



Research Paper

Development and Evaluation of Flow Characteristics of Co-processed Acacia Gum and Cassava Starch as a Direct Compression Excipient

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ABSTRACT: Direct compression excipients are special products and should possess good flowability and compressibility. Native cassava (*Manihot esculenta*) starch exhibits limitations in direct compression due to poor flow and compressibility. The aim of this study was to develop and characterize co-processed acacia gum and cassava starch as a potential direct compression excipient. Cassava starch was extracted from its tubers. Acacia gum was co-processed with cassava starch at varying ratios (1:49, 1.5:48.5, 2:48, 2.5:47.5, 3:47, and 3.5:46.5), gum: starch by wet granulation method. The resultant co-processed excipient was characterized for bulk and tapped densities, Carr's compressibility index, Hausner's ratio, and angle of repose to assess its flow and packing properties. The co-processed excipient (Batch F) exhibited satisfactory flow characteristics, with an angle of repose of 24.70° and a Hausner's ratio of 1.30, Carr's index 24.80% indicating good flowability. Co-processing acacia gum with cassava starch significantly improved the flow characteristics of the resulting excipient and compared well with co-processed excipient containing acacia gum and corn starch as a standard for comparison.

KEYWORDS: Cassava starch, Acacia gum, Co-processed excipient, Direct compression, Wet granulation method

Received 12 Oct., 2025; Revised 22 Oct., 2025; Accepted 24 Oct., 2025 © The author(s) 2025.

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I. INTRODUCTION

Tablets are the most common solid dosage form because they are convenient, stable, and allow accurate dosing [1]. The quality of tablets depends not only on the active pharmaceutical ingredient but also on the excipients incorporated in the formulation [2]. Among excipients, fillers and binders are especially important, as they influence powder flow, compressibility, hardness, disintegration, and drug release [3]. Direct compression has gained prominence in tablet manufacturing due to its simplicity, cost-effectiveness, and fewer processing steps [4]. However, the method requires excipients with excellent flowability and compressibility, which are not always readily available. Starch is one of the most widely used excipients in pharmaceutical formulations [5]. Cassava (*Manihot esculenta*) starch, in particular, is abundant, inexpensive, and biodegradable, making it an attractive option in sub-Saharan Africa and other regions where cassava is a staple crop [6]. Despite these advantages, the use of native cassava starch in direct compression is limited by poor flow and weak binding capacity [7]. Therefore, modification techniques are necessary to enhance its performance. One such approach is co-processing, which involves combining two or more excipients at the sub-particle level without significant chemical alteration [8]. This technique often results in synergistic improvements in functionality, producing excipients with superior properties compared to their individual components. Acacia gum, obtained from *Acacia senegal*, is a natural polymer widely used as a binder, emulsifier, and stabilizer in pharmaceutical formulations [9]. Its adhesive and binding properties make it a suitable candidate for co-processing with starch to improve flow and compatibility. Previous studies have shown that co-processing natural polymers can yield excipients with improved mechanical and disintegration characteristics [10]. Such innovations are particularly important in low- and middle-income countries, where the pharmaceutical industry depends heavily on imported excipients, raising production costs and limiting self-sufficiency [11]. This study was undertaken to evaluate the suitability of co-processed acacia gum and cassava

starch as a direct compression excipient. The co-processed material was characterized for its flow and compressibility indices. The findings are expected to contribute to the development of cost-effective, locally sourced excipients that could reduce dependence on imported materials and strengthen the pharmaceutical manufacturing base in developing regions.

II. MATERIALS AND METHODS

Cassavastarch (*Manihot esculenta*) was extracted from fresh cassava tubers obtained locally. Acacia gum powder (Loba Chemie Pvt. Ltd., India), Corn starch (Universal Starch Chem-Allied Ltd., India), Acetone (Prasol Chemicals Pvt. Ltd., India).

2.1 Preparation of Co-processed Excipient Acacia gum and Cassava starch

A 50 g batch of acacia gum–cassava starch mixtures was prepared at varying ratios(1:49, 1.5:48.5, 2:48, 2.5:47.5, 3:47, and 3.5:46.5), gum: starch was co-processed respectively. The weighed quantities of acacia gum and cassava starch weremixed in a dry porcelain mortar usingthe doubling-up technique to ensure uniform distribution. Amixture of acetone and water (2:1) was then gradually incorporated into the powder mixture to form a wet coherent mass, which was subsequently passed through a 460µmmesh sieve to obtain wet granules. The wet granules were dried at 50 °C for 120 minutes in a hot-air oven. The dried granules were dry-screened using a 300 µmmesh and stored in airtight glass containers. Acacia gum was co-processed with corn starch (3.5:46.5) as standard for comparison using the same method.

Table 1: Formulae for preparation of batches of co-processed excipient

Materials	Batch Ratios					
	A	B	C	D	E	F
Acacia gum(g)	1	1.5	2	2.5	3	3.5
Cassava starch(g)	49	48.5	48	47.5	47	46.5

2.2 Determination of Bulk Densities of the Excipients

A 30g each of cassava starch, acacia gum powder, co-processed excipients (Batches A–F, corn starch–acacia gum3.5:46.5, gum: starch of the best-performing batch (Batch F) were accurately weighed and transferred into a dry 100 mL graduated cylinder of known internal diameter, positioned at a 45° angle. The initial height (h) of the powder bed at zero pressure was recorded. The procedure was performed in triplicate for each sample, and the mean value was used for subsequent calculations. The bulk density (BD) was calculated as the weight per unit volume of the excipient. The bulk volume V_o was calculated using the formula:

$$V_o = \pi r^2 h \text{ — — — — — (1)}$$

Where:

V_o = bulk volume

r = radius of the measuring cylinder

h = height of excipient at zero pressure

2.3 Determination of Tapped Density of the Excipients

A 30g of each excipient cassava starch, acacia gum powder, co-processed excipients (Batches A–F, corn starch–acacia gum3.5:46.5, gum: starch of the best-performing batch (Batch F) was weighed, and the bulk height at zero pressure was first recorded. Each sample was then subjected to 20, 40, 60, 80, and 100 taps on a soft padded table surface, after which the corresponding powder height was measured and recorded. The procedure was carried out in triplicate, and the mean values were used for analysis. Tapped density (TD) at 100 taps was calculated as the ratio of sample weight (w) to tapped volume (V_t).

The tapped volume V_{100} was calculated using the formula:

$$V_{100} = \pi r^2 h \text{ — — — — — (2)}$$

Where:

V_{100} = tapped volume,

r = radius of the measuring cylinder,

h = height occupied by the excipient at 100 taps

Carr's compressibility index

This was calculated using the equation:

$$CI = \frac{\text{Tapped density} - \text{Bulk density}}{\text{Tapped density}} \times 100 \quad \text{--- (3)}$$

Where:

CI = Carr's index

Hausner ratio

Hausner ratio, HR was calculated as the ratio of tapped density to bulk density of the excipients.

$$HR = \frac{\text{Tapped density}}{\text{Bulk density}} \quad \text{--- (4)}$$

2.4 Determination of Angle of Repose of the Excipients

A 30g of each excipient cassava starch, acacia gum powder, co-processed excipients (Batches A–F and corn starch–acacia gum, 3.5:46.5, gum: starch of the best-performing batch (Batch F) was carefully passed through a conical funnel clamped to a retort stand, with the tip of the funnel positioned 5 cm above a flat table surface. A clean plain sheet of paper was placed beneath the funnel, and the resulting powder heap was allowed to form freely. The height (h , cm) of the heap was measured, and the diameter of its circular base was determined and halved to obtain the radius (r). Each determination was carried out in triplicate, and the mean values were recorded.

The angle of repose was calculated using the equation below:

$$\theta = \tan^{-1} h/r \quad \text{--- (5)}$$

Where:

H=height of the powder cone (cm)

R=radius of the cone base (cm)

III. RESULTS AND DISCUSSION

3.1 Physical Properties of Excipients

The physical properties of the excipients are presented in Tables 2 and 3. The Hausner ratio was used to evaluate flow properties. A Hausner ratio < 1.25 indicates good flowability, whereas values > 1.50 suggest poor flow [16]. Cassava starch showed a ratio of 1.35, acacia gum 1.38, and the co-processed batches ranged 1.56–1.30, with Batch F showing the lowest value (1.30), indicating improved flow.

The co-processed excipients comprising acacia gum and cassava starch (Batches A–F) showed Hausner ratios of 1.56, 1.67, 1.46, 1.38, 1.30, and 1.30, respectively. Among these, Batch F exhibited the lowest Hausner ratio (1.30), indicating superior flow properties and was therefore considered the most suitable batch for the formulation of directly compressible tablets. Comparatively, the co-processed batches performed favorably relative to the corn starch–acacia gum system, suggesting that the inclusion of acacia gum improved the flow behavior of cassava starch.

Angle of repose is used to assess the flow properties of excipients [17]. The angle of repose is an indication of the inter-particulate frictional forces operating within the powder system by quantifying the resistance of the powder mass to flow. Values less than 25° is indicative of fair to good powder flow, while values greater than about 50° suggests that the material has extremely poor flow [18]. From the results above, both cassava starch and acacia gum gave value 38.5° and 43.4° while among the co-processed excipient, Batch F reflected the lowest value of 24.70° respectively, hence Batch F gave a good flow compared to its natives for manufacturing of tablets. This could be due to the particle size or shape which was improved by co-processing the natives and consequently improve their flowability. The co-processed excipient with the ratio of (3.6:46.5) Batch F reflected the best flow and passed with a value of 24.70% compared to the batches A to E.

Carr's index is an indication of the compressibility of powder [19]. As a general rule, powders with Carr's index of above 23% means the powder possesses poor flow and therefore will require the use of a glidants to improve its flowability. Powders with Carr's index between below 5-15% has excellent flowability. From the results above, acacia gum was found to possess a poor flowability with Carr's index of 27.87%, also cassava starch which gave Carr's index of 28.00% and which also means poor flow of powder. It was found that co-processed corn starch with acacia gum gave Carr's index of 23%. Batches A to F possessed 36.09, 36.09, 31.54, 27.56, 25.4, 24.80% Carr's index respectively with Batch F having the lowest Carr's index of 24.80%.

Table 2: Physical properties of excipients

Parameters	Cassava starch	Acacia gum	Co-processed corn starch and acacia gum (3.5:46.5)
Bulk density (g/cm ³)	0.45	0.642	0.40
Tapped density (g/cm ³)	0.60	0.870	0.51
Carr's index (%)	28.0	27.87	23
Hausner Ratio	1.35	1.38	1.30
Angle of repose(°)	36	41.5	25

Table 3: Physical Properties of Co-Processed Excipients of Various Batches

Parameters	Batch A	Batch B	Batch C	Batch D	Batch E	Batch F
Bulk density (g/cm ³)	0.340	0.340	0.345	0.318	0.311	0.309
Tapped density (g/cm ³)	0.532	0.507	0.504	0.439	0.415	0.411
Carr's Index (%)	36.09	36.09	31.54	27.56	25.24	24.80
Hausner ratio	1.56	1.67	1.46	1.38	1.30	1.3
Angle of repose (°)	28.61	28.91	30.46	26.34	25.60	24.70

Comparative flow properties of cassava starch, acacia gum, co-processed corn starch–acacia gum, and co-processed Batch F (3.5:46.5). Batch F demonstrated acceptable Carr's index (24.8%) and Hausner ratio (1.3), and an excellent angle of repose (24.7°), confirming superior flowability and compressibility compared to its native excipients.

The Fourier Transform Infrared (FTIR) spectra of the excipients are presented in Figures 1 to 3. The FTIR analysis revealed no evidence of chemical interaction between the components of the co-processed excipient—acacia gum and cassava starch as the characteristic absorption peaks of the individual materials were retained after co-processing [20]. This indicates that the molecular structures of the native excipients remained intact, confirming physical rather than chemical modification. The absence of new or shifted peaks suggests that no chemical bonds were formed during co-processing. Such spectral stability is a desirable attribute for co-processed excipients, as it ensures compatibility and functional integrity of the individual components. These observations were consistent for cassava starch, acacia gum, and the dried powder of Batch F co-processed excipient.

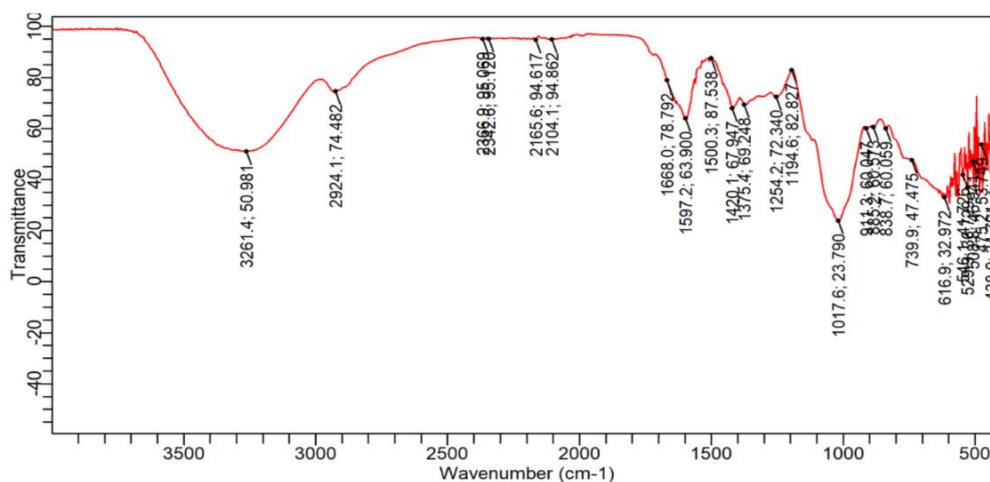


Figure 1 Fourier Transform Infrared Spectrum of Dried Powder of Acacia Gum

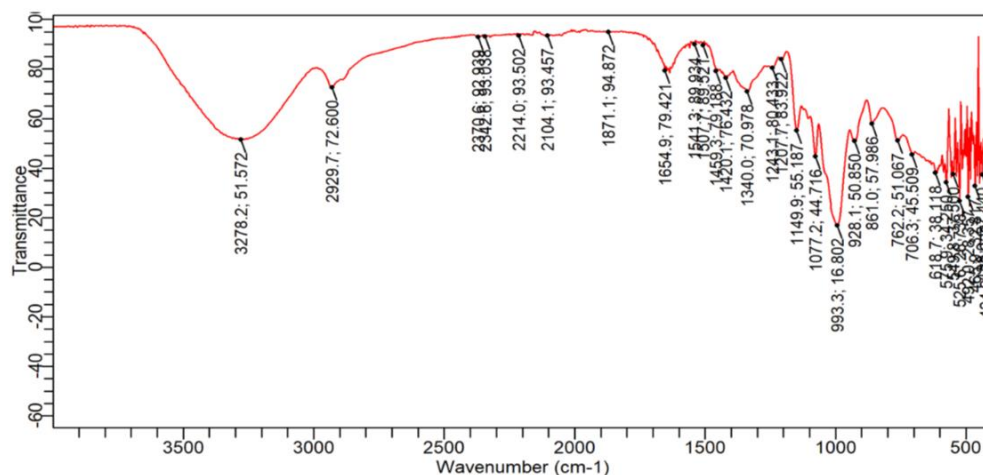


Figure 2 Fourier Transform Infrared Spectrum of Dried Powder of Cassava Starch

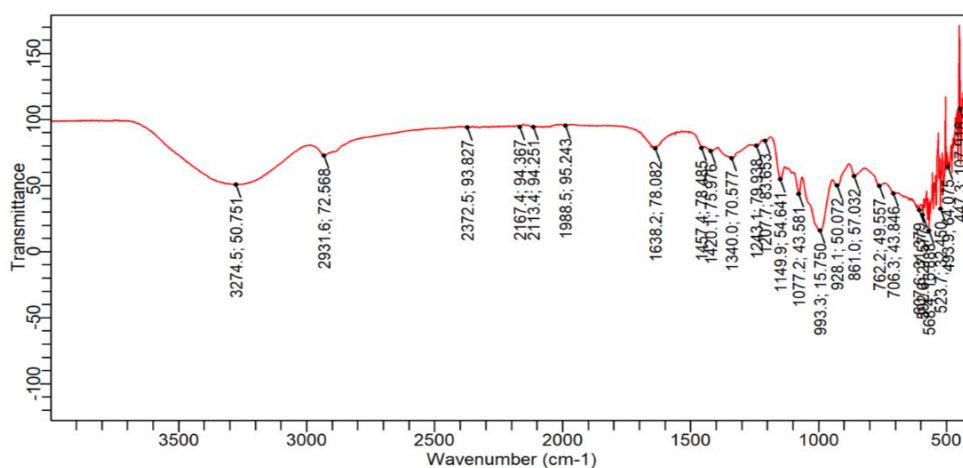


Figure 3 Fourier Transform Infrared Spectrum of Dried Powder of Batch FCo-processed Excipient

IV. CONCLUSION

The present study successfully developed and characterized a co-processed excipient derived from acacia gum and cassava starch for direct compression. The co-processed system demonstrated superior flowability and compressibility. This enhancement underscores its potential as a cost-effective and locally sourced multifunctional excipient suitable for direct compression in pharmaceutical tablet formulations.

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