Drug Discovery

To Cite:
Nnamani ND, Muazu IK. Development and evaluation of co-processed *Terminalia avicennoides* gum resin as drug-release matrix for aceclofenac tablet. *Drug Discovery* 2026; 20: e6dd3049
doi:

Author Affiliation:
Department of Pharmaceutics and Pharmaceutica Technology, Dora Akunyili College of Pharmacy, Igbinedion University, Okada, Edo State, Nigeria.

***Corresponding Author:**
Nnabuike Didacus Nnamani,
Department of Pharmaceutics and Pharmaceutica Technology, Dora Akunyili College of Pharmacy, Igbinedion University, Okada, Edo State, Nigeria.
Email: nnamani.didacus@iuokada.edu.ng, nnnabuike@gmail.com
Phone; +2348033276431

Peer-Review History
Received: 25 September 2025
Reviewed & Revised: 11/October/2025 to 03/February/2026
Accepted: 12 February 2026
Published: 21 February 2026

Peer-Review Model
External peer-review was done through double-blind method.

Drug Discovery
pISSN 2278–540X; eISSN 2278–5396

Development and evaluation of co-processed *Terminalia avicennoides* gum resin as drug-release matrix for aceclofenac tablet

Nnabuike Didacus Nnamani*, Ibrahim Khaleed Muazu

ABSTRACT

Modification of biomaterials is continually providing new and improved excipients for drug formulation and delivery. The goal of this research was to evaluate the drug-release potential of *Terminalia avicennoides* gum resin matrix in aceclofenac tablets. Aceclofenac-gum resin interaction studies were carried out using infrared, microscopy, and calorimetric analysis. The gum resin was co-processed with acacia or starch. Batches A- I of aceclofenac granules were formulated with 47.4 % matrices of gum resin, acacia, starch, or their co-processed forms. The granules were subjected to pre-compression properties tests, and thereafter compressed into tablets. The tablets were examined for physicochemical and drug release properties. The gum resin showed compatibility with aceclofenac powder. The granules showed good processing properties. The tablets formulated with co-processed gum resin matrices showed strong mechanical properties with hardness > 6.83 KgF and friability < 0.52 %. Tablets with 1:3 gum resin: acacia co-excipient binder fitted to Fickian diffusion Higuchi release model with coefficient of correlation 0.9929 and release exponent - 0.658. The findings demonstrate that *Terminalia avicennoides* gum resin co-processed with acacia extended acacelofenac drug release.

Keywords: Pre-compression properties, drug release kinetics, Fickian diffusion, Higuchi release model.

1. INTRODUCTION

The pharmaceutical industry is continually seeking new and improved excipients to enhance the formulation and delivery of drugs (Purohit *et al*., 2022; Yadav *et al*., 2022). Plant gum resins have gained significant attention as potential pharmaceutical excipient due to their ability to swell, form viscous solutions, or provide biodegradable texture matrix/coating drug carrier, biocompatibility and cost-effectiveness (Bhardwaj *et al*., 2000; Muzib *et al*., 2024; Nagendra *et al*., 2024; Anusha *et al*., 2025). With a clearer understanding of functional properties of plant gum resin, recent research has focused on improving their extraction techniques and developing novel modified gum excipients and co-excipients (Froelich *et al*., 2023; Nagendra *et al*., 2024).

Modified gum excipients or co-excipients may function as hydrophilic, hydrophobic or amphiphilic polymers or as co-polymers for matrix systems, coating systems or microspheres for incorporating drugs for varied release properties (Nardi-Ricart *et al*., 2020; Kaur & Kumar, 2022; Schilling *et al*., 2022; Devi *et al*., 2025; Khadka *et al*., 2025). Polymer-matrix formulations can maintain a steady and programmed therapeutic level of drug, thereby avoiding unhelpful rapid peaks and troughs in drug active concentration (Kaur & Kumar, 2022; Bodke *et al*., 2024; Devi *et al*., 2025).

Acacia gum, *Terminalia avicennoides* gum, starch and other natural polymers have been investigated for application as drug-release matrices for different delivery systems (Badshah *et al*., 2011; Saxena & Verma, 2021; Muzib *et al*., 2024; Khadka *et al*., 2025). *Terminalia avicennoides* plant stem bark exudate has been intensively studied phytochemically due to its use for food, incense, tanning, anti-corrosive coating, direct compression, immediate and controlled-release formulations and ethno-medicine (Bamiro *et al*, 2011; Bamiro *et al*., 2014; Azeez *et al*., 2015; Omoniyi *et al*., 2015; Sulaiman *et al*., 2016; Kennedy *et al*., 2025). *Terminalia avicennoides* gum has poor swelling property in water, but its solubility in water increases with an increase in temperature (Omoniyi *et al*., 2015). Acacia gum is soluble in both cold and hot water. It has low viscosity at low concentration, a shear-thickening viscosity profile and excellent compressibility. Acacia gum is an excellent emulsifier and stabilizer, and can form flexible films suitable for coating and encapsulation. Acacia gum has various applications such as tablet binder, sustained drug release excipient, drug delivery systems carrier and wound healing application for promoting tissue regeneration and reducing inflammation, antimicrobial coating, or wound dressing (Ashour *et al*., 2022; Dingwoke *et al*., 2025). Starch is a versatile and widely used biopolymer in dosage design (Ahmed *et al*., 2025). Starch can be blended with other materials to improve its functionality and expand other potential applications in drug dosage design (Khairnar *et al*., 2024; Koekuyt *et al*., 2025).

Understanding the properties of natural and co-processed excipients and their interaction with drug actives is crucial for developing effective and stable tablet formulations. This study will focus on the design and evaluation of *Terminalia avicennoides* gum and its co-processed forms with acacia gum or corn starch as matrix-forming excipients in aceclofenac tablet formulations. To the knowledge of these researchers, this gum resin has not been co-processed for evaluation as a controlled release matrix for aceclofenac tablets.

Aceclofenac is a non-steroidal, anti-inflammatory drug (NSAID). It has a higher anti-inflammatory action or at least comparable effects to conventional NSAIDs (Halwai & Mishra, 2023; Bhatta et al., 2025). Aceclofenac is used for managing pain and inflammation and for treating conditions like osteoarthritis, rheumatoid arthritis and ankylosing spondylitis (Netrapal & Azharuddin, 2025). Aceclofenac has poor solubility and high permeability and is classified under the biopharmaceutical classification system (BCS) as a class II drug (Kumar & Kumar, 2024). Formulation techniques that delay solubility or availability for dissolution will therefore extend the release and activity of aceclofenac. Aceclofenac tablet can be formulated as 200 mg controlled release aceclofenac to be taken once daily, and provides equivalent pain relief as an immediate-release 100 mg aceclofenac tablet taken twice daily (Moon et al, 2014; Halwai & Mishra, 2023; Bhatta et al., 2025).

In this study, starch or acacia will be used to co-process *Terminalia avicennoides* gum resin for application as a drug release polymer matrix for aceclofenac tablets. The study will be limited to the characterization of the gums, micromeritics and compressibility determination of the co-processed materials, as well as the evaluation of the physicochemical and in vitro performance of the formulated tablets, and determination of its drug release mechanism. The study will not investigate the in vivo performance or clinical efficacy of the formulated tablets.

2. MATERIALS AND METHODS

Gum resin exudates were extracted from the tree bark of Terminalia avicennoides found in the botanical garden of the Department of Pharmacognosy, Dora Akunyili College of Pharmacy, Igbinedion University, Okada, Edo state, Nigeria. Aceclofenac IP (Amoli Organics Pvt Ltd, Mumbai, India), corn starch, BP (Bosida Starch Technology, Royi, China), microcrystalline cellulose (Vijlak Pharma Limited, India), lactose monohydrate, USP-NF (Danone GmbH, Germany), methylparaben and magnesium stearate (BOC Sciences Daily Chemical, Portland, London) were gifted by Dizpharm Nigeria Limited. All other chemicals and reagents used were of analytical grade.

Collection and identification of *Terminalia avicennoides* tree bark exudate

The *Terminalia avicennoides* (Combretaceae) tree was identified and authenticated by the Department of Pharmacognosy of Dora Akunyili College Pharmacy, Igbinedion University, Okada, Edo state and given herbarium number: IUO/16/127. Raw gum resin

exudates were extracted from the healing bark of the scratched bark of the *Terminalia avicennoides* tree. The extracted exudates were cleaned by washing thoroughly with distilled water, and dried in a hot-air oven (Model DHG-9053A, Ocean Medical, England) at 50 °C for 24 h. The cleaned and dried exudates were pulverized to fines using an electric miller (Eurosonic, China) fitted with 150 µm sieve mesh. Soluble impurities were removed using 70 % ethanol at 60 ℃ for 24 h, and the pure gum resin dried in a hot air oven for 5 h at 40°C, then milled and screened through a 150 µm sieve mesh.

Compatibility characterization of gum resin

The samples of aceclofenac, *Terminalia avicennoides* gum resin and 1:1 dispersion of *Terminalia avicennoides* gum resin plus aceclofenac were characterized using Differential Scanning Calorimetry, Scanning Electron Microscopy and Fourier Transform Infrared analysis.

Differential Scanning Calorimetry (DSC) analysis

DSC analysis was done using (DSC 60, Schimadzu, Japan) with DuPont 9900 thermal analyser. A 2 mg sample was sealed in one aluminum pan, while another empty pan served as a reference. Both pans were transferred into a calibrated DSC instrument and were subjected to control heating at a rate of 10 °C per minute under a continuous nitrogen flow of 20–50 mL/min. The difference in heat flow between the sample and the reference was measured as a function of temperature by the DSC analyzer and presented as a thermogram. The resulting thermogram showed thermal transition information on melting point, crystallization and glass transition temperatures.

Scanning Electron Microscope (SEM) analysis

Surface morphology of samples was determined using a scanning electron microscope (JEOL JSM-6480LV, Japan). The dried sample was mounted on an aluminum stub using a double-sided carbon adhesive tape. The mounted sample was then coated with approximately 10 nm layer of gold using a sputter coater (Quorum SC7620, UK) and subsequently examined under high-vacuum mode using the SEM microscope operated at an accelerating voltage of 15 kV and at varying magnifications ranging from ×500 to ×5000 to observe particle size.

Fourier Transform Infrared (FTIR) analysis

FTIR analysis was carried out using a Fourier Transform Infrared spectrometer (FTIR-8400S, Schimadzu, Japan) with a spectral range of 4000-400 / cm and resolution of 4 / cm and 16 / cm. The sample was pulverized to fines and dried. A 2.0 mg of the dried fine was analyzed using an ATR accessory. A background spectrum was collected using a clean reference material (KBr), followed by sample analysis with a sufficient signal-to-noise ratio. The spectrum was evaluated for atmospheric interference. The peaks seen in the spectrum were matched with functional groups using reference spectra and software.

Co-processing binder excipients

Co-processed binder excipients were prepared using the formula in Table 1. The *Terminalia avicennoides* gum resin, acacia gum and corn starch binders were dispersed in 10 ml of distilled water to form a uniform mixture. The blend was homogenized and oven-dried at 50°C for 1 hr. The dried mass was pulverized and sieved through a 250 µm mesh to obtain uniform co-processed binder powders. The powder were poured into airtight containers and stored before formulation.

Dry granulation

Using the formula in Table 1, aceclofenac, lactose, microcrystalline cellulose, methylparaben and co-processed binder(s) were blended thoroughly in a clean, dry mortar using a pestle to ensure uniform mixing. The mixture was fed into a single-punch tablet presser and compressed to large compact slugs. The slugs were milled and passed through a 1.0 mm sieve to obtain granules of uniform size distribution. The granules obtained were subjected to flow and densification properties tested before lubrication.

Evaluation of granules

The granules were subjected to flow and densification properties analyses. Twenty gram of powder was carefully poured into a 100ml measuring cylinder and tapped three times to balance the meniscus of the powder. The volume occupied by the powder was noted and recorded as bulk volume. The powder's bulk density was derived by the division of the powder weight with its bulk volume. The measuring cylinder was then mechanically tapped on a flat surface 100, 200, 400, 600, 800, 1000 times to a constant volume, recorded as

the tapped volume. The final tapped density of the powder was derived from the division of the powder weight with the tapped volume. This test was done in triplicate. The mean density value was used to calculate the Hausner Ratio and Carr's Index. The tapped volumes were used to plot the Kawakita densification graph of $\frac{N}{C}$ Vs. N (where N= number of taps; C = degree of volume reduction. C is calculated from $\frac{V0-Vn}{V0}$, with vo = initial volume; vn = volume after N taps).

Table 1: Formula for preparing 50 tablets of 200 mg aceclofenac tablets

Constituents	Quantities (g)								
Batch	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Aceclofenac	10	10	10	10	10	10	10	10	10
T. avicennoides binder	14.4	-	-	10.8	7.2	3.6	10.8	7.2	3.6
Acacia gum binder	-	14.4	-	3.6	7.2	10.8	-	-	-
Corn starch binder	-	-	14.4	-	-	-	3.6	7.2	10.8
Lactose	4	4	4	4	4	4	4	4	4
Microcrystalline cellulose	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Methyl paraben	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
Magnesium stearate	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Total	29.48	29.48	29.48	29.48	29.48	29.48	29.48	29.48	29.48

Compression of granules

Magnesium stearate was added to the granules and blended gently for 2–3 minutes to ensure uniform distribution without overwriting the granule surface. The granules were compressed using a Model ZP-7 small rotary tablet press (Taizhou Quanta Machinery Equipment Co Ltd, China) set to compress weighing 580 mg tablets at 35 KN. The compressed tablets were collected and stored to cure in a desiccator for 7 days at room temperature until analysis.

Evaluation of compressed tablets

Weight variation: Twenty tablets were randomly selected from each batch and weighed using an analytical balance (Mettler, Switzerland) and the mean weight calculated. The individual tablets were weighed, and its standard deviation from the mean weight was determined.

Tablet hardness: The individual hardness of ten (10) tablets randomly selected from a batch was determined using a Model HT- 30/50 Campbell electronic hardness tester (India). The mean hardness and standard deviation were calculated and recorded.

Percentage friability: Using a single drum friabilator (PTF 10E, Pharma Test Instruments India Pvt. Limited, India), the friability of ten (10) randomly selected tablets from a batch was determined. The ten tablets were pre-weighed tablets, placed in the friabilator and subjected to 25 revolutions per minute (rpm) for 4 minutes, for a total of 100 revolutions. After the test, tablets were de-dusted and reweighed. The percentage weight loss was calculated and recorded as percentage friability.

Disintegration time test: Disintegration time was determined using a USP disintegration test apparatus (Model MK4, Manesty Machine Limited, England) containing six tubes and a basket rack assembly. A randomly selected tablet from a batch was placed in the basket assembly of the disintegration apparatus and lowered into the disintegration beaker containing 1 L of distilled water maintained at 37 ± 0.5 ℃, and operated at 30 cycles/min. The time required for the complete disintegration of each tablet with no palpable residue was recorded as tablet disintegration time. The mean disintegration time for the six tablets was calculated and recorded for each batch.

Dissolution studies: The *in vitro* tablet dissolution test was carried out using a paddle-type USP Dissolution Apparatus II at 37 ± 2°C and 50 rpm rotation speed with 0.1 N HCl dissolution medium (900 ml) for 2 hr and then switched to phosphate buffer pH 7.4 dissolution medium for the next 24 hrs. At 1, 4, 8, 16 and 24 hrs of operation, 5 ml aliquot was withdrawn with a pipette fitted with cotton wool filter and replaced with 5 ml dissolution fluid. The withdrawn aliquot was analysed for absorbance using a UV-spectrophotometer (Model 23D, Uniscope, England) at 274.65 nm. The drug concentration was calculated from a previously constructed calibration curve of aceclofenac, and the percentage drug release calculated. Each determination was carried out in triplicate and its mean values recorded. Dissolution profiles were compared to assess batch uniformity and release characteristics (USP, 2020).

Tablet release kinetics studies: Drug release data from the dissolution studies were fitted into the different mathematical model of equations 1 – 4 (Bose *et al*., 2013).

Zero-order equation: $Q_t = Q_0 - K_{0t}$ …….1

Where Q_0 = amount of drug in solution (Q_0 is often = 0). Q_t = amount of drug released at time t. K_0 is the zero-order release rate.

First-order equation: $\ln Q_t = \ln Q_0 + K_{1t}$ …….2

Where Q_0 = amount of drug in solution (Q_0 is often = 0). Q_t = amount of drug released at time t, K_1 is the first order release rate.

Higuchi's equation: $Q = K_H t^{1/2}$ …….3

Where Q = fraction of drug released at time t, K_H is the Higuchi diffusion rate constant. $t^{1/2}$= time to dissolve half of the drug.

Korsemeyer-Peppas equation: $Mt / M\varphi = kt^n$ …….4

Where Mt / Mφ is the fractional release of drug, Mt is the amount of drug released at time t. Mφ is the amount of drug released after infinite time and k is the constant incorporating structural and geometric characteristics of the dosage; and n = release exponent indicative of mechanism of release obtained from the slope of a plot of log (Mt / Mφ) vs. log (t).

The correlation coefficient (R^2) was calculated from the plot of each equation. The mechanism with $R^2 \geq 0.9$ is interpreted to have a significant effect on the drug release. The value of the release exponent (n) from the Korsemeyer-Peppas plot is used to indicate the type of diffusion, where n=0.5 is Fickian diffusion; 0.5<n<1 is Anomalous diffusion; n=1.0 is Case II transport, and n>1.0 is Super case II diffusion (Fu & Kao, 2010; Miao *et al*., 2017 and Danyuo *et al*., 2019).

3. RESULTS

Yield of gum resin

The percentage yield of extracted *Terminalia avicennoides* gum resin was 86.21%.

Compatibility of gum resin

DSC thermograph

The DSC analysis result is displayed in Figure 1. The thermoragh showed a sharp endothermic peak at 151 – 156 ℃ for both the aceclofenac active and the dispersed aceclofenac-gum.

SEM micrograph

SEM analysis results are presented in Figure 2. The aceclofenac API exhibited rod-shaped or prismatic crystals with distinct hexagonal or rectangular faces and sharp edges. These crystals are relatively large, typically reaching a few micrometers in length, although some smaller agglomerates are also present. The *Terminalia avicennoides* gum resin displayed a distinct structure. It appears as a tangled network web. The SEM of Aceclofenac-gum dispersion retained the characteristic rod-shaped crystals of aceclofenac. It showed that aceclofenac was interspersed within the fibrous and tangled network of the gum. The dispersion showed no visual evidence of physical erosion, dissolution, or loss of edges for the gum

FTIR spectrum

As presented in Figure 3, The FTIR spectrum of Terminalia avicennoides gum resin shows a very broad and intense peak centered around 3200 – 3500 / cm, peaks at 2800-3000, strong peaks in 1600 -1700 and 1500-1200 / cm regions. The aceclofenac and aceclofenac dispersion both showed sharp peaks around 610, 748, 1255, 1715, 2937 and 3318 /cm regions.

Granules properties

The micromeritics properties of the granules are presented on Table 2. It showed flow properties of B>C>D>H>G>I>A>F.

Tablet properties

Physicochemical properties

As presented in Table 3, mean hardness of tablets of I>H>A>D>E>C>G>F>B, percentage friability of <B<F<E<D<I<C<H<G<A, and disintegration time of C<I<G<H<A<B<F<E<D. Increase in gum-resin concentration resulted in an increase in hardness of tablets. Tablets with acacia or co-processed acacia had friability < 0.52 %.

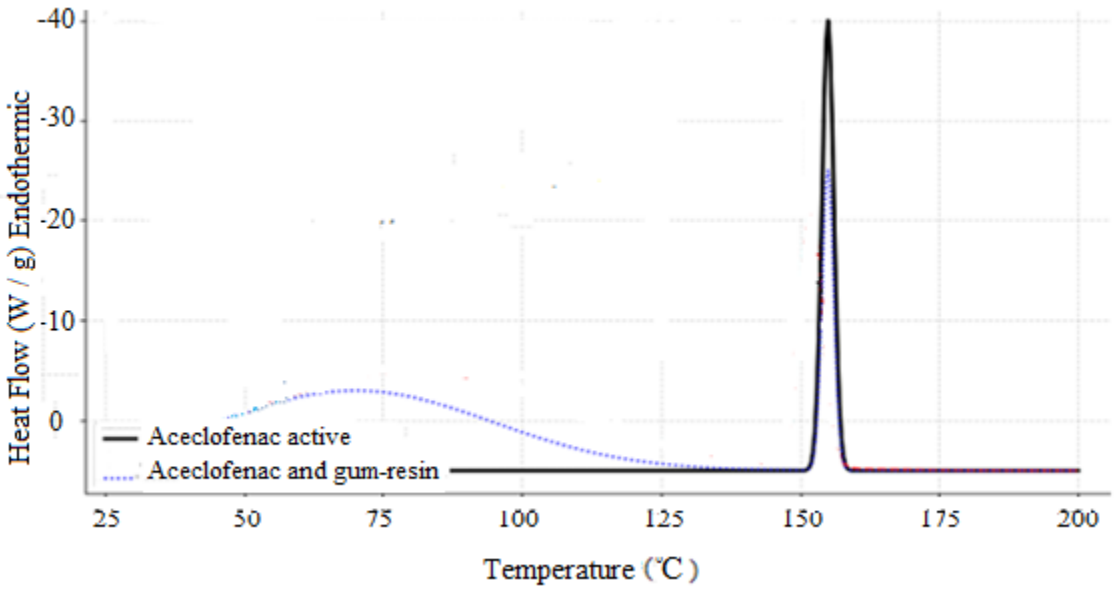

Figure 1: Overlay thermograph of aceclofenac compatibility ℃

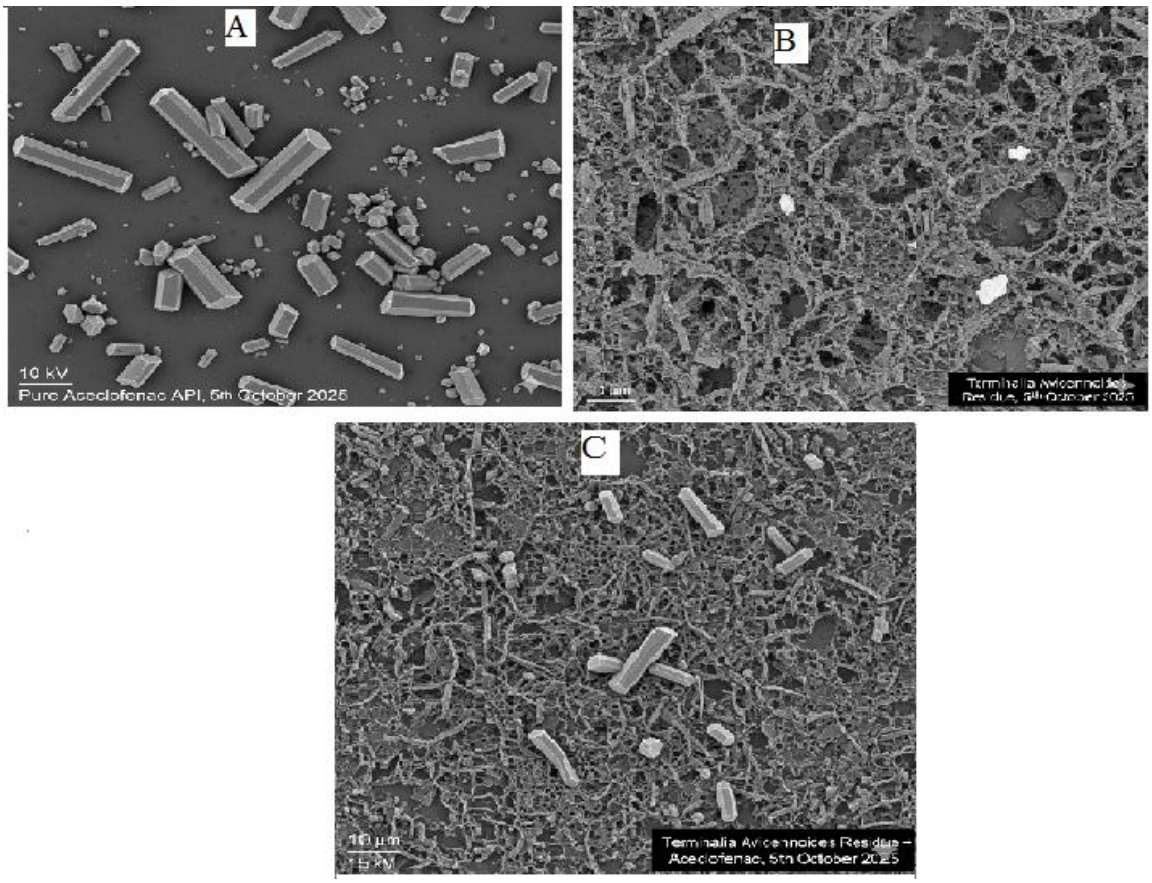

Figure 2: SEM micrographs of (A) Aceclofenac API, (B) *Terminalia avicennoides* gum resin, (C) 1:1 Dispersion of Aceclofenac: *Terminalia avicennoides* gum resin.

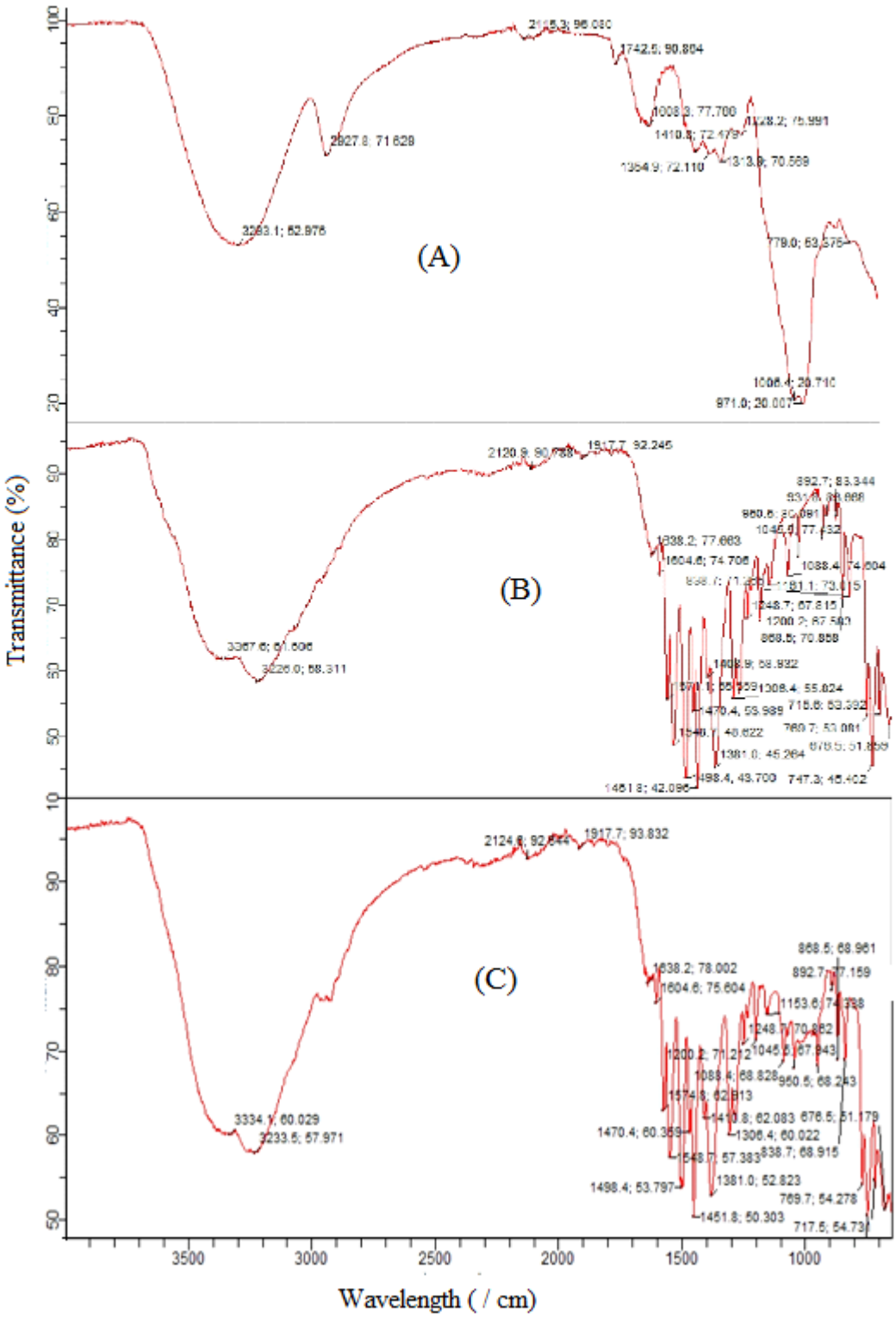

Figure 3: FTIR spectra of (A) *Terminalia avicennoides* gum resin, (B) Aceclofenac API, (C) 1:1 dispersion of aceclofenac: *Terminalia avicennoides* gum resin

Table 2: Micromeritics properties of aceclofenac granules

Batch	Carr's Index (%)	Hausner Ratio	Flow Rate (g/s)	Angle of Repose (°)
A	20.75 ± 0.62	1.26 ± 0.05	5.44 ± 0.51	37.95 ± 0.62
B	10.0 ± 1.0	1.11 ± 0.04	5.86 ± 0.28	34.35 ± 1.21
C	13.79 ± 0.53	1.16 ± 0.05	7.64 ± 0.2	29.96 ± 1.26
D	16.07 ± 1.41	1.19 ± 0.05	5.28 ± 0.53	25.95 ± 1.06
E	20.83 ± 0.76	1.26 ± 0.04	4.9 ± 0.48	29.66 ± 1.27
F	25.49 ± 1.16	1.34 ± 0.05	6.21 ± 0.49	29.88 ± 0.99
G	16.28 ± 0.81	1.19 ± 0.02	4.2 ± 0.51	35.94 ± 1.02
H	16.13 ± 1.02	1.19 ± 0.03	7.51 ± 0.23	34.56 ± 0.93
I	18.97 ± 1.05	1.23 ± 0.02	3.87 ± 0.34	38.31 ± 0.53

Key: A = *Terminalia avicennoides* gum resin, B = acacia gum, C = starch, D = 3:1 *Terminalia avicennoides* gum resin : acacia gum, E = 1:1 *Terminalia avicennoides* gum resin: acacia gum, F = 1:3 *Terminalia avicennoides* gum resin: acacia gum, G = 3:1 *Terminalia avicennoides* gum resin: starch, H = 1: *Terminalia avicennoides* gum resin: starch, I = 1:3 *Terminalia avicennoides* gum resin: starch.

Dissolution profile

The dissolution profile of the tablets in acidic and basic media are shown in Figure 4**.** Batches I, G, H and C with high starch components showed higher dissolution profile in acidic pH, while batches A, B, D, E and F with gum resin or acacia gum showed lower dissolution profile in acidic pH.

Drug release kinetics

The tablet release kinetic extrapolated from the plots of the mathematical models of drug release data are presented in Table 4. Tablets with starch or only gum resin showed First-order release. Tablets with co-processed gum resin or acacia showed Higuchi model with release exponent <0.5.

Statistical analysis

The results were given as mean ± standard error mean (SEM). The significant difference was determined using one-way analysis of variance (ANOVA), with p values < 0.05 being considered significant.

Table 3: Physicochemical properties of aceclofenac tablets

Batch	Mean Weight	Hardness (Kg)	% Friability	DT (Min)
A	0.55±0.06	8.47±1.5	7.78	42.22
B	0.6±0.03	4.67±2.08	0.34	44.18
C	0.57±0.02	7.33±1.89	1.18	2.1
D	0.59±0.02	8.17±1.76	0.52	58.39
E	0.58±0.04	7.33±2.08	0.51	55.55
F	0.6±0.03	6.83±2.36	0.44	51.18
G	0.6±0.02	6.83±1.04	3.66	24.36
H	0.59±0.03	9.33±2.31	1.72	27.48
I	0.57±0.02	10.67±1.15	1.12	13.12

NB: DT is disintegration time.

Key: A = *Terminalia avicennoides* gum resin, B = acacia gum, C = starch, D = 3:1 *Terminalia avicennoides* gum resin : acacia gum, E = 1:1 *Terminalia avicennoides* gum resin: acacia gum, F = 1:3 *Terminalia avicennoides* gum resin: acacia gum, G = 3:1 *Terminalia avicennoides* gum resin: starch, H = 1: *Terminalia avicennoides* gum resin: starch, I = 1:3 *Terminalia avicennoides* gum resin: starch.

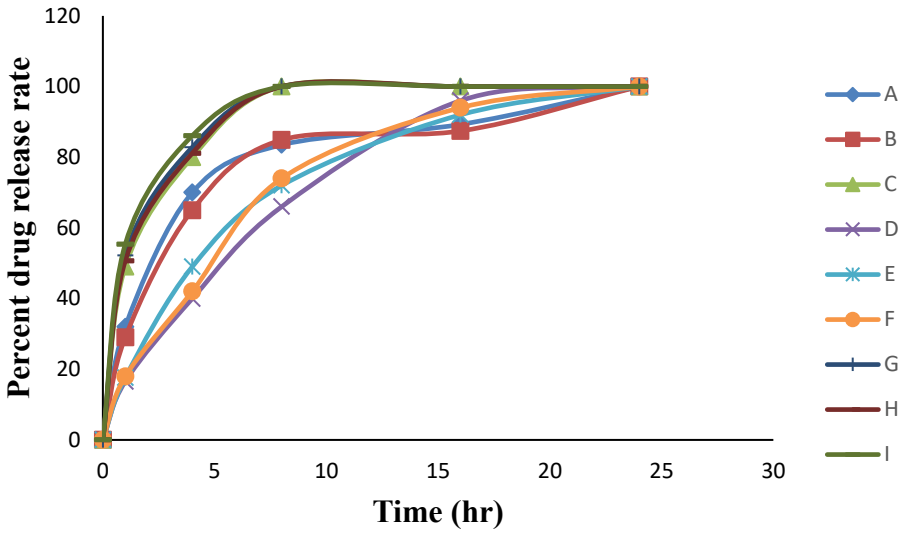

Figure 4: Drug release profile for aceclofenac tablets

Key: A = *Terminalia avicennoides* gum resin, B = acacia gum, C = starch, D = 3:1 *Terminalia avicennoides* gum resin : acacia gum, E = 1:1 *Terminalia avicennoides* gum resin: acacia gum, F = 1:3 *Terminalia avicennoides* gum resin: acacia gum, G = 3:1 *Terminalia avicennoides* gum resin: starch, H = 1: *Terminalia avicennoides* gum resin: starch, I = 1:3 *Terminalia avicennoides* gum resin: starch.

Table 4: Correlation coefficient (R^2) and K-P release exponent (n) of aceclofenac tablet dissolution studies.

Batch	Correlation coefficient (R^2)				Korsemeyer-Peppas release exponent (n)
	Zero-order plot	First-order plot	Higuchi model plot	Korsemeyer-Peppas plot	
A	0.7168	0.9379	0.8573	0.8336	-0.3979
B	0.7228	0.9252	0.8615	0.8385	-0.4363
C	0.5521	0.9331	0.7279	0.7567	-0.2374
D	0.8831	0.6423	0.9664	0.8972	-0.6911
E	0.8475	0.7169	0.9554	0.8739	0.6354
F	0.8468	0.7023	0.9484	0.9929	-0.6508
G	0.5372	0.9245	0.7146	0.7484	-0.2139
H	0.5479	0.9331	0.7242	0.7549	-0.2374
I	0.5136	0.9154	0.6925	0.7334	-0.1916

Key: A = *Terminalia avicennoides* gum resin, B = acacia gum, C = starch, D = 3:1 *Terminalia avicennoides* gum resin : acacia gum, E = 1:1 *Terminalia avicennoides* gum resin: acacia gum, F = 1:3 *Terminalia avicennoides* gum resin: acacia gum, G = 3:1 *Terminalia avicennoides* gum resin: starch, H = 1: *Terminalia avicennoides* gum resin: starch, I = 1:3 *Terminalia avicennoides* gum resin: starch.

4. DISCUSSION

The very high yield (86.21 %) of coarse and gritty textured gum resin makes for effective extraction and processing. The depression of the endothermic heat flow for the aceclofenac-gum dispersion, at the same 151 – 156 ℃ endothermic peak is an indication of physical interaction of aceclofenac. The sharpness and high intensity of the endothermic peak of the aceclofenac and aceclofenac-gum dispersion indicate purity and crystallinity for the aceclofenac in both samples (Uppugalla *et al* 2011; Shete *et al.*, 2022). This aceclofenac-gum thermograph indicates that there was no chemical alteration or distortion to the crystallinity and stability of the aceclofenac in the dispersion. These results suggest that aceclofenac active has acceptable thermal compatibility with the *Terminalia avicennoides* gum resin components. This interpretation is in line with studies from Uppugalla *et al*. (2011) and Shete *et al*. (2022) studies on aceclofenac.

The aceclofenac API SEM showed a highly crystalline nature typical of a crystalline API. The distinct structure displayed by *Terminalia avicennoides* gum resin is typical of high-molecular-weight components such as plant cellulose and lignins. The presence of

the visibly intact rod-shaped crystals in the aceclofenac-gum dispersion SEM that is typical of aceclofenac indicates a primarily physical mixture likely through surface adsorption and interlocking within the fibrous structure, with minimal to no significant destructive physicochemical interaction on the surface of the aceclofenac crystals in line with results from Thiyagarajan *et al*. (2011). The sharp endothermic peak observed with DSC analysis and the ordered shape in SEM photomicrograph aligns with reports by Thiyagarajan *et al*. (2011) on aceclofenac crystalline nature.

The FTIR spectrum of *Terminalia avicennoides* gum resin exhibited features typical of natural gums, specifically polysaccharides and/or polyphenols as interpreted from FTIR study on aceclofenac by Rashid *et al*. (2022). The broad peak around 3200 – 3500 / cm corresponds to the O-H stretch characteristic of the hydroxyl groups found in the water, alcohols and sugars of plant materials. The peaks at 2800 - 3000 are indicative of the hydrocarbon backbone of polysaccharide structures. The strong peaks in the 1600 -1700 / cm region are typical of the C=O stretch modes found in polysaccharide structures. The peak in the region of 1500-1200 / cm (at 1424 / cm) is due to vibration of $–CH_2$ and –C-OH monomeric unit groups. These peaks are often present in natural gums as explained by Thombare *et al*. (2023). The sharp peaks of the aceclofenac and its dispersion around 610, 748, 1255, 1715, 2937 and 3318 /cm associated with C – Cl aromatic ring stretching, aromatic-H stretching, C-O stretching in the molecule, C=O carbonyl stretch, C-H stretching and N-H amine bond stretching respectively, were noticeable in both the pure aceclofenac and the aceclofenac-gum dispersion. The stretched O-H region at 748 / cm of the aceclofenac dispersion can be interpreted as evidence of hydrogen bonding between the aceclofenac and the hydroxyl-rich components of the gum. The reduced intensity of the C=O peaks in the dispersion are indicative of physical interaction without major chemical change

The aceclofenac granules showed good flow properties with Carr's index <10.0 %, Hausner ratio < 1.1, flow rate >4.86 g / s, and angle of repose < 34.35 °. Granules with corn starch, acacia or co-processed excipients showed better flow properties compared to formulation with the gum resin alone. The better flow properties of granules can be attributed to the binding properties of acacia and corn starch as reported by researchers such as Ashour *et al*. (2022) and Khairnar *et al*. (2024).

The tablets with acacia gum or starch binders showed better compaction compared to tablets with the gum resin alone. Addition of acacia gum to the gum resin improved granules' binding properties and resulted in better compaction and reduced friability of its tablet. This aligns with reports by Ashour *et al*. (2022) and Khairnar *et al*. (2024) that tablets prepared with acacia gum showed acceptable crushing strength, tensile strength, friability and disintegration time.

Tablets with starch or gum resin or their co-processed excipients showed better hardness compared to tablets with acacia gum or its co-processed excipients. Higher concentration of acacia gum resulted in reduced hardness. This may be related to excessive binding capacity of acacia at high concentration, which has been reported by Mahours *et al*. (2017) to affect compressibility properties of some granules. Tablets formulated with gum resin, acacia, or co-processed gum resin and acacia exhibited the slow disintegration (> 42.22 min). This slow disintegration is probably because of the highly viscous nature and reduced hydration rate of the two natural gums, which hinder drug release. Tablets with starch or starch co-excipient showed better drug release from in both acidic and basic media compared to tablets with test gum resin or acacia. This confirms the diluent potentials of starch (Khairnar *et al*., 2024; Koekuyt *et al*., 2025). Tablets containing starch, co-processed starch, gum resin or acacia showed first order reaction. This indicates that the formulation matrices did not interfere with drug reaction in the dissolution medium, and that dissolution is mainly dependent on the concentration of drug. This interpretation follows the explanation of Ambika *et al*, (2025) on first order kinetics. The dissolution and kinetic release studies of the tablets containing co-processed gum resin and acacia, indicate a Fickian diffusion Higuchi release. Using the explanation of Fu and Kao (2010), Bose *et al*. (2013), Talevi and Ruiz (2022) and Ghizdovat *et al*. 2025, this release study indicates that the co-processed gum resin and acacia matrices created robbery polymers with longer relaxation time and no sharp boundaries with aceclofenac, allowing for concentration gradient diffusion of drug, decomposition and interaction of polymer with dissolution medium. This Higuchi model of drug release from this study is different from the zero-order drug release kinetics reported by Bamiro *et al*. (2011) for carvediol matrix tablets with *Terminalia avicennoides* gum matrix. This different drug release model may be as a result of the robbery matrix formed from co-processing the gum resin with acacia and aligns with a report by Sakkal *et al*. (2024) on the effect of polymer type, grade and form on drug-release.

5. CONCLUSION

The primary goal of the research was to evaluate the drug-release properties of co-processed *Terminalia avicennoides* gum resin matrix in aceclofenac tablets. Tablets formulated with co-processed gum resin and acacia had high tensile strength, and low friability, and showed controlled release properties. Batch F with 1:3 gum resin: acacia co-excipient binder showed good tablet mechanical properties

of > 6.83 KgF hardness and < 0.44 % friability and optimal controlled drug release properties. Tablets formulated with co-processed gum resin and corn starch matrix showed moderate drug release in both acidic and basic media and improved compaction but failed friability properties. Co-processing *Terminalia avicennoides* gum resin and acacia created a denser, more robust polymeric network that significantly enhanced the binding capacity, tablet integrity and created drug release properties that follow the Fickian diffusion Higuchi release model. The findings reveal that co-processing *Terminalia avicennoides* gum resin with different co-excipient affects the quality and drug release properties of its tablet.

Acknowledgements
The authors are grateful to the laboratory staff of Department of Pharmaceutics and Pharmaceutical Technology, Dora Akunyili College of Pharmacy, Igbinedion University Okada for making laboratory space available and their technical support.

Author Contributions:
Dr Nnamani designed the research studies and interpreted the research findings. Pharm Muazu carried out the dosage formulation and analysis.

Ethical Approval
In this article, the plant guidelines are followed as per the ethical committee guidelines of Department of Pharmaceutics and Pharmaceutica Technology, Dora Akunyili College of Pharmacy, Igbinedion University, Okada, Edo State, Nigeria; the authors studied the development and evaluation of co-processed *Terminalia avicennoides* gum resin as drug-release matrix for aceclofenac tablet. The *Terminalia avicennoides* (Combretaceae) tree was identified and authenticated by the Department of Pharmacognosy of Ɗora Akunyili College Pharmacy, Igbinedion University, Okada, Edo state and given herbarium number: IUO/16/127. The ethical guidelines for plants & plant materials are followed in the study for observation, identification & experimentation.

Informed Consent
Not applicable.

Conflicts of interests
The authors declare that they have no conflicts of interest, competing financial interests or personal relationships that could have influenced the work reported in this paper.

Funding
This research did not receive any external funding like specific grant from funding agencies in the public, commercial, or nonprofit sectors.

Data and materials availability
All data associated with this study will be available based on the reasonable request to corresponding author.

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