

COMPARATIVE IN-VITRO CHARACTERIZATION OF MATRIX TABLETS OF DICLOFENAC SODIUM PREPARED FROM ALKALI ISOLATED AND PHOSPHORYLATED BARNYARD MILLET STARCH**Anal Sutar, Reena Shende*, Satkar Prasad****RKDF School of Pharmaceutical Sciences, BHABHA University, Madhya Pradesh, India***Corresponding Author's E mail: ryadav@yahoo.com

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ABSTRACT

The development of modified-release drug delivery systems has improved the safety, efficacy, and patient compliance of pharmaceutical therapies. Matrix tablets represent a simple, cost-effective strategy for achieving sustained or controlled drug release, particularly when formulated with appropriate polymeric excipients. Natural starches are attractive excipients due to their biocompatibility, biodegradability, non-toxicity, and abundance; however, native starches often display poor mechanical strength, high swelling, and inconsistent release behavior, limiting their application in controlled-release formulations. Chemical modification, such as phosphorylation or cross-linking, enhances the physicochemical and functional properties of starch, improving water resistance, thermal stability, gel strength, and flow characteristics. In this study, phosphorylated barnyard millet (*Echinochloa frumentacea*) starch and cross-linked Zingora starch were evaluated as matrix-forming agents. Cross-linking increased starch yield ($97.8 \pm 0.57\%$ w/w vs. $14.68 \pm 0.52\%$ w/w for alkali-isolated starch), moderated pH (6.8 vs. 11), reduced moisture and amylose content, and improved water-binding capacity and swelling behavior. Precompression studies indicated better flow properties, while tablet evaluation revealed enhanced hardness (4.2 ± 0.04 kg/cm²), reduced friability ($0.68 \pm 0.04\%$), and slower disintegration, demonstrating improved mechanical integrity. Film-coated matrix tablets formulated with these modified starches exhibited controlled release and structural stability under in vitro conditions. These findings suggest that phosphorylated and cross-linked millet starches are promising, sustainable excipients for developing advanced controlled-release tablet formulations.

Keywords: Modified-release drug delivery; Matrix tablets; Barnyard millet starch; Phosphorylated starch.

INTRODUCTION

The development of modified release drug delivery systems has significantly advanced the effectiveness, safety, and patient compliance of pharmaceutical therapies. Among the various

approaches, matrix tablet systems offer a simple, cost-effective strategy to achieve sustained or controlled drug release, particularly when formulated with suitable polymeric excipients. Natural polymers such as starches have gained substantial attention in this context due to their biocompatibility, biodegradability, non-toxicity, and wide availability. However, native starches often exhibit limitations such as poor mechanical strength, high swelling, and inconsistent release behavior, which restrict their utility in sustained release formulations¹⁻⁵.

To overcome these limitations, chemical modifications—such as phosphorylation—have been employed to alter the physicochemical and functional properties of starch. Phosphorylation improves water resistance, thermal stability, and gel strength, making the modified starch more suitable for controlled drug release applications. Barnyard millet (*Echinochloa frumentacea*), a drought-resistant and underutilized cereal crop, offers a sustainable source of starch with favorable baseline properties such as moderate amylose content and small granule size. When phosphorylated, barnyard millet starch holds promise as a novel, cost-effective matrix-forming agent capable of modulating drug release profiles^{6,7}.

Film coating of matrix tablets serves a dual purpose: it enhances aesthetic and mechanical properties while offering an additional layer of control over the release of the active pharmaceutical ingredient (API). Incorporating a film coating over matrix tablets containing phosphorylated barnyard millet starch could further optimize the drug release kinetics and protect the formulation from environmental factors^{8,9}.

The present study aims to develop and evaluate film-coated matrix tablets formulated with phosphorylated barnyard millet starch for modified release. The formulation was characterized for physicochemical properties, drug release behavior, and matrix integrity under in-vitro conditions. This work contributes to the growing body of research focused on utilizing modified natural polymers as sustainable and effective excipients in advanced drug delivery systems.

Materials

Barnyard Millet Starch was extracted from *Echinochloa frumentacea* grains sodium trimetaphosphate (STMP) and sodium tripolyphosphate (STPP) from, Diclofenac Sodium, from Supplier Name, Country]; Polyvinyl Alcohol (PVA); Hydroxypropyl Methylcellulose (HPMC K15M); Magnesium

Stearate; Talc; Microcrystalline Cellulose (MCC, Avicel PH 102); Polyvinyl alcohol (PVA); PEG 400 or PEG 6000; Titanium Dioxide; Distilled Water; Phosphate Buffer Saline (PBS), pH 6.8 and 7.4.

Methods

Procurement and authentication of plant material

Healthy, mature plants were collected during the flowering/fruiting stage from the agricultural research plots within the university campus. Samples were air-dried and stored in clean paper bags prior to starch extraction.

Extraction of Barnyard Millet Starch

Barnyard millet grains (*Echinochloa frumentacea*) were cleaned, washed, and soaked in 0.1% sodium metabisulfite solution for 24 hours. The soaked grains were wet-milled and passed through muslin cloth to separate the starch milk. The filtrate was allowed to settle, and the supernatant was decanted. The sediment starch was washed repeatedly with distilled water, dried at 40 °C, and sieved through a 100-mesh sieve^{11,12}.

Phosphorylation of Barnyard Millet Starch

The native starch was modified using a dry phosphorylation method. Briefly, starch was mixed with sodium trimetaphosphate (STMP) and sodium tripolyphosphate (STPP) in a 99:1:1 ratio (w/w). The mixture was adjusted to pH 10 using 1 N NaOH and incubated at 45–50 °C for 3 hours. After modification, the starch was neutralized with 0.1 N HCl, washed thoroughly with distilled water, and dried at 40 °C. The phosphorylated starch was then sieved and stored in airtight containers for further use¹³.

Preformulation study of alkali isolated Alkali-isolated zingora starch (AMS) and Cross-linked zingora starch (PZS)

a. Yield:

Weigh the dried millet grains (W_1), extract and dry the starch to constant weight (W_2), then calculate the percent yield using:

$$\text{Percent yield (\%)} = \frac{W_1}{W_2} \times 100 \dots \dots \dots i$$

b. pH:

Prepare a 1% starch suspension in distilled water, stir well, and measure the pH at room temperature using a calibrated pH meter.

c. Swelling power

Weigh 0.5 g of starch, add 25 mL of water, and heat at 85°C for 30 minutes. After cooling, centrifuge, decant the supernatant, weigh the swollen sediment, and calculate swelling power as:

$$\text{Swelling power } \left(\frac{\text{g}}{\text{g}}\right) = \frac{\text{wt of dry starch}}{\text{weight of swollen sediment}} \dots \dots \dots ii$$

d. Moisture content

Weigh ~2 g of starch (W_1) into a pre-weighed dish, dry at 105°C until constant weight (W_2), and calculate moisture content using:

$$\text{Moisture content (\%)} = \frac{W_1 - W_2}{W_1} \times 100 \dots \dots \dots iii$$

e. Paste clarity

Prepare a 1% starch suspension, heat to form a paste, cool to room temperature, and measure the transmittance (%T) at 650 nm using a spectrophotometer. Higher %T indicates greater paste clarity.

f. Pre-compression Parameters

i. Angle of repose ($\emptyset$)

After precisely weighing 100 grams of the mixture, it was carefully poured through a funnel with the tip fastened 2.5 cm above the graph paper that was set out on a horizontal surface. The mixture was poured until the conical pile's apex barely touched the funnel's tip. Table 1 illustrates the relationship between the powder's flow characteristics and angle of repose. Equation iv provides the following formula for calculating angle of repose¹⁴⁻¹⁶.

$$\emptyset = \tan^{-1} \left(\frac{h}{r} \right) \dots \dots \dots iv$$

Where, θ = angle of repose, r = radius of the pile, h = height of the pile.

Table 1: Correlation of angle of repose with flow properties of powder

S. No	Angle of repose (θ)	Powder flow
1	25-30	Excellent
2	31-35	Good
3	36-40	Fair
4	41-45	Passable
5	46-55	Poor
6	56-65	Very Poor
7	>66	Extremely poor

ii. Bulk density

Apparent bulk density (ρ_b) was determined by pouring the blend into a graduated cylinder. The bulk volume (V_b) and weight of the powder (M) was determined. The bulk density was calculated using the formula given in Equation v¹⁴⁻¹⁶.

$$\rho_b = \frac{M}{V_b} \dots \dots \dots v$$

iii. Tapped density

The measuring cylinder containing a known mass of blend was tapped for a fixed time (around 250). The minimum volume (V_t) occupied in the cylinder and the weight (M) of the blend was measured. The tapped density (ρ_t) was calculated using the formula given in Equation vi¹⁴⁻¹⁶.

$$\rho_t = \frac{M}{V_t} \dots \dots \dots vi$$

iv. Carr's index

The simplest way for measurement of free flow of powder is compressibility, an indication of the ease with which a material can be induced to flow is given by compressibility index (C.I) which is calculated using the formula given in Equation vii. The correlation between the compressibility index and flow properties of powder are shown in the Table 2¹⁴⁻¹⁶.

$$C.I (\%) = \frac{(tapped\ density - Bulk\ density) \times 100}{Tapped\ density} \dots\dots\dots vii$$

Table 2:Correlationbetweencompressibilityindexandflowpropertiesof powder

S. No	% Compressibility Index	Powder flow
1	<10	Excellent
2	11-15	Good
3	16-20s	Fair
4	21-25	Passable
5	26-31	Poor
6	32-37	Very Poor
7	>38	Extremely poor

v. Hausner'sratio

Hausner's ratio is an indirect index of ease of powder flow. It was calculated by the using the formula given in Equation viii.The correlation between the hausner's ratio and flow properties of powder are shown in the Table 3¹⁴⁻¹⁶.

$$\text{Hausner'sratio} = \frac{t}{d} \dots\dots\dots viii$$

Where *t=tappeddensityand *d=bulk density

Table3:CorrelationofHausner'sratiowithflowproperties

S. No	Hausner'sratio	Powder flow
1	1.00-1.11	Excellent
2	1.12-1.18	Good
3	1.19-1.25	Fair
4	1.26-1.34	Passable
5	1.35-1.45	Poor
6	1.46-1.59	Very Poor
7	>1.60	Extremely poor

These were evaluated to assess powder flow properties before compression.

Formulation of Matrix Tablets

Matrix tablets were prepared using the direct compression method. The model drug, phosphorylated barnyard millet starch (as the primary matrix-former), microcrystalline cellulose (as diluent), and other excipients were accurately weighed and blended in a mortar for 10 minutes. Magnesium stearate and talc were added as lubricant and glidant, respectively. The mixture was compressed into tablets using a single-punch tablet press with a flat-faced punch (10 mm diameter)¹⁷⁻¹⁹.

Film Coating of Matrix Tablets

Tablets were coated using a 5% w/v aqueous solution of polyvinyl alcohol (PVA), plasticized with 1% PEG 400. Coating was performed in a conventional pan coater at 45–50 °C with intermittent rotation. Coating was continued until a uniform film was formed (coating weight gain ~3–5%). The coated tablets were dried and stored in desiccators for further analysis²⁰.

Characterization of Matrix Tablets

a. Post-compression Parameters

Twenty tablets were chosen at random, and their average weight was calculated. The percentage deviation from the average was then computed after each tablet was weighed separately. The weight variation limits listed in Table 4²¹⁻²⁵.

Table 4: Percentage deviation allowed for the tablets

PharmaceuticalForm	Avg.Weight in mg	%Deviation
Tablets	130 mg or less	10
	More than 130 mg	7.5
	More than 324 mg	5

b. Thickness

Controlling the tablets' physical attributes, like their thickness and size, is crucial for both tablet uniformity and consumer acceptance. The die and punches used to make the tablets determine their diameter and punch size. A screw gauge is used to measure the tablet's thickness. The tablet's thickness

and hardness are correlated. The thickness of tablets should be kept within a standard range of $\pm 5\%$. Controlling thickness is also necessary to make packaging easier. A screw gauge was used to measure each of the ten pre-weighed tablets' thickness in millimeters (mm). Both the standard deviation and the average thickness were reported^{21,22}.

c. Hardness

Tensile strength (Kg/cm^2) is a measure of tablet strength. The force needed to compress a tablet into pieces is known as the tablet crushing load. A tablet hardness tester (Monsanto hardness tester) was used to measure it. For every formulation batch, three tablets were randomly tested, and the average reading was recorded^{21,22}.

d. Friability

The Roche Friabilator (Electrolab, India) was used to assess the tablets' friability. This apparatus consists of a plastic chamber that is programmed to rotate at a speed of 25 rpm for four minutes, dropping the tablets six inches apart with each rotation. Twenty tablets that had been previously weighed were put in the friabilator and rotated 100 times. The tablets were reweighed after being cleaned with a gentle muslin cloth. Equation vi provides the formula for the friability (% F)^{21,22}.

$$\% F = (1 - W_0/W) \times 100 \dots \dots \dots \text{vi}$$

Where, W_0 is weight of the tablets before the test and W is the weight of the tablets after test

e. Content Uniformity

Tablets are finely powdered and powder equivalent mg of drug is accurately weighed and transferred to 100 ml volumetric flasks containing solution of desired pH. The flask is shaken to mix the contents thoroughly. The volume is made up to the mark with solution and filtered. One ml of the filtrate is suitably diluted and drug content is estimated using a double beam UV-visible spectrophotometer. This procedure is repeated thrice and the average value is calculated²³.

f. Disintegration time

Disintegration time was measured using a disintegration apparatus. For this purpose, a glass beaker was filled with 900 ml of media at $37^\circ\text{C} \pm 0.5^\circ\text{C}$. The tablet was carefully put in the center of the tablet assembly and the time for the tablet to completely disintegrate into fine particles was noted²⁴.

g. In-vitro drug release

Dissolution studies were performed using a USP Type II paddle apparatus. The tablets were placed in 900 mL of phosphate buffer (pH 6.8 or 7.4) at 37 ± 0.5 °C and 50 rpm. Samples were withdrawn at predetermined intervals (e.g., 1, 2, 4, 6, 8, 10, 12 hours), filtered, and analyzed using UV spectrophotometry. Drug release profiles were compared between uncoated and film-coated tablets, and release kinetics were assessed using mathematical models (zero-order, first-order, Higuchi, Korsmeyer-Peppas)²⁵.

Table 5: Summary of in vitro dissolution study of atorvastatin calcium solid dispersion tablets

Parameter	Condition
Temperature	$37 \pm 0.5^{\circ}\text{C}$
Dissolution media	6.8pHphosphate buffer
Volume of dissolution media	900 ml
Aliquot withdrawn	5 ml
Aliquot replaced	5ml of the fresh buffer solution
Dissolution apparatus	USP type II (paddle)
Revolutions per minute (speed)	100 RPM
Sampling time intervals	10, 20, 30, 40, 50 and 60 min

Absorbance of solution was checked by UV Spectrophotometer (UV 1800 double beam spectrophotometer) at a wavelength of 274.8 nm and drug release was determined from standard curve²⁶.

h. Swelling and Erosion Studies

Swelling index was determined by weighing tablets before and after immersion in dissolution media. Erosion was calculated by the difference in dry weight before and after immersion and drying²⁷.

i. Stability Studies

The optimized formulation of atorvastatin calcium tablets was subjected to stability studies at $40^{\circ}\text{C} \pm 2^{\circ}\text{C} / 75\% \pm 2\% \text{ RH}$ for period of one month. Each tablet was individually wrapped in aluminum foil and packed in amber colored bottle and put at above specified condition in a heating humidity

chamber for one month. The tablets were analyzed for the hardness, disintegration time, and drug content and in-vitro drug release²⁷.

RESULTS AND DISCUSSION

Preformulation study of alkali isolated Alkali-isolated zhingora starch (AMS) and Cross-linked zhingora starch (PZS)

a. Percent Yield

The yield of isolated starch using alkali isolation method was $14.68 \pm 0.52\%$ w/w, and the yield of cross-linked starch was $97.8 \pm 0.57\%$ w/w (Table 6).

b. pH of Starch

The pH of the alkali-isolated aqueous dispersion of zhingora starch was found to be 12, whereas, pH of the 1% w/v starch dispersion of PZS was found to be 6.5 (Table 6).

c. Determination of Swelling Power

There are several factors that influence the swelling capacity of starch, including protein content, starch type, granule size, etc. Starch has comparatively higher swelling power if the protein content is higher. It was studied that PZS had a swelling power of $194.3 \pm 0.0064\%$ w/w (Table 6).

d. Determination of Moisture Content

The moisture content of the excipients generally influences the stability. The moisture content was determined to be $15.33 \pm 1.01\%$ w/w for AZS as shown in Table 1. The cross-linked zhingora starch moisture content dropped down by up to 20% (Table 6).

e. Determination of Swelling Power

The water-binding capacity of AZS was found to be $0.867 \pm 0.0431\%$ w/w, while that of the cross-linked zhingora starch was found to be 1.65 ± 0.15 w/w (Table 6).

f. Determination of Paste Clarity

Light transmittance (%T) at 650 nm was used to assess the PZS and AZS paste clarity which was found to be $3.40 \pm 0.32\%$ T for AZS and $2.56 \pm 0.115\%$ T for cross-linked starch (Table 6).

Table 6: Preformulation study data for alkali isolated Alkali-isolated zhingora starch (AMS) and Cross-linked zhingora starch (PZS)

Property	Alkali-isolated zhingora starch (AMS), (mean±S.D.)	Cross-linked zhingora starch (PZS), (mean±S.D.)
Yield (%)	14.68 ± 0.52% w/w	97.8 ± 0.57% w/w
Total ash content (dry basis db, % w/w)	0.061±0.051	0.082±0.021
pH of aqueous dispersion	11± 0.43	6.8±0.23
Paste clarity of starch (%)	3.40±0.321	2.56±0.115
Swelling power of starch (% w/w)	194.3±0.006	180.1±0.285
Moisture content (% w/w)	15.33±1.012	11.264±0.715
Water-binding capacity (% w/w)	0.86±0.043	1.6±0.152
Amylose content (% w/w)	19.96±3.565	9.65±2.144

g. Determination of precompression parameters for preformulation study of alkali isolated Alkali-isolated zhingora starch (AMS) and Cross-linked zhingora starch (PZS)

The physicochemical properties of alkali-isolated Zhingora starch (AMS) and cross-linked Zhingora starch (PZS) were evaluated, and the results are summarized in Table 8. The bulk density of AMS and PZS was found to be 0.33 ± 0.01 g/mL and 0.34 ± 0.01 g/mL, respectively, indicating comparable

packing characteristics. The tapped density of AMS (0.41 ± 0.02 g/mL) and PZS (0.43 ± 0.05 g/mL) showed a slight increase upon cross-linking, suggesting a minor improvement in packing efficiency. The Carr's index values were $19.51 \pm 0.16\%$ for AMS and $15.78 \pm 0.12\%$ for PZS, demonstrating that cross-linked starch exhibited better flowability compared to the native form. Similarly, the Hausner's ratio values for AMS and PZS were 1.24 ± 0.14 and 1.25 ± 0.19 , respectively, which fall within the acceptable range for good flow properties. Overall, the results indicate that cross-linking slightly enhanced the flow and packing characteristics of Zhingora starch.

Table 7: Evaluation of pre-compression parameters for Alkali isolated Alkali-isolated zhingora starch (AMS) and Cross-linked zhingora starch (PZS)

Property	Alkali-isolated zhingora starch		Cross-linkedzhingorastarch (PZS), (mean±S.D.)
	(AMS),	(mean±S.D.)	
Bulk density		0.33±0.01	0.34±0.01
Tapped density		0.41±0.02	0.43±0.05
Carr's index		19.51±0.16	15.78±0.12
Hausner's ratio		1.24±0.14	1.25±0.19

h. Evaluation of tablets prepared from alkali isolated Alkali-isolated zhingora starch (AMS) and Cross-linked zhingora starch (PZS)

The physical evaluation of tablets prepared using alkali-isolated Zhingora starch (AMS) and cross-linked Zhingora starch (PZS) as binders revealed distinct differences in their mechanical properties and disintegration behavior (Table 8). The hardness of tablets formulated with AMS was found to be 3.4 ± 0.06 kg/cm², whereas those containing PZS exhibited a slightly higher hardness of 4.2 ± 0.04 kg/cm², indicating improved mechanical strength upon cross-linking of the starch.

The friability values were $0.72 \pm 0.08\%$ for AMS-based tablets and $0.68 \pm 0.04\%$ for PZS-based tablets, both of which were within the acceptable limit of less than 1%, suggesting good mechanical integrity. The average thickness of the tablets was comparable for both formulations, recorded as 2.87 ± 0.07 mm for AMS and 2.87 ± 0.09 mm for PZS.

In terms of disintegration, tablets formulated with AMS disintegrated within 1 hour in simulated gastric fluid (SGF, pH 1.2). In contrast, tablets containing PZS did not disintegrate (NDa) within the same time

frame, suggesting that cross-linking enhanced the structural stability of the tablets, leading to slower disintegration.

Table 8: Evaluation of tablets prepared from alkali isolated Alkali-isolated zhingorastarch (AMS) and Cross-linked zhingora starch (PZS)

Tablet formulations	Hardness (mean±SD)	Friability(%) (mean±SD)	Thickness, mm (mean±SD)	Disintegration in simulated gastric fluid (SGF, pH1.2)
Alkali-isolated zhingorastarch (AMS), (mean±S.D.)	3.4±0.06	0.72±0.08	2.87±0.07	1h
Cross-linked zhingorastarch (PZS), (mean±S.D.)	4.2±0.04	0.68±0.04	2.87±0.09	ND ^a within 1h

i. In-vitro drug release tablets prepared from alkali isolated Alkali-isolated zhingora starch (AMS) and Cross-linked zhingora starch (PZS)

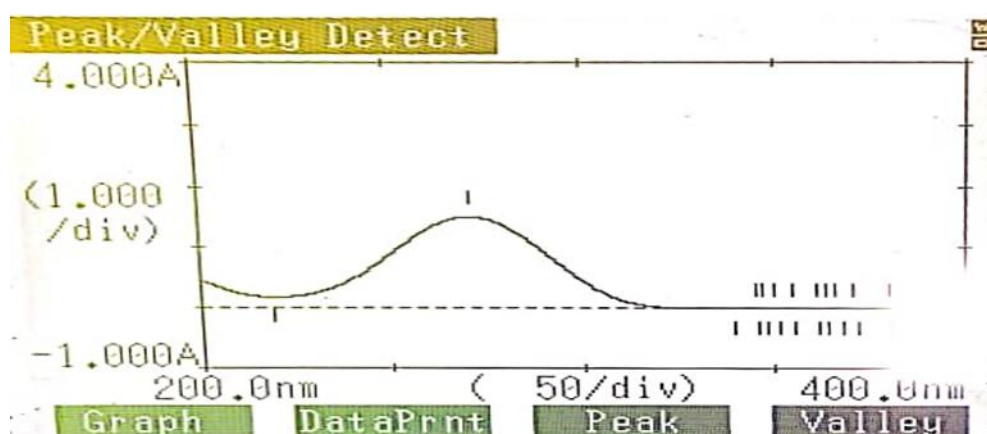


Figure 1: Scanning spectra of the drug aceclofenac in methanol for λ_{max} determination

Peak Detection			
λ (nm)	Abs	λ (nm)	Abs
386.70	0.005	271.00	0.511
379.90	0.006		
371.10	0.006		
365.70	0.006		
363.50	0.006		
361.00	0.006		
355.30	0.006		
350.00	0.006		
346.70	0.006		
345.10	0.006		

Figure 2: Characteristic absorbance of the drug aceclofenac in methanol at different wavelength and at λ_{max} 271 nm

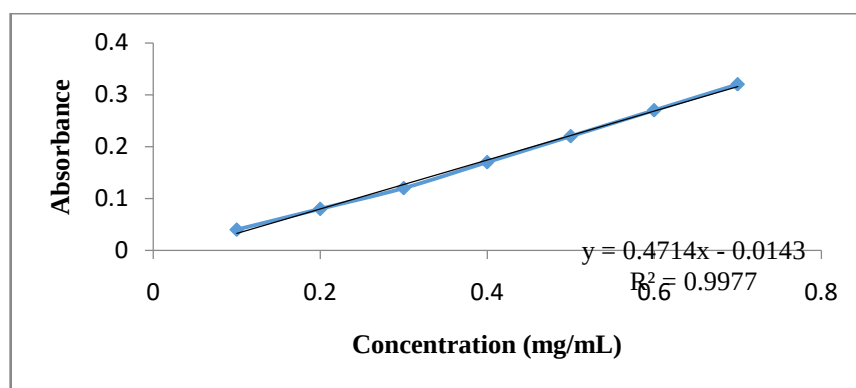


Figure 3: Calibration curve of the drug aceclofenac in methanol at 271 nm

Table 9: Data showing results of regression and optical features of the analytical method of aceclofenac

Parameters	Values
Linear dynamic range ($\mu\text{g/mL}$)	0.1-0.7
Regression equation	$y = 0.4714x - 0.0143$
Correlation coefficient (r)	$R^2 = 0.9977$
SE intercept	0.00451754
SD intercept	0.01195
LOD ($\mu\text{g/mL}$)	0.2431
LOQ ($\mu\text{g/mL}$)	1.0523
Variance of the calibration line	0.05153

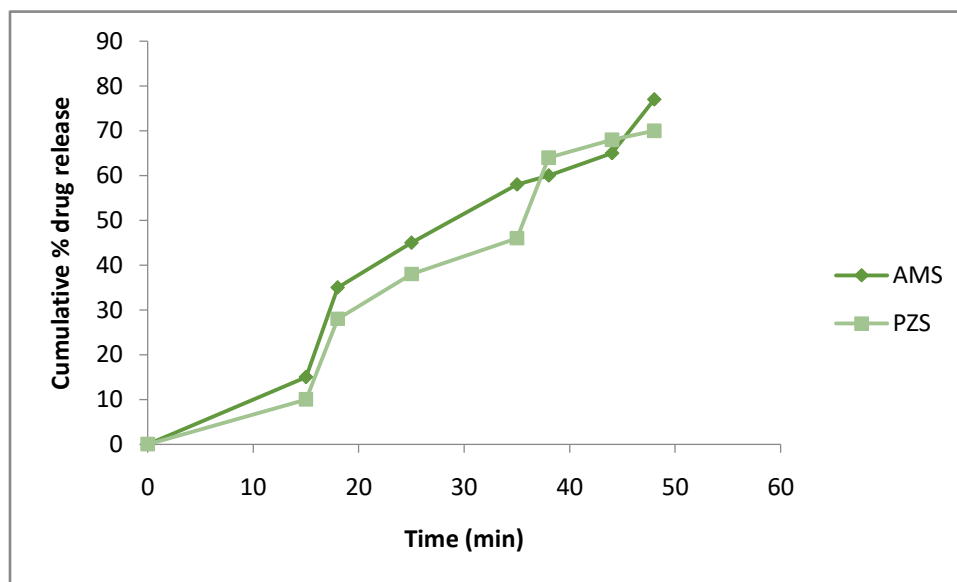


Figure 4: Drug dissolution profile of tablets containing aceclofenac from both alkali isolated Alkali-isolated zhingorastarch (AMS) and Cross-linked zhingora starch (PZS)

CONCLUSION

The preformulation studies of alkali-isolated Zhingora starch (AMS) and cross-linked Zhingora starch (PZS) revealed significant improvements in the physicochemical and functional properties of the starch upon cross-linking. The yield of cross-linked starch was markedly higher ($97.8 \pm 0.57\%$ w/w) compared to the alkali-isolated form ($14.68 \pm 0.52\%$ w/w), indicating the efficiency of the modification process. The pH of AMS was highly alkaline (pH 11), while PZS exhibited a near-neutral pH (pH 6.8), making it more suitable for pharmaceutical applications.

Cross-linking led to a reduction in moisture content and amylose content, while enhancing water-binding capacity and maintaining moderate swelling power, which collectively contribute to improved stability and functionality of the starch. Although paste clarity slightly decreased in PZS, this is consistent with the formation of stronger intermolecular bonds that limit granule swelling and transparency. The evaluation of precompression parameters showed that PZS possessed better flow characteristics, as evidenced by a lower Carr's index ($15.78 \pm 0.12\%$) compared to AMS ($19.51 \pm 0.16\%$), and acceptable Hausner's ratio values for both, indicating good flow and packing properties suitable for tablet formulation. Tablet evaluation further demonstrated that the cross-linked starch produced tablets with higher hardness (4.2 ± 0.04 kg/cm²) and lower friability ($0.68 \pm 0.04\%$), indicating improved mechanical strength and durability. However, the PZS-based tablets did not

disintegrate within 1 hour in simulated gastric fluid (pH 1.2), unlike AMS-based tablets which disintegrated within the same period. This suggests that cross-linking enhanced the binding capacity and structural integrity of the starch, leading to slower disintegration. The findings confirm that cross-linked Zhingora starch (PZS) exhibits superior physicochemical and mechanical characteristics compared to alkali-isolated starch (AMS), making it a promising excipient for use as a binder or matrix-forming agent in sustained-release or controlled-release tablet formulations.

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