mucilage (GF1–GF4) were assessed. GF1–GF4 formulations had thickness values between 5.3 and 5.4 mm, whereas GA1–GA4 tablets had somewhat higher thickness values between 4.6 and 4.8 mm. GF1–GF4's diameter ranged from 12.5–12.7 mm, while GA1–GA4's values ranged from 11.4–11.7 mm, suggesting consistent dimensions for both binder groups. With values ranging from 4.0 to 6.7 kg/cm^2, the hardness of all GF1–GF4 tablets was higher than the minimal pharmacopeial criterion of 4 kg/cm^2.

In a similar vein, three formulations made with gum acacia (GA2–GA4) showed hardness ranging from 4.3 to 7.2 kg/cm^2, although GA1 had a somewhat lower hardness of 3.8 kg/cm^2, which was below the recommended range. All the formulations in this investigation (GF1–GF4 and GA1–GA4) met the IP's (1996) requirement that uncoated tablets have friability of <1%. Since none of the tablets varied more than the permitted range of 5% for average tablet weight above 250 mg, weight variation testing further verified that all batches complied with pharmacopeial limitations.[43]

Since the DT is the rate-limiting step for bioavailability in traditional dosage forms, it has a significant impact on drug release and subsequent absorption. Uncoated pills must dissolve in 15 min according to pharmacopeial guidelines. With values below 4 min, every formulation in this investigation showed rapid disintegration well below the permitted limit. GF1 and GA1 broke down the quickest among the batches, taking 1.5 and 2.1 min, respectively. The DTs were 2.6 and 2.2 min for GF2 and A2, 3.9 and 3.0 min for GF3 and GA3, and 4.0 and 3.2 min for GF4 and GA4.

These findings demonstrate that tablets made with isolated *G. xanthochymus* mucilage are equivalent to those made using gum acacia as a binder and satisfy the necessary quality control requirements. Uniformity of content, which guarantees that every unit contains the quantity of medication stated on the label, is another essential pharmacopeial criteria for tablets. Formulations made with *G. xanthochymus* mucilage (GF1–GF4) had drug contents between 93.5 and 99.5%, while those made with gum acacia (GA1–GA2) had drug contents between 92.8 and 96.9%, meeting regulatory standards.

Table 5: Flowability characterization of granules prepared from the mucilage of *Garcinia xanthochymus* and gum acacia (GF1–GF4=G. *xanthochymus* fruit mucilage powder and GA1–GA4=Acacia Gum)

Parameters	All the values are mean±S.D. for *n*=3							
	***G. xanthochymus* fruits mucilage**				**Acacia gum**			
	GF1	**GF2**	**GF3**	**GF4**	**GA1**	**GA2**	**GA3**	**GA4**
Bulk density (g/mL)±S.D.	0.52±0.03	0.47±0.03	0.45±0.03	0.43±0.02	0.65±0.02	0.58±0.05	0.51±0.05	0.45±0.03
Tapped density (g/mL)±S.D.	0.58±0.01	0.55±0.02	0.52±0.02	0.5±0.02	0.72±0.02	0.65±0.02	0.58±0.05	0.53±0.04
Carr's compressibility index (%)±S.D.	10.34±0.22	14.54±0.4	13.46±0.42	14.0±0.32	9.7±0.22	10.7±0.24	12.06±0.35	15.09±0.42
Hausner ratio±S.D.	1.11±0.04	1.17±0.05	1.15±0.04	1.16±0.06	1.10±0.05	1.12±0.05	1.13±0.07	1.17±0.07
Angle of repose (O)±S.D.	30.1±0.7	29.8±0.68	31.4±0.9	31.9±0.92	29.02±0.8	31.27±85	31.56±0.9	32.25±0.9

SD: Standard deviation

Table 6: Compendial and non-compendial evaluation parameters of all prepared formulations

All the values are mean±S.D. for *n*=3	***Garcinia xanthochymus* fruits Mucilage**				**Acacia gum**			
Parameter	**GF1 3%**	**GF2 5%**	**GF3 10%**	**GF4 15%**	**GA1 3%**	**GA2 5%**	**GA3 10%**	**GA4 15%**
Diameter (mm)±S.D.	12.6±0.10	12.7±0.11	12.5±0.11	12.6±0.10	11.4±0.12	11.7±0.11	11.5±0.12	11.7±0.12
Thickness (mm)±S.D.	5.3±0.04	5.4±0.05	5.3±0.04	5.4±0.06	4.6±0.05	4.7±0.07	4.6±0.05	4.8±0.07
Hardness (kg/cm^3)±S.D.	4.1±0.45	6.0±0.5	5.5±0.35	6.2±0.42	3.8±0.42	4.3±0.35	5.8±0.40	7.2±0.50
Uniformity of weight (mg)±S.D.	650.2±0.010	650.4±0.013	649.5±0.011	649.9±0.013	649.2±0.07	649.9±0.05	650.5±0.02	651.4±0.08
Disintegration of time (minutes)±S.D.	1.5±0.03	2.6±0.07	3.9±0.11	4.0±0.11	2.1±0.36	2.2±0.58	3.0±0.13	3.2±0.25
Drug content (%)±S.D.	99.5±0.3	93.5±0.3	99.2±0.4	97.1±0.5	94.6±0.2	96.3±0.3	92.8±0.6	96.9±0.4
Friability (%)±S.D.	<1% in all formulations							

SD: Standard deviation

Formulations 2 and 3 made with *G. xanthochymus* mucilage can be considered the most optimized batches, showing superior balance between mechanical strength and disintegration behavior, when considering the overall results of both compendial parameters (uniformity of weight, drug content, DT, and friability) and non-compendial parameters (thickness, diameter, and hardness).[44]

In vitro release study

A medicine must have a suitable release pattern from its dose form to have adequate bioavailability. To assess this, *in vitro* dissolution research was conducted on all batches of uncoated tablets (GF1–GF4) made with isolated *G. xanthochymus* mucilage and compared with tablets (GA1–GA4) made with gum acacia. The IP states that at least 25–30% of the medication should be delivered during the first interval, at least 50% during the second, and more than 80% during the third cut-off time.[45,46]

The dissolution profiles showed that the drug release rate in tablets made with both gum acacia and the mucilage of Tamala fruits reduced as the binder content increased. Figure 5a-f shows the drug release profiles. Among the formulations, GF1 (containing 3% mucilage) demonstrated a cumulative release of over 98% in 30 min, whereas GF2 (containing 5% mucilage) demonstrated a release of around 98% concurrently. By contrast, in 30 min, formulations GA1 and GA2 made with 3% and 5% acacia gum as a binder demonstrated 95% and 93% release, respectively. Overall, all formulations showed linear release patterns, demonstrating that *G. xanthochymus* isolated mucilage offers a natural binding agent for tablet formulation that is as effective as gum acacia. As shown in Table 7.[47,48]

Table 7: *In vitro* drug release study

	Cumulative % drug release							
Time (min)	**GF1 3%**	**GF2 5%**	**GF3 10%**	**GF4 15%**	**GA1 3%**	**GA2 5%**	**GA3 10%**	**GA4 15%**
5	30.56	29.95	27.96	20.32	28.25	28.43	29.52	18.54
10	58.63	62.56	55.23	40.69	55.32	59.52	61.63	36.57
15	90.56	90.23	85.36	58.23	85.56	87.65	90.68	56.66
20	95.62	92.88	97.36	75.56	93.62	91.72	94.77	72.78
25	96.22	95.45	97.95	90.58	92.75	91.85	94.85	89.81
30	99.62	98.45	98.33	95.59	90.94	91.92	93.91	97.91

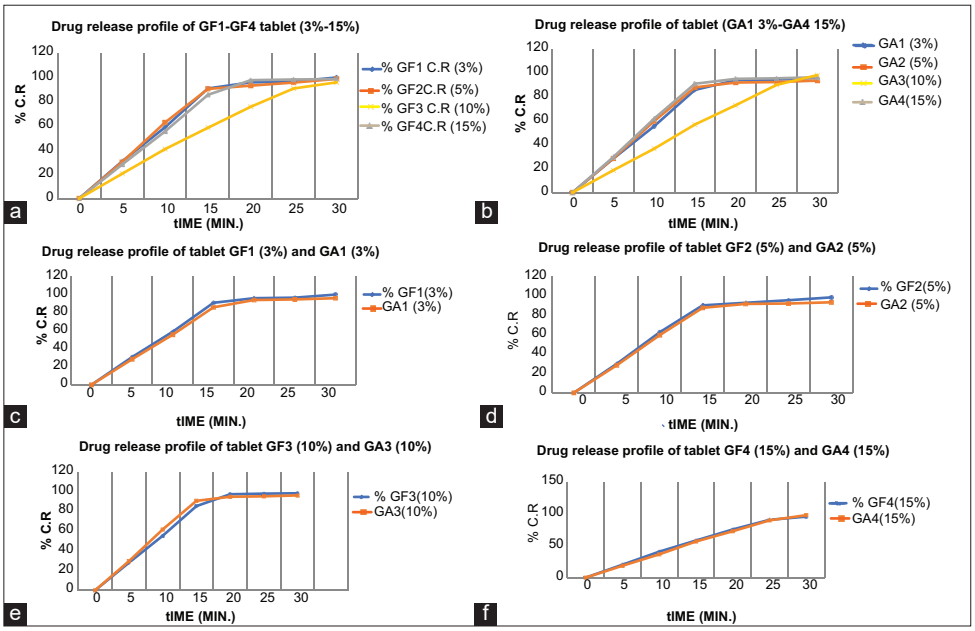

Figure 5: (a) *In vitro* % cumulative drug released profile of PCM tablets prepared using *Garcinia xanthochymus* mucilage as a binder (GF1–GF4). (b) *In vitro* % cumulative drug released profile of paracetamol tablets prepared using gum acacia as a binder (GA1–GA4). (c) Comparative *in vitro* drug release profile of formulation prepared using 3% w/v binder of *G. xanthochymus* mucilage (GF1) and acacia gum (GA1). (d) Comparative *in vitro* drug release profile of formulation prepared using 5% w/v binder of *G. xanthochymus* mucilage (GF2) and acacia gum (GA2). (e) Comparative *in vitro* drug release profile of formulation prepared using 10% w/v binder of *G. xanthochymus* mucilage (GF3) and acacia gum (GA3). (f) Comparative *in vitro* drug release profile of formulation prepared using 15% w/v binder of *G. xanthochymus* mucilage (GF4) and acacia gum (GA4)

DISCUSSION

The mucilage extracted from *G. xanthochymus* (Tamala fruits) was examined in this study as a possible natural binder for uncoated tablets. Because they are more affordable, safe, and biocompatible than synthetic binders, natural polymers are becoming increasingly regarded as pharmaceutical excipients. According to physicochemical studies, the mucilage has a nearly neutral pH (6.8) and is readily soluble in hot water and dispersible in cold water, making it appropriate for tablet formulations. While PXRD revealed an amorphous form that favored its binding and swelling capabilities, thermal analysis DSC verified its stability. Microbiological analysis revealed no contamination, and phytochemical testing verified polysaccharides as the primary component, guaranteeing its safety for use.

According to micromeritic studies, granules made with different mucilage concentrations showed favorable values for angle of repose, Carr's index, and Hausner's ratio, as well as good flow characteristics, especially at 5–10% levels. Pharmacopeial requirements for hardness, friability, drug content, and weight variation were all satisfied by tablet evaluations. With some batches disintegrating as quickly as 1.5–4.0 min, the DTs were well within tolerances. The effectiveness of Tamala fruit mucilage was further validated by in vitro release studies, which showed that formulations with 3% and 5% binder achieved nearly complete drug release (98–99%) within 30 min, outperforming tablets made with acacia gum. Overall, the findings point to the mucilage from Tamala fruits as a safe, efficient, and thermally stable natural binder. It is a promising alternative pharmaceutical excipient because of its concentration-dependent performance, which

highlights its potential in both conventional tablets and modified release systems.

CONCLUSION

In this study, mucilage from *G. xanthochymus* (Tamala fruits) was extracted, and its suitability as a natural pharmaceutical excipient was assessed. Tablet evaluation parameters and in vitro dissolution studies were conducted in conjunction with physicochemical, phytochemical, microbiological, and thermal analyses. DSC thermograms verified that the isolated mucilage was non-toxic, biodegradable, and thermally stable, with a yield of 11.3%. Spectroscopic analysis verified non-reducing sugars, while PXRD and DSC studies revealed its amorphous nature. The mucilage is appropriate for wet granulation in tablet formulations, according to analyses of PSD and flow characteristics. Good micromeritic characteristics, such as a favorable angle of repose and compressibility index, were displayed by granules made from the mucilage of Tamala fruits. Mucilage-formulated tablets passed quality control tests for disintegration, hardness, friability, weight variation, and drug content. Even at lower binder concentrations, tablets containing isolated mucilage demonstrated faster drug release than those containing gum acacia, according to in vitro dissolution studies. According to the results, isolated mucilage from *G. xanthochymus* may be used as an eco-friendly, adaptable excipient in modified drug delivery systems and as a natural binding agent for uncoated tablets.

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AUTHORS' CONTRIBUTIONS

All authors contributed significantly to the conception, design, execution, and interpretation of this research. They have accepted full responsibility for the content of the manuscript, thoroughly reviewed all experimental results, and provided critical revisions to enhance the quality of the work. All authors approved the final version of the manuscript and consented to its submission for publication.

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