

Original Research Article

Formulation of keratin/HPMC matrix tablets for sustained delivery of diclofenac potassium for the management of inflammation

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Abstract

Purpose: To investigate the excipient properties of keratin/HPMC in sustained-release diclofenac matrix tablets.

Method: Tablets were prepared by wet granulation using different keratin/HPMC ratios. The granules were evaluated for pre-compression parameters such as flow properties, Hausner's ratio, Carr's index, while the matrix tablets were evaluated for post-compression parameters such as hardness, disintegration time, in-vitro drug release and release kinetics.

Results: There was no significant difference ($p > 0.05$) in flow properties and compression characteristics in formulations containing either keratin alone or in combination with HPMC. Furthermore, formulations containing keratin/HPMC in equal proportions exhibited better sustained release profiles ($p < 0.05$). The FTIR spectra revealed no change in the functional groups of diclofenac potassium.

Conclusion: Combination of keratin/HPMC improves the sustained release profile of diclofenac matrix tablets compared to either ingredient alone.

Keywords: Keratin/HPMC polymer, Matrix tablet, Diclofenac, In vitro drug release

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INTRODUCTION

Diclofenac is a non-steroidal anti-inflammatory drug (NSAID) used in the treatment of mild to moderate pain [1]. There are however, varying formulations of diclofenac which include conventional tablets and more advanced systems such as sustained and extended-release tablets, and these are in the

pharmaceutical market already. These formulations have been developed with efficient and more expensive polymers, resulting in higher costs. Keratin has garnered attention for its potential in pharmaceutical applications. It is a biodegradable and biocompatible polymer that is used in drug delivery to control or sustain the release of the active ingredient from matrix tablets [2].

Previous studies that had investigated the excipient properties of various forms of keratin, including oxidized samples, suggested that keratin may be beneficial in sustaining the release of drugs from solid dosage forms [3]. Keratin is obtained from several agricultural wastes, including chicken feathers. Keratin extracted from waste sources presents a promising opportunity for high-yield production, offering a sustainable and cost-effective solution for pharmaceutical applications [3,4]. Incorporating this waste in sustained-release formulation as a substitute for more expensive polymers will offer a more cost-effective alternative. This may reduce over-dependency on other pharmaceutical excipients. Also, keratin is resistant to common protein-digesting enzymes such as pepsin or trypsin [5] and stomach acidic fluid, preserving the integrity of the drug while in the stomach, and ensuring that the drug is released in the small intestine. Therefore, this study investigated the potential of keratin as a release modifier in diclofenac matrix tablets.

EXPERIMENTAL

Materials

Freshly removed white chicken feathers (*Gallus gallus domesticus*) were obtained from a local chicken farm in Anambra State (Latitude - 6.33815 and Longitude - 5.62575), Nigeria, in May 2022. Diclofenac potassium (Wuhan Grand Pharmaceuticals, China), hydroxypropyl methylcellulose and disodium hydrogen phosphate (Loba Chemie Pvt. Ltd, Mumbai India); maize starch, lactose, and talc (Chengdu Kamel Pharmaceutical Company, Ltd, China); hydrochloric acid (Merck Schuchardt OHG Hohenbrunn, Germany), acetone (Gunsgdong Guandgua Chemical Factory Company, Ltd, China), sodium hydroxide (NaOH) and potassium dihydrogen phosphate (BDH Chemicals Ltd Poole England).

Keratin extraction

Keratin was extracted from chicken feathers using alkaline-hydrolysis method previously reported by Meko et al [4]. Fresh chicken feathers were pretreated by washing with distilled water, degreased using acetone and air-dried. The feathers (10 g) were dissolved in 200 mL 3M NaOH for 24 h and neutralized with equimolar solution of hydrochloric acid to precipitate keratin. The keratin was collected, washed with distilled water several times and air-dried.

Preparation of granules

Diclofenac potassium granules were prepared using wet granulation (Table 1). Diclofenac powder (100 mg) and other excipients, except magnesium stearate and talc, were weighed and sieved. The powder mix was triturated in a mortar, after which it was moistened with water as the granulating fluid to form a collapsible, damp mass. The wet mass was passed through a 1000 µm sieve to produce wet granules. The wet granules were dried in a hot air oven at 60 °C for 30 minutes. Dried granules were passed through an 800 µm sieve and further dried. The granules obtained were evaluated for powder flow before magnesium stearate and talc were added and mixed properly. Granules were compressed into tablets with a multi-punch rotary tablet press (Pharmed Tech Pvt Co. Ltd, Kolkata India). Thereafter, the tablets were evaluated [5].

Characterization of granules

Flow rate and angle of repose

This was done using the funnel method reported by Carstensen and Chan [6]. A funnel having a closed tip was hung to a retort stand 5 cm from a flat slab. The granules (20 g) were transferred into the funnel and allowed to flow through the orifice. The time for the granules to completely flow through the funnel orifice was recorded. Flow rate was calculated using Eq 1.

Table 1: Formulation table

Ingredient	T1	T2	T3	T4	T5	T6	T7	T8
Diclofenac Potassium (mg)	100	100	100	100	100	100	100	100
Keratin (mg)	-	2	1	0.5	0.25	0.25	0.5	1
HPMC (mg)	2	-	-	-	-	1.75	1.5	1
Maize starch (mg)	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Talc (mg)	2	2	2	2	2	2	2	2
Magnesium stearate (mg)	2	2	2	2	2	2	2	2
Lactose (mg)	131.5	131.5	132.5	133	133.25	131.5	131.5	131.5
Total (mg)	250	250	250	250	250	250	250	250

The height and diameter of the heap base were recorded and the angle of repose was calculated using Eq 2. The determinations were done in triplicate.

$$\text{Flow rate (g/sec)} = w/t \dots\dots\dots (1)$$

$$\text{Angle of repose} = \tan \Theta = (2h/d) \dots\dots\dots (2)$$

Where w = weight of granules; t = time taken for the granules to flow through a funnel orifice; h = height of heap of granule cone; r = radius of marked granule cone base; d = diameter of base of granule cone.

Powder densities

The granules (20 g) were transferred into a 250 mL measuring cylinder. The volume occupied was recorded as bulk volume (V_b). The measuring cylinder was tapped 100 times on a padded surface and the new volume of the bed was recorded (V_t). Bulk density, tapped density, Hausner's ratio, and Carr's index were calculated using Eq 3 - 6.

$$\text{Bulk density (BD)} = m/V_b \dots\dots\dots (3)$$

$$\text{Tapped density (TD)} = m/V_t \dots\dots\dots (4)$$

Where m is the mass of granules (g).

$$\text{Hausner's ratio (HR)} = (TD/BD) \dots\dots\dots (5)$$

$$\text{Compressibility index (\%)} = (TD-BD) / BD \times 100 \dots\dots\dots (6)$$

Evaluation of tablets

Tablets were evaluated using official and unofficial tests. Evaluations include weight variation test, hardness test, friability test, drug content, moisture content, moisture re-uptake, disintegration test and dissolution test.

Weight variation test

A total of 20 tablets were randomly selected from each batch, weighed and the average weight recorded (A). Also, the individual weights were recorded (B). Percentage deviation of each weight from the average weight was estimated according to Eq 7.

$$\% \text{ déviation} = \{(B-A)/A\}100 \dots\dots\dots (7)$$

Hardness test

Tablet hardness was determined using a hardness tester (Biobase Biodustry, Shandong

Co., Ltd., China). The tablets (3) were picked randomly from each batch and each one was placed in a hardness tester to estimate the force required to induce fracture. The average hardness force (kg/cm^2) was recorded.

Friability test

A total of 10 flawless tablets were randomly selected, dusted, weighed, transferred into a friabilator (Biobase Biodustry Shandong Co., Ltd., China) and rotated at 100 rpm. Finally, the tablets were re-dusted, and weighed and % friability was determined using Eq 8.

$$\% \text{ friability} = \{(A-B)/A\}100 \dots\dots\dots (8)$$

Where A is the initial weight, and B is the final weight.

Moisture content

A total of 3 tablets were weighed individually and transferred into a desiccator (model 200, SIMAX - Czech Republic) containing activated silica gel as a desiccant. Tablets were withdrawn at time intervals up to 48 h and weighed till no further loss in weight was observed. Average weight was recorded and moisture content was calculated using Eq 9.

$$\text{Moisture content (\%)} = \{(IW-FW)/FW\}100 \dots\dots\dots (9)$$

Where IW is the initial weight, FW is the final weight.

Moisture reuptake

Moisture reuptake was determined by 3 tablets individually from the various batches and kept in a desiccator containing distilled water. The tablets were reweighed after 48 h, and the average weight was taken. Percentage moisture uptake was determined using Eq 10.

$$\text{Moisture uptake (\%)} = \{(FW-IW)/IW\}100 \dots\dots\dots (10)$$

Where FW is the final weight, IW is the initial weight.

Disintegration test

A total of 6 tablets were selected randomly from each batch and placed in a disintegration apparatus (Biobase Biodustry (Shandong) Co., Ltd., China) containing distilled water at 37 °C. The time at which no fragment of any tablet was left on the mesh of the basket rack was recorded

as disintegration time. Determination was done in triplicate and the average was taken.

Content uniformity test

A total of 5 tablets from each batch were randomly selected and crushed in a mortar. Thereafter, a quantity equivalent to 100 mg of diclofenac was weighed and dissolved in 10 mL 0.1 M phosphate buffer (pH 6.8). The solution obtained was further diluted, and the absorbance was read using a UV-VIS spectrometer (T70, PG Instruments Ltd, United Kingdom) at 276 nm.

Drug release

The *in vitro* release profile of diclofenac potassium matrix tablets was determined using USP type I (Rotating basket) dissolution apparatus (Biobase Biodustry, Shandong Co., Ltd. China) at 50 rpm. A tablet was put into the rotating basket. The dissolution was carried out in a biphasic media (900 mL 0.1N HCL for 2 h and continued in 900 mL phosphate buffer at pH 7.4 for 10 h) maintained at 37 ± 0.5 °C.

Samples (5 mL) were withdrawn every hour and replaced with an equal volume of dissolution medium. Each sample was filtered and analyzed with a UV spectrophotometer at 276 nm. The percentage of cumulative drug release was calculated and recorded.

Release kinetics

Data obtained from *in vitro* release studies were subjected to zero-order, first-order, Higuchi, and Korsmeyer-Peppas drug release models.

Infrared spectroscopy

Potassium bromide powder (KBr; 0.5 g) was mixed with 0.5 g of crushed diclofenac tablet and compressed into pellets using a tablet press. The pellet was placed in the sample compartment. Spectra were recorded on an FT-IR spectrometer

(Beaconsfield Bucks, England) and scanned at an IR range of 4000 - 800 cm^{-1} , with a resolution of 4 cm^{-1} .

Statistical analysis

Data was analyzed using Statistical Packages for Social Sciences version 23.0 (IBM, Armonk, NY, USA). Determinations were done in triplicate and values were expressed as mean $\pm$ standard deviation (SD). Mean differences were compared using a one-way analysis of variance (ANOVA). $P < 0.05$ was considered statistically significant.

RESULTS

Physicochemical properties of keratin

The physicochemical properties of the keratin have been presented in previous findings [3]. A yield of 62 % keratin was obtained from 3 M NaOH solution at 37 °C for 24 hours. The keratin powder was irregular with a rough surface and a mean particle size of 336 μm . Its melting point was 226 °C.

Flow properties

There was no significant difference in flow properties between keratin and keratin/HPMC granules (Table 2; $p > 0.05$).

Post-compression properties

There was no significant difference in post-compression characteristics of the tablets formulated with keratin and keratin/HPMC (Table 3; $p > 0.05$).

In vitro dissolution

Batch T1 had 77 % of drug release at 12 h. T2 to T5 gave a cumulative release of 69 to 79 %, while T6 to T8 gave 61 to 79 % drug release at 12 h (Figure 1).

Table 2: Flow properties of various batches of keratin/HPMC matrix granules of diclofenac potassium

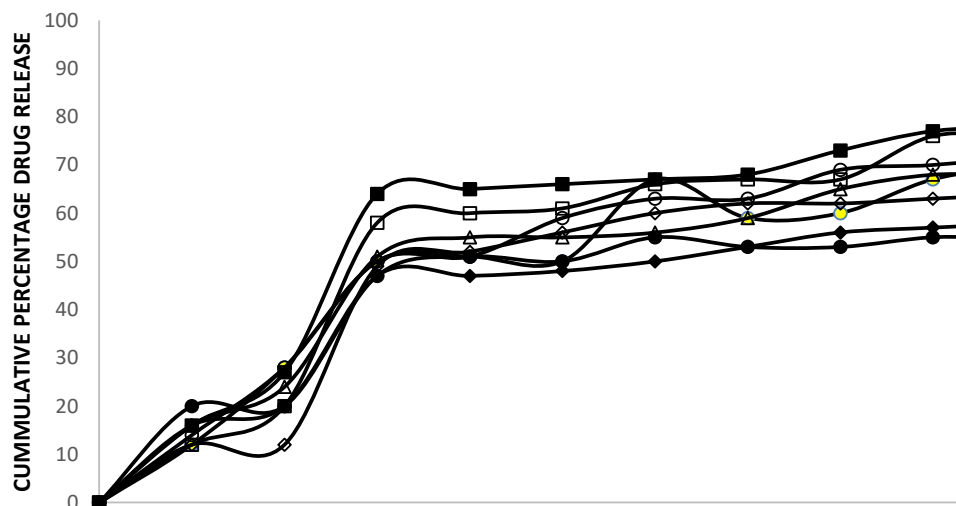
Batch	Bulk density (g/mL)	Tapped density (g/mL)	Hausner's ratio	Carr's index (%)	Angle of repose (°)	Flow rate (g/s)
T1	0.66 $\pm$ 0.03	0.76 $\pm$ 0.01	1.15 $\pm$ 0.04	13.26 $\pm$ 0.03	29.73 $\pm$ 0.12	3.33 $\pm$ 0.15
T2	0.62 $\pm$ 0.08	0.67 $\pm$ 0.04	1.08 $\pm$ 0.03	7.82 $\pm$ 0.07	29.74 $\pm$ 0.16	2.86 $\pm$ 0.20
T3	0.62 $\pm$ 0.04	0.72 $\pm$ 0.08	1.16 $\pm$ 0.03	14.03 $\pm$ 0.02	29.38 $\pm$ 0.18	3.35 $\pm$ 0.24
T4	0.62 $\pm$ 0.07	0.70 $\pm$ 0.09	1.12 $\pm$ 0.02	10.97 $\pm$ 0.01	30.11 $\pm$ 0.19	3.38 $\pm$ 0.22
T5	0.61 $\pm$ 0.05	0.66 $\pm$ 0.07	1.08 $\pm$ 0.01	7.80 $\pm$ 0.05	29.07 $\pm$ 0.20	2.80 $\pm$ 0.17
T6	0.61 $\pm$ 0.09	0.70 $\pm$ 0.05	1.14 $\pm$ 0.04	12.39 $\pm$ 0.02	30.84 $\pm$ 0.14	2.85 $\pm$ 0.29
T7	0.69 $\pm$ 0.11	0.80 $\pm$ 0.09	1.15 $\pm$ 0.04	13.75 $\pm$ 0.02	30.46 $\pm$ 0.15	3.30 $\pm$ 0.21
T8	0.66 $\pm$ 0.05	0.74 $\pm$ 0.02	1.11 $\pm$ 0.03	6.34 $\pm$ 0.02	30.46 $\pm$ 0.15	2.78 $\pm$ 0.16

Results are presented as mean $\pm$ SD (n = 3)

Table 3: Post-compression properties of keratin/HPMC matrix tablets containing diclofenac potassium

Batches	Hardness (kg/cm ²)	Friability (%)	Disintegration time (min: sec)	Drug content (%)	Uniformity of weight (mg)	Moisture content (%)	Moisture reuptake (%)
T1	9.76±0.51	0.15±0.02	13:44±0.83	92.38±0.00	258.75±6.18	4.32±1.50	4.45±0.71
T2	9.86±0.30	0.24±0.06	13:59±0.48	99.10±0.00	253.70±6.17	2.88±0.20	4.47±0.51
T3	9.33±0.38	0.37±0.04	10:31±0.19	94.17±0.00	247.00±6.33	3.67±0.87	6.19±1.25
T4	9.60±0.27	0.15±0.02	12:29±1.33	91.93±0.00	255.45±5.66	2.01±0.69	3.48±1.38
T5	9.22±0.23	0.27±0.07	12:55±0.53	90.58±0.00	254.60±5.35	3.43±1.08	8.87±0.67
T6	9.07±0.48	0.46±0.10	13:00±0.47	98.21±0.00	253.75±5.45	4.36±1.52	6.93±1.82
T7	9.59±0.22	0.14±0.03	12:13±0.32	96.41±0.00	255.45±5.28	4.93±0.90	4.78±1.76
T8	9.47±0.71	0.15±0.05	12:18±0.13	90.13±0.00	255.00±5.58	4.79±1.21	6.43±1.43

Results are presented as mean ± SD (n = 3)

**Figure 1:** *In vitro* release profile of diclofenac potassium from keratin/HPMC matrix tablets**Table 4:** Kinetic data analysis showing R² values for different release models

Code	Zero order	First order	Higuchi	Korsmeyer and peppas	(n)
T1	0.8254	0.8950	0.9359	0.8756	0.6516
T2	0.8413	0.9472	0.9568	0.9077	0.6332
T3	0.7493	0.7940	0.8719	0.788	0.7445
T4	0.7792	0.8765	0.8988	0.8392	0.724
T5	0.8017	0.8935	0.9321	0.8823	0.5812
T6	0.7312	0.8289	0.8836	0.8255	0.600
T7	0.7847	0.8289	0.9206	0.862	0.5441
T8	0.6880	0.7097	0.8641	0.7868	0.4566

n ≤ 0.45 means Fickian diffusion; n = 0.45 – 1 means a non-Fickian or an anomalous diffusion mechanism; n = 1 means zero order release; n > 1= super case II transport

Kinetic data analysis

The result of the release data was fitted into different kinetic models (Table 4). Release of diclofenac from keratin/HPMC matrix showed the highest linearity ($r^2 = 1.0000$) following the Higuchi model.

Spectroscopy

There was no significant change in the FTIR spectrum of the keratin/HPMC diclofenac matrix

tablets indicating drug-excipient compatibility. The spectrum revealed the presence of C-Cl dichloro stretching at 790cm⁻¹ wavelength. Wavelength at 1612 cm⁻¹ showed the presence of aniline and 1° amine N-H symmetric stretching of diclofenac and keratin respectively. Wavelength at 2087 cm⁻¹ is assigned to COOH carboxylic acid stretching vibration of keratin and diclofenac while at 1416 cm⁻¹ is assigned to phenyl group of diclofenac. The wavelength at 2210 cm⁻¹ and the medium band at 1290 cm⁻¹ are assigned to the carbonyl and methyl group of

HPMC respectively. The OH stretching vibration of 1°, 2°, 3° alcohol in keratin, HPMC are assigned to the wavenumbers 3015 cm⁻¹, 3172 cm⁻¹, 3359 cm⁻¹, 3504 cm⁻¹, 3840 cm⁻¹ (Figure 2).

DISCUSSION

The utilization of feather biomass has gained considerable attention in recent times due to the need to protect the environment and to produce valuable pharmaceutical and cosmetic products. Chicken feathers consist of 90 % keratin (an insoluble, fibrous and structural protein). It is one of the most abundant forms of hard protein in nature [7], rich in amino acids such as cysteine, arginine, and threonine, with high nutrient potential [8]. Studies on chicken keratin have been pursued recently to generate valuable bio-based materials [9] and delivery systems [3]. This study investigated the release-modifying potential of keratin and keratin/HPMC in diclofenac matrix tablets. The results revealed that there was no significant difference in the flow properties of granules prepared with keratin and keratin/HPMC. The granules showed Hausner's ratio below 1.25 and Carr's compressibility index below 16 %, indicating good compressibility. They showed good to excellent flow, which indicates that the tablets will have a uniform weight. Weight uniformity is an important factor in

solid dosage forms as it assures that the active ingredient in the dosage form is uniformly distributed. The British Pharmacopoeia [10] specifies that not more than two of the individual weights should deviate from the average weight by more than ± 7.5 %, and none should deviate by twice ± 7.5 % for tablets weighing between 130 – 324 mg. Variations in diclofenac matrix tablets were not more than ± 5 % of the calculated mean weight, conforming to the BP specifications. Tablets' hardness/crushing strength was uniform, with no significant deviations in hardness ($p < 0.05$). All the tablets showed hardness values that were satisfactory for sustained-release formulation. This is in tandem with a previous study, which reported a crushing strength of > 7.0 kp, however, using *Pennisetum glaucum* [11]. Friability is an index of tablet strength, and it is used to evaluate tablet's ability to withstand mechanical shock during transportation and handling to avoid breakage or wearing off.

Friability test according to official specifications should not exceed 1 %. The matrix tablets exhibited less than 1 % friability, indicating good mechanical resistance. The BP specifies that diclofenac extended-release tablets should contain not less than 90 % and not more than 110 % of the labeled drug content [11].

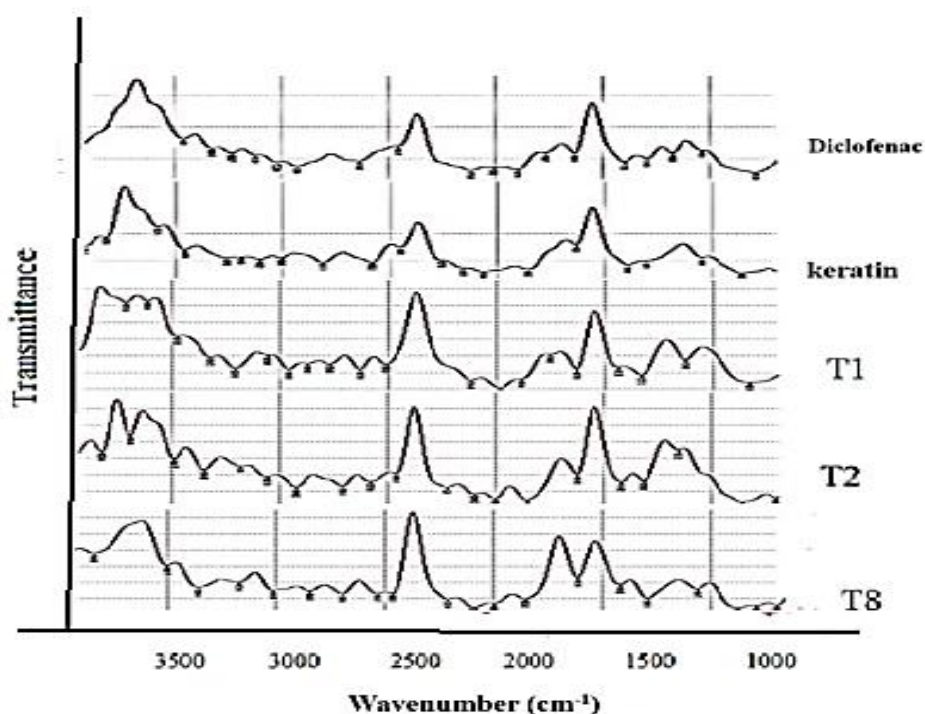


Figure 2: FTIR spectra of diclofenac powder, keratin powder, Formulation T1 (matrix tablet containing HPMC alone), Formulation T2 (matrix tablet containing keratin alone), T8 (matrix tablet containing high keratin + high HPMC)

Matrix tablets from all the batches passed the drug content test. It is very important for matrix tablets to exhibit content uniformity, as this ensures that a consistent dose of the active ingredients is maintained, which would provide the needed therapeutic effect.

Disintegration time is the time taken for the drug to break into tiny fragments. Prior to the dissolution of a solid dosage form, tablets must first break down into smaller particles, allowing greater surface area, solubility and bioavailability of the drug when administered [12]. The disintegration time of all the batches was within the specifications for uncoated tablets [10]. Moisture content and reuptake are quality control parameters that account for the mechanical strength, solubility and overall shelf-life stability of finished pharmaceutical products and therefore should not be too low or too high [13,14]. There was no significant difference ($p < 0.05$) in moisture content and moisture reuptake of the tablets, indicating moisture stability. All the formulations did not disintegrate and exhibited slow-release profile in the acid phase (first 2 h in 0.1 N HCl). This was due to poor solubility of keratin in acidic pH, and as a result, the matrix tablets are able to retain most of their diclofenac content in gastric medium.

All matrix tablets for different batches disintegrated in alkaline pH (phosphate buffer 6.8), with an initial high release of the drug within 3 h in phosphate buffer. This profile may be needed to attain at least the minimum effective concentration (MEC) required to give a therapeutic response and thereafter maintain a slower release throughout the dissolution study. Batch T2 to T5 released more diclofenac compared to T1. This may be due to the less retardant effect of keratin in phosphate buffer releasing more of the drug from the matrix. Batch T6 to T8 containing both HPMC and keratin retarded the release of diclofenac compared to HPMC alone (T1) and keratin alone (T2-T5). This may be due to the interaction between both polymers which appear to have formed more cohesive bonds and hence retarding release. Though there was no significant difference ($p < 0.05$) in release profiles from T2 - T5 and T6 - T8 comparatively, formulations T6 - T8 showed better sustained release compared to T1 and T2 - T5. Therefore, it may be considered a better system for the sustained release of diclofenac potassium. Variation in release pattern was not polymer concentration dependent. This might be attributed to the type of polymer used and formulation composition. It has been shown that polymer type, concentration, molecular weight, drug solubility, and formulation composition play

an important role in sustained drug release from matrix systems [15]. The release kinetics reveal that drug release from the matrix is best explained by the Higuchi model of drug release, which showed the highest linearity (r^2 approximately = 1.0000). According to Higuchi's model, drug release from a matrix follows a square root of a time-dependent process, governed by Fickian diffusion principles. The model demonstrates the drug release mechanism from polymeric matrices, confirming its relevance to the formulation under investigation [16]. The FTIR analysis revealed no significant changes in FTIR spectra of the keratin/HPMC matrix tablet as a result of different functional groups present in keratin, HPMC and diclofenac. It showed the presence of functional groups such as dichloro (C-Cl) in diclofenac, amino (-NH₂), and carboxylic acid (-COOH) in keratin and diclofenac. It also showed the presence of carbonyl (COO) in HPMC, methyl group of HPMC, and hydroxyl (-OH) group in keratin and HPMC. Therefore, the matrix tablet revealed the FTIR spectra patterns which have the functional groups present in the drug and polymers excluding additional spectra.

CONCLUSION

Keratin/HPMC exhibits good flow, compression characteristics and retards the release of diclofenac from the matrix tablet. Further studies are therefore required to optimize the concentration of keratin/HPMC needed to produce matrix tablets that meet specifications and offer drug release at a constant rate.

DECLARATIONS

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Ethical approval

None required.

Use of Artificial intelligence/Large language models

We declare also that we did not use Generative artificial intelligence (AI) and AI-assisted technologies in writing the manuscript.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflict of interest

No conflict of interest is associated with this work.

Contribution of authors

We declare that this work was done by the author(s) named in this article, and all liabilities pertaining to claims relating to the content of this article will be borne by the authors.

REFERENCES

1. Barros NR, Augusto PC, Borges FA, Gemeinder JP, Miranda MC, Garms BC, Herculano RD. Diclofenac potassium transdermal patches using natural rubber latex biomembranes as carriers. *J Mater* 2015; 1: 1-7.
2. Sanchez Ramirez DO, Vineis C, Cruz-Maya I, Tonetti C, Guarino V, Varesano A. Wool Keratin Nanofibers for Bioinspired and Sustainable Use in Biomedical Field. *J Funct Biomater*. 2022; 14(1):5.
3. Agbamu E, Meko OA, Alalor CA, Maduako VN, Umunadi KE, Arhewoh MI. Investigation of the effect of oxidation on keratin obtained from chicken feathers. *Trop J Pharm Res* 2025; 24(2): 132.
4. Meko OA, Eraga SO, Arhewoh MI. Effect of extraction parameters on some properties of keratin obtained from waste chicken feathers. *Trop J Nat Prod Res* 2024; 8(6):7423-7430.
5. Vidmar B, Vodovnik M. Microbial Keratinases: Enzymes with Promising Biotechnological Applications. *Food Technol Biotechnol*. 2018 Sep;56(3):312-328. doi: 10.17113/ftb.56.03.18.5658.
6. Okafo SE, Avbunudiogba JA, Ejomafuvwe E. Formulation and evaluation of sustained release diclofenac sodium matrix tablets produced using *Brachystegia eurycoma* gum. *J Pharm Biores* 2020; 17(1): 34–43.
7. Carstensen JJ, Chan PC. Flow rates and repose angles of wet-processed granulations. *J Pharm Sci* 1977; 60: 1235 – 1239
8. Reddy N, Yang Y. Structure and properties of chicken feather barbs as natural protein fibers. *J Polym Environ* 2007; 15: 81–87
9. Tiwary E, Gupta R. Medium optimization for a novel 58 kDa dimeric keratinase from *Bacillus licheniformis* ER-15: biochemical characterization and application in feather degradation and dehairing of hides. *Biores Technol* 2010; 101: 6103–6110.
10. Poole AJ, Church JS. The effects of physical and chemical treatments on Na2S produced feather keratin films. *Int J Biol Macromol* 2015; 73: 99–108
11. British Pharmacopoeia (BP). Her Majesty's Stationery Office. Vol. I & II, 2009: 3952
12. Meko OA, Mudiaga-Ojemu BO, Ubah CP, Eraga SO, Iwuagwu MA. Investigation into the use of acid-modified millet (*Pennisetum glaucum*) starch mucilage as tablet binder *J Sci Prac Pharm* 2018; 5 (2): 267-274.
13. Meko OA, Eraga SO, Arhewoh MI. Transdermal delivery of metoclopramide using eucalyptus oil and shear Butter. *Afr J Pharma Res Dev* 2020; 2: 1-9.
14. Eraga SO, Arhewoh MI, Meko OA. Evaluation of transdermal formulations of metoclopramide prepared using arachis oil and liquid paraffin as permeation enhancers. *Pharmaceutical and Biomedical Research* 2020; 6(3): 213-222.
15. Al Hanbali OA, Hamed R, Arafat M, Bakkour Y, Al-Matubsi H, Mansour R, Al-Bataineh Y, Aldhoun M, Sarfraz M, Yousef Dardas AK. Formulation and evaluation of diclofenac-controlled release matrix tablets made of HPMC and Poloxamer 188 polymer: An assessment on the mechanism of drug release. *Pak J Pharma Sci* 2018; 31(1): 345–351.
16. Paul DR. Elaborations on the Higuchi model for drug delivery. *Int J Pharma* 2011; 418(1): 13-17.