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Valorization of *Musa Parasidiaca* Pseudostem Biomass as Extended-Release Matrix for Diclofenac Tablet

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ABSTRACT

This study investigates the potential application of valorized Musa parasidiaca pseudostem biomass (VPB) as an extended-release tablet excipient. Musa parasidiaca plant is cultivated for its fruit, while its pseudostem is often discarded. M. parasidiaca pseudostem biomass was processed to VPB through soft-chemical treatment. A polymer alloy of VPB with polyethylene glycol (PEG 6000) was produced through the Kinetisol compounding technique. Nine diclofenac sodium batches (A-I) were granulated and tableted, in which batches A-E contained the alloy, F and G contained Avicel® PH 101-based, while H and I contained physical blends of the VPB and PEG 6000. The VPB, alloy, granules, and tablets were evaluated for compression properties and characterized through FTIR, DSC, SEM, and XRD analysis. A VPB yield of 12.9% was obtained. Batches A- E exhibited good granule flow (Hausner's ratio <1.2, Carr's index <16.7%) and tablet properties (tensile strength> 9.96 Kg/cm^2, friability, and disintegration times>36.69 min). Dissolution studies revealed that alloy-based batches (A-E) achieved extended-release properties with ≤60% drug release within 8 hours, and a correlation coefficient R^2 that followed Zero-order release kinetics. The FTIR, DSC, and SEM confirmed partial amorphization of diclofenac within the alloy. The study demonstrates the potential of valorized M. parasidiaca pseudostem biomass as a pharmaceutical grade extended-release tablet excipient. Future work can focus on optimizing the processing technique and pharmaceutical application of M. paradisiaca pseudostem biomass waste in a circular economy. Soft-chemical, Kinetisol compounding, polymer-alloy, pharmaceutical grade, tablet excipient, circular economy.

Keywords: *Musa parasidiaca pseudostem*, Biomass, Extended-release, Tablet. Pharmaceutical grade.

INTRODUCTION

Musa parasidiaca plant is widely cultivated for its edible fruit, while the rest of the plant is cut down and discarded to allow new plant shoots to sprout (Kumar *et al*., 2024; Maseko *et al*., 2024). The total discarded plant parts, consisting of the pseudostem, leaves and fruit peel wastes, are about 85 % of the crop. These discarded parts litter the farmland and constitute significant challenges such as greenhouse gas emissions of methane during decomposition, water and soil contamination and subsequent deforestation, and destruction of habitat (Gomez *et al*., 2023). Considering the rapid growth of global population, the need for more food, and the protection of the environment, there is a need to adopt resource efficiency, environmental protection, and innovative applications of biomaterials (Hugar *et al*., 2025). This can be achieved by the application of a circular economy model in the cultivation, use, and processing of *M. parasidiaca* plant produce, and valorization of plant by-products using green chemistry. In line with this objective, *M. parasidiaca* plant wastes are now been used for eco-friendly applications such as in production of ethanol, biofuels, biogas and biodiesel; and for production of biodegradable plastics and composite materials, activated carbon for wastewater treatment and other uses; fertilizers, and baking powder for food industry (Gomez *et al*., 2023; Ortiz *et al*., 2021; Nweke *et al*., 2023; Castillo *et al*.,

2023; Kumar *et al*., 2024; Hugar *et al*., 2025).

Biowastes from *M. parasidiaca* have been investigated in pharmacy for use as absorbent packs and packaging material, antimicrobial and wound-healing applications, and dosage form excipients such as disintegrant, binder, and drug-release matrix (Srivastava et *al.,* 2022; Nnamani *et al*., 2023; Shruthi *et al*., 2024; Umapathi *et al*., 2025; Waithaka *et al*., 2025). To the knowledge of this researcher, *M. parasidiaca* polymer has not been co-processed with a matrix polymer for application in extended-release formulation.

This study will focus on the application of the biomass polymer as a co-excipient for production of an extended-release matrix for diclofenac tablets. Diclofenac has been chosen as the model drug for this study as it is a common non-steroidal anti-inflammatory drug (Martinez-Rodriguez *et al*., 2025). Diclofenac is indicated for a wide range of conditions, including rheumatoid arthritis, osteoarthritis, pain, various non-rheumatic inflammatory conditions, dysmenorrhea, renal colic, and management of post-operative pain. Various formulation strategies have been explored to improve stability and bioavailability of diclofenac (Amanullah *et al*., 2022). Because of the short biological half-life (2 h) of diclofenac, it is preferred as a controlled-release formulation to reduce frequency of dosing (Sanjay *et al*., 2014).

MATERIALS AND METHODS

Diclofenac sodium powder, polyethylene glycol (PEG 6000), and magnesium stearate (William Ransom and Son Plc, Hitchin, Hertfordshire, England),crospovidone (Tianjin Kermel Chemical Reagent Co. Ltd, Tianjin City, China), avicel® PH 101 microcrystalline cellulose (FM Biopolymers, USA), lactose (Sigma Chemicals, St. Louis, USA), crospovidone, magnesium stearate (A.H.A International Co. Ltd, China). All chemicals used in the study were of analytical grade. Fresh M. parasidiaca pseudostem was harvested from a farm in Ekiadolor, Ovia North-East Local Government Area, Edo State, Nigeria

IDENTIFICATION OF *M. PARADIASCA* PSEUDOSTEM

The harvested *M. parasidiaca* pseudostem was identified by Mr. Awolabi of the Department of Pharmacognosy, Igbinedion University, Okada, Edo State. A voucher number IUO/25/410 was prepared for the pseudostem and preserved in the Pharmacognosy Herbarium, College of Pharmacy, Igbinedion University, Okada, for future reference.

VALORIZATION OF *M. PARADIASIACA* PSEUDOSTEM BIOMASS (VPB)

Adapting the methods of Gomez *et al.* (2023), Ortiz *et al.* (2021), Nweke *et al.* (2023) and Kumar *et al*. (2022)for waste valorization, and the College of Pharmacy, University of Okada multi-purpose production plant design for biofuel, eco-friendly fiber and cellulose nanoparticles and nanoplastics (Fig. 1), the downed pseudostem were split into two equal parts with a machete, washed and fed through a chopping machine to cut the pseudostem into small pieces of about 2 to 3 cm, weighed, and sun-dried for 3 days at 9 h per day. The dried material was pulverized to fines using a Eurosonic electric blender. Adapting a soft chemical treatment method from Amin *et al*. (2025), 1 kg of fines was delignified by treating with 10 L of 2 % sodium hydroxide solution at 100 ℃ for 3h, washed with distilled water, and treated further with 8 L of 17.5 % $^{w}/_{V}$ sodium hydrochloride solution at 80 ℃ for 1 h. The delignified biomass was then bleached using 2 L of a 1:1 mixture of 3.85 % $^{w}/_{v}$ sodium hypochlorite solution at 40 ℃ for 2 h. The bleached biomass was neutralized with 3.5 % $^{w}/_{v}$ sodium hydroxide and thoroughly washed with distilled water. The neutralized biomass was air-dried for 24 h, and then oven-dried at 60 ℃ for 1h. The dried biomass was milled using the Eurosonic blender, passed through a 0.2 mm stainless steel sieve, weighed, labelled as VPB (valorized pseudostem biomass), and stored in an airtight container for 48 h before

characterization and use.

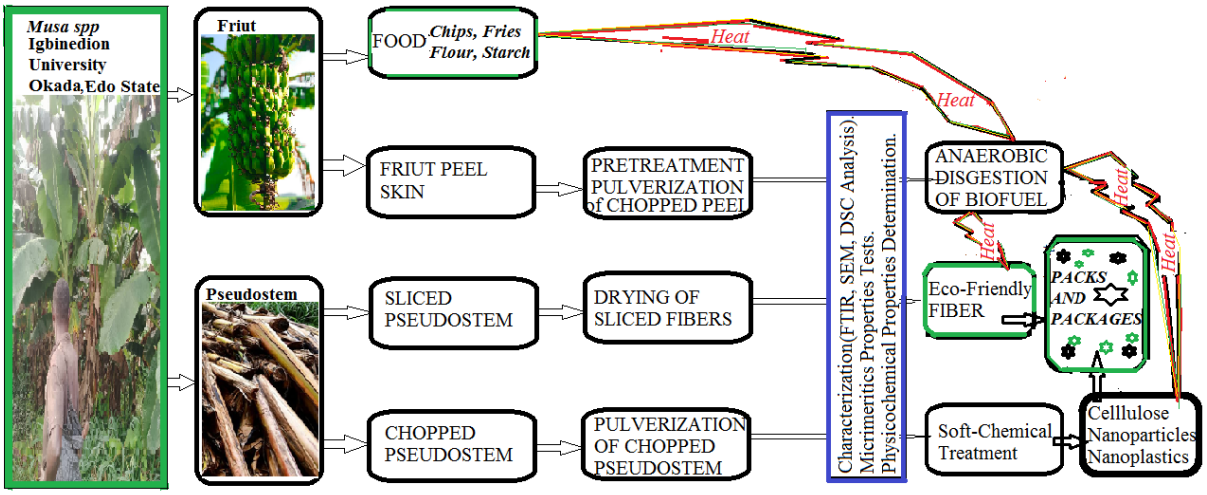


Figure 1: Flowchart of valorization of *M. parasidiaca* plant produce

PEG-VPB ALLOY

Formation: The Thompson *et al*. (2023) Kinetisol compounding technique for preparing polymer alloys was adapted. Using the formula in Table 1, VPB and PEG 6000 were blended in a mortar and mixed with 5 mL of 20 % ethanol. The mixture was dried to powder in a hot air oven at 60℃ for 30 min., and allowed to stand and cool at room temperature to get a solid polymer alloy. The PEG-VPB alloy was milled for 5 min in a Kenwood Multi-mill tube mill fitted with a 250 µm stainless sieve.

Organoleptic properties: The VPB was observed for colour, texture and smell.

Swelling Capacity: The swelling index of the VPB was calculated using the method of Malviya *et al*. (2021). A 2.2 cm butter paper was weighed and then dipped in a Petri dish containing 15 mL of water. A 100 mg VPB was placed on the butter paper and kept to swell. The weight of the swelled VPB was measured after 24 h at 25 ± 2 °C, and the swelling index was calculated by Equation 1.

$$\text{Swelling Index} = \frac{\text{Initial Weight} - \text{Final Weight}}{\text{Initial Weight}}$$ - - - - - Equation 1

Moisture content: One gram of the VPB was dried in a hot-air oven (Model DHG-9053A, Ocean Medical, England) at 105 °C for 4 h. The weight loss was used to calculate moisture content.

Solubility: A 100 mg of VPB was dispersed in 2 mL of water at room temperature, shaken, filtered, and the residue air-dried. The difference in weight before and after was taken as the solubility index.

pH: One gram of VPB was poured into a cylinder, made to 50 ml with distilled water, and centrifuged for 5 min. The electrode of a pH meter (pH-S25 EC/ORD, China) was dipped into the cylinder. The pH was read after 2 min. This test was repeated thrice, recorded and the average calculated.

DOSAGE DESIGN

Granulation

The diclofenac sodium, lactose, Avicel, PEG-VPB alloy, physical blend and crospovidone were passed through a 0.25 mm stainless steel sieve and were blended thoroughly in a

clean, dry mortar using a pestle to ensure uniform mixture. Magnesium stearate was added to the mixture and blended gently for 2 mins to produce lubricated granules. The lubricated granules were labelled and stored for 24 h before evaluation and compression.

Evaluation of granules properties

Angle of repose: Twenty-five grams of granules were poured into a stoppered funnel clamped at 5.0 cm above a flat surface and allowed to flow freely to form a heap. The height and base diameter of the heap were measured, and the angle of repose was calculated with equation 2. Where h is the height of the powder heap and r is the radius of the circular base. Measurements were repeated three times, and mean values recorded. This procedure was repeated for the batches of powder mix.

Angle of repose (θ) = $\tan^{-1}\ \frac{h}{r}$ .....equation 2

Compression

The diclofenac sodium solid dispersion was compressed into tablets using a type F8 single punch machine (Manesty Machines Limited, England) with a 10 mm die cavity and a set of upper and lower flat-faced punches to produce 300 mg tablets at 40 KN. The tablets produced were stored in a desiccator for 24 h awaiting analysis.

Table 1:Formula for producing 100 tablets of 100 mg diclofenac sodium tablet

Components		Batches (g)								
		A	B	C	D	E	F	G	H	I
Diclofenac Sodium		10	10	10	10	10	10	10	10	10
Lactose		4	4	4	4	4	4	9	4	4
Avicel PH 101							15	10		
PEG-VPB alloy	VPB	5	6	7.5	9	10				
	PEG	10	9	7.5	6	5				
Physical blend	VPB								10	7.5
	PEG								5	7.5
Crospovidone		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Magnesium stearate		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total		30	30	30	30	30	30	30	30	30

NB: PEG = Polyethylene glycol 600

Evaluation of tablet properties: *Weight uniformity*. The weight of 20 tablets randomly selected from a batch was taken using an electronic balance (Mettler, Switzerland). The individual weight of each of the 20 tablets was also taken. The mean weight and the deviation of the individual weight from the mean weight of the 20 tablets were calculated.

Tensile strength: The thickness and diameter of a randomly selected tablet was measured with a micrometer screw gauge (Gallenkamp, England). The tablet was then subjected to a hardness test using a Mosanto tablet hardness tester (Model MHT-20, The Rmonik, Campbell Electronics, India). The diameter (d), thickness (T) and hardness (F) of the tablets were recorded and used to calculate the tablet tensile strength (δ) using equation3. The test was done in triplicate, and the mean tensile strength recorded.

$\delta = \frac{2F}{\pi dT}$ .....equation 3

Friability: Ten pre-weighed tablets from a batch were placed inside the single drum of friabilator (PTF 10E, Pharma Test Instruments India Pvt. Limited, India)and rotated for 4 min at 25 rpm. The tablets were removed from the drum, dedusted, and reweighed. The

percentage weight loss calculated. Tests were conducted in triplicate, with mean percentage weight loss recorded as percentage friability.

Disintegration time: Six randomly selected tablets from a batch were placed in the six tubes of a disintegration tester (Model MK4, Manesty Machine Limited, England) basket rack. The basket was then immersed into the disintegration apparatus beaker containing distilled water at 37± 1.0 ℃ and the tester operated at 30 cycles/ min. The time taken for fragments of the tablets to completely pass through all the tube meshes was recorded. The test for all the batches was done in triplicates. Mean disintegration times with standard deviation were recorded.

Dissolution rate: Using a dissolution apparatus (Caleva ST7, UK) and basket method, the dissolution test for a tablet was carried out in a holding vessel of 900mL of 0.1N hydrochloric acid (HCL, pH1.2) medium maintained at 37 + 0.5 C. The apparatus was operated at 100rpm for the initial 2h in order to simulate stomach, gastric conditions. Following this stage, the holding vessel was replaced with 900mL of phosphate buffer (pH 6.8) maintained at 37 + 0.5 C, and the dissolution experiment was continued for an additional 6h under the same agitation conditions to mimic the intestinal environment. At predetermined intervals throughout both stages, 5mL aliquots of the dissolution medium were withdrawn and replaced with equal volumes of fresh medium maintained at 37 + 0.5 C to preserve sink conditions. The withdrawn samples were filtered, appropriately diluted with the corresponding dissolution medium, and analyzed spectrophotometrically at the wavelength maximum (max) of 275 nm using a T70 UV-Visible spectrophotometer (PG Instruments Ltd, UK). Drug concentrations at each time point were determined with reference to a calibration curve constructed from pure diclofenac powder. This test was done in triplicate and the mean drug concentration was used to calculate the percentage drug release.

Drug-excipient Compatibility Studies: Ten tablets randomly selected from Batch C (that contain a 1:1 ratio of VPB to PEG 6000) were crushed to powder. The crushed powder, pseudostem VPB and diclofenac sodium powder were packed as individual samples and characterized using Fourier transform infrared (FTIR), Scanning electron microscopy (SEM), and Differential Scanning Calorimetry (DSC) analysis.

The FTIR analysis of each sample was carried out on the FTIR 4100 spectrophotometer (Shimadzu Co., Japan) using the potassium bromide (KBr) pellet method. The sample (5 mg) was blended with potassium bromide to give 200 mg of the mixture. The mixture was then compressed using a Sigma KBr press into a tablet, and the tablet was placed in the sample compartment of the spectrophotometer. The spectrum of the sample was recorded in the range of 4000-750 cm^{-1}.

The DSC analysis of each sample was carried out using a DSC apparatus (Netzsch DSC 204F1 Phoenix, Germany). Four milligrams (4mg) of a sample were weighed into an aluminum pan. The seal of the pan was pierced and placed in the calorimeter previously calibrated with indium and nitrogen as the purge gas. Heating of the sample was carried out at the rate of 10 °C per min from 30 to 350 °C under nitrogen at a flow rate of 70 ml/min.

RESULTS

Percentage yield, organoleptic and hydration properties of VPB extract: The percentage yield of VPB from the *M. parasidiaca* pseudostem was 12.9%. The VPB was creamy in colour, odourless, with a fluffy texture, and had poor solubility, all of which are characteristic features of native cellulose. It exhibited a moisture content of 2.24% and a swelling capacity

of 66.67%.

Pre-Compression property of powder blends

The angle of repose of granules was 21.5, 28.6, 26.4, 33.9, 25.3, 34.6, 40.0, 34.3, and 35.5° for batches A, B, C, D, E, G, G, H, and I, respectively.

Physicochemical properties of tablet

As displayed in Table 2, the tablets' weight range was 0.292-0.301 g, while their percentage friability was < 0.68 %. Tablet tensile strength of > 16.01, 9.61-11.61, 9.56, and 5.14 Kg/cm^2 were exhibited by batches F and G, A-E, I, and H, respectively, as shown in Table 2. The friability of all batches was ≤1 %. Batches G, F, H, G, and A-E had disintegration times of 13.25, 13.6, 35.01, 36.59, and >36.69 min, respectively.

Table 2: Physicochemical properties of diclofenac tablets

Batch	Tensile strength	% Friability	Weight (g)	Disintegration Time	D120 in pH 1.2	D480 at pH 6.8
A	11.61	0.68	0.296±0.0010	36.69	6.46	53.54
B	9.93	0	0.297±0.0108	48.54	3.42	35.35
C	11.48	0.34	0.301±0.0830	61.02	4.62	46.15
D	9.61	0.33	0.298±0.0221	67	6	48.46
E	11.14	0	0.301±0.0060	65	3.05	29.26
F	>16.01	0.34	0.301±0.0076	13.6	89	0
G	>16.44	0.34	0.292±0.0109	13.25	97	0
H	5.14	0.34	0.299±0.0093	35.01	3.66	33.27
I	9.56	0.35	0.295±0.0089	36.59	6.14	47.06

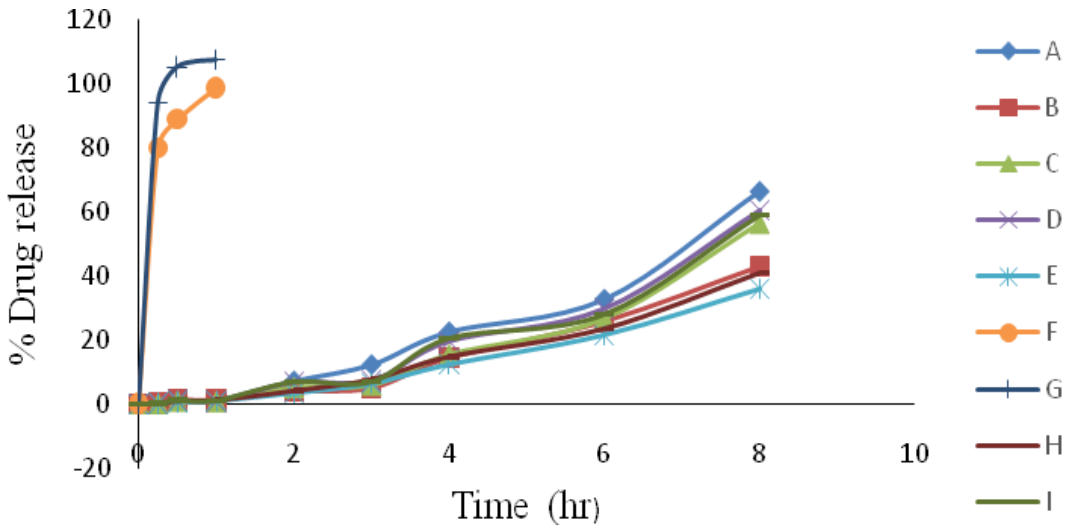


Figure 2: Drug release profile for diclofenac tablets

Dissolution and drug release properties

Dissolution study results are shown in Table 2 and the drug release profile in Fig. 2, with batches F and G releasing about 90 % drug within 2 h, while tablets with VPB released < 6.46 within the same 2 h. The correlation coefficient R^2 displayed in Table 3 revealed that batches A – E showed higher readings (0.8946-0.9528) with Zero-order release kinetics.

Table 3: Correlation coefficient (R^2) and K-P release exponent (n) of diclofenac tablet dissolution studies.

	Zero	First	Higuchi	K-P	N
A	0.9318	0.8328	0.7666	0.6213	-1.4429
B	0.9327	0.7422	0.7564	0.5383	-1.6711
C	0.8946	0.6536	0.7088	0.601	-1.8491
D	0.9142	0.6837	0.7384	0.6041	-1.7593
E	0.9528	0.7403	0.7863	0.5722	-1.7373
F	0.6337	0.5054	0.89	0.8755	-0.0276
G	0.5607	0.4882	0.8408	0.901	-0.0036
H	0.9535	0.7083	0.7909	0.5697	-1.7261
I	0.9102	0.6452	0.7387	0.5996	-1.7755

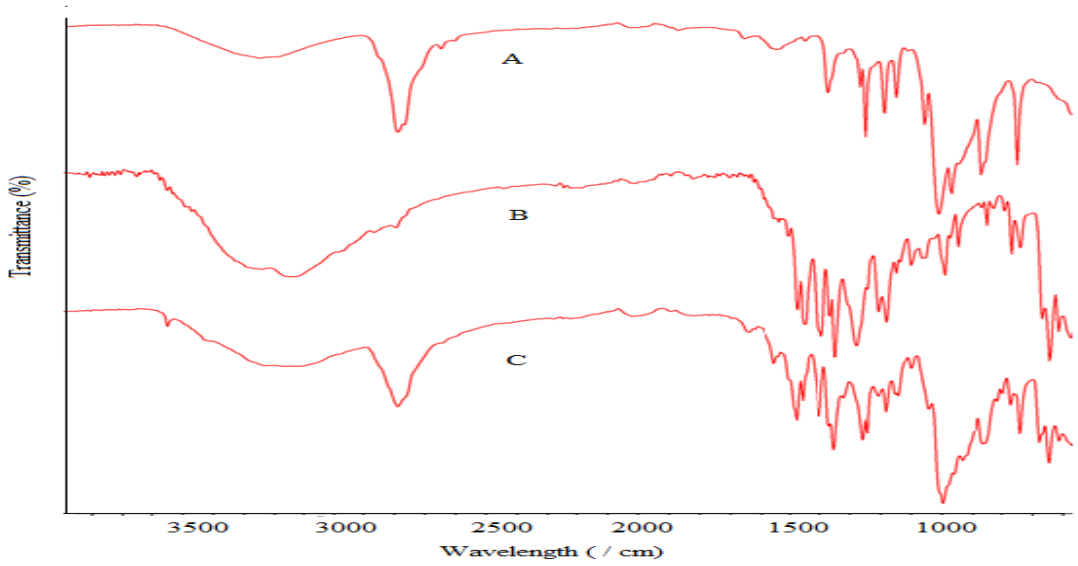


Figure 3: FTIR Spectrum of (A) PEG-VPB alloy, (B) Diclofenac sodium, (C) Batch C tablet

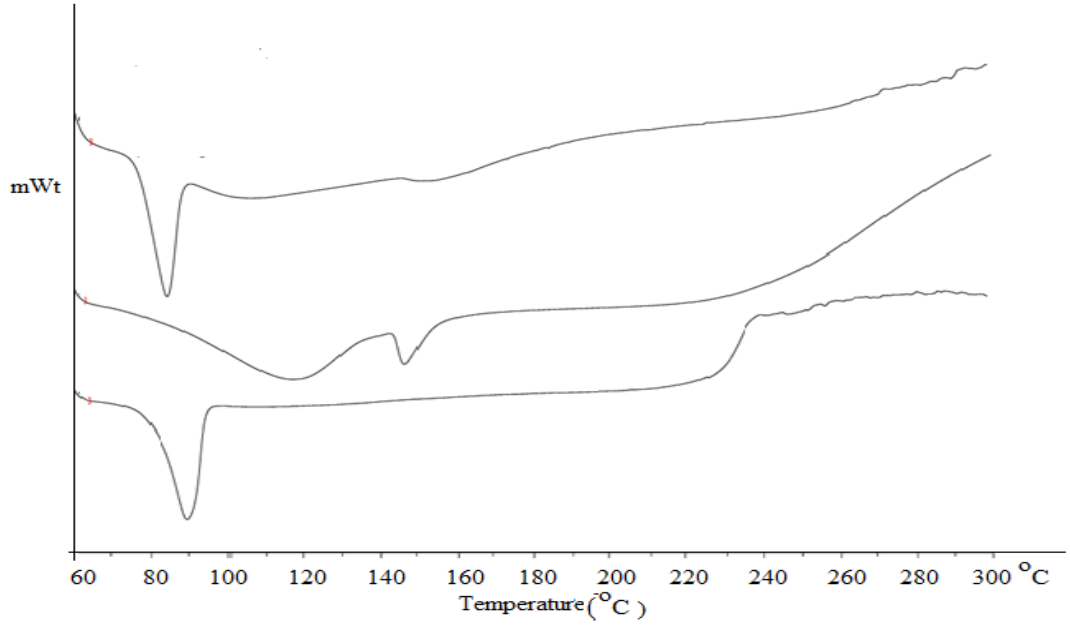


Figure 4: DSC thermogram of (A) VPB alloy, (B) Diclofenac sodium, (C) Batch C tablet

Alloy Characterization and Drug-excipient Compatibility

The FTIR readings of the samples are revealed in Figure 3. FTIRspectrum ofPEG-VPB alloy showed strong and broad peaks at ~3400 cm^{-1} (O-H stretching) and ~1100 cm^{-1} (C-O-

C stretching). The FTIR spectrum of diclofenac showed distinct absorption bands at ~3400 cm^{-1} (N-H stretching medium stretching), ~1750 cm^{-1} (C=O stretching of carboxylate), ~1650 (C=C stretching), ~1450 cm^{-1} (aromatic C- H bending), and 1342 cm^{-1} (aromatic C-N stretching). In the alloy tablet, diclofenac's bands appeared broadened and shifted, particularly around the carboxylate and N-H regions.

Differential Scanning Calorimetry (DSC)

DSC thermogram of the PEG-VPB alloy, shown in Figure 4, exhibited two endothermic events at approximately 77 °C and 288 °C. Diclofenac displayed a sharp endothermic peak at 290 °C. In the alloy-based tablet, the sharp melting endotherm of diclofenac was absent. Instead, broader and less intense transitions were observed within the 109–181 °C and 217 °C ranges.

DISCUSSION

The low moisture content of the VPB suggests good storage stability and reduced risk of microbial contamination, while the high swelling capacity is indicative of potential functionality as a tablet disintegrant. The near-neutral pH (6.4) indicates compatibility with most drugs intended for oral use. These findings are consistent with earlier reports on naturally derived celluloses (Waithaka *et al.*, 2025; Rana *et al.*, 2022).

The angle of repose for granules with PEG-VPB alloy indicated good flowability. This result is consistent with findings of Shailendra and Priti (2011) and Christoforou *et al.* (2025)on binding, plasticity, and improved processing ability by PEG 6000. The flow properties of the granules with PEG- VPB alloy were better than the flow properties of granules with conventional Avicel® PH 101 reported by Rana *et al.* (2022), Adeleye *et al.* (2025), and More *et al.* (2026). These results suggest that co-processing enhanced the flow properties of granules.

All the batches complied with BP tablet specifications for uniformity of weight, and the tablet friability values were within pharmacopeial limits, confirming adequate mechanical strength. Batches F and G with Avicel® PH 101 disintegrated within the pharmacopeial limit for conventional tablets. The dissolution studies revealed that Batches F and G which contain Avicel PH 101, exhibited very rapid drug release. This enhanced binding, filling, disintegration, and rapid drug release of Avicel PH 101 agree with previous reports by Adeleye *et al.* (2025) that the porous and fast-wicking nature of Avicel promoted rapid disintegration and drug dissolution. Tablets with co-processed VPB-PEG alloy systems displayed controlled release patterns. Increasing the VPB proportion in the PEG-VPB alloy progressively reduced drug release, attributable to VPB insoluble behaviour that restricted medium penetration and contact with drugs. This VPB behavior is consistent with the controlled drug release attributes of polymers from agricultural waste as reported by Sango-Parco *et al.* (2025). A physical blend of PEG and VPB released drugs more rapidly than the corresponding co-processed systems. Using the explanations by Li *et al.* (2021) and Laracuente *et al.* (2020), the correlation coefficient R^2showed that co-processed systems displayednon-Fickian diffusion zero-order release kinetics. These findings align with the established behaviour of mixed hydrophilic–hydrophobic polymer matrices used for controlled-release formulations (Eraga *et al.*, 2023).

The strong and broad O-H stretching and C-O-C stretching peaks of the PEG-VPB alloy FTIR spectrum are characteristic of cellulose (Thompson *et al.*, 2023). FTIR spectra further highlighted the interaction between diclofenac and the PEG-VPB alloy. The observed shifts and broadening in carboxylate and N-H stretching bands point towards hydrogen bonding and intermolecular forces. These interactions explain the stabilization of diclofenac in an

amorphous form within the tablet (Nnamani *et al.*, 2023). The two endothermic events of the PEG-VPB alloy DSC thermogram correspond to the melting transition of PEG and the degradation temperature of cellulose for VPB, respectively. The DSC result of the alloy tablet showed the disappearance of diclofenac's sharp melting endotherm, replaced by broad transitions. The thermal, structural, and morphological analyses collectively confirm the transformation of diclofenac from crystalline to a more amorphous form within the PEG-VPB alloy system. Using the explanation of Hazarika *et al.* (2024), the thermal behavior of the alloy tablet strongly suggests molecular dispersion of diclofenac within the alloy matrix from amorphization, and possible drug-excipient interactions. Similar findings have been reported in Shah and Kakumanu (2015) for poorly soluble drugs dispersed in PEG-cellulose systems.

CONCLUSION AND RECOMMENDATIONS

Valorized *M. parasidiaca* pseudostem biomass improved the flow and compaction properties of granules and improved the mechanical strength of tablets. Tablets containing the biomass and polyethylene glycol (PEG) in the alloy system exhibited more extended drug release characteristics than tablets containing physical blends of the biomass and PEG, while Avicel-based tablets showed typical immediate-release behaviour. The *M. paradisiaca* pseudostem biomass – PEG alloy system improved diclofenac solubility and created a matrix system that controlled the release of diclofenac. Future work can focus on optimizing *M. paradisiaca* pseudostem biomass processing to pharmaceutical-grade excipients, and further computational chemistry, molecular docking, and drug design modelling to maximize and scale up this waste valorization innovation for more pharmaceutical industrial application in a circular economy.

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