

## RESEARCH ARTICLE

# Formulation, Development and *In-vitro* Characterization of Modified Release Tablets of Curcumin

Vikrant Nikam\*, Sachin Suryawanshi, Nikita Rathod, Shruti Kadam

*Department of Pharmaceutics, Amrutvahini College of Pharmacy, Sangamner, Maharashtra, India*

*Received: 25<sup>th</sup> January, 2024; Revised: 20<sup>th</sup> March, 2024; Accepted: 10<sup>th</sup> May, 2024; Available Online: 25<sup>th</sup> June, 2024*

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### ABSTRACT

**Objective:** The current study set out to design and test a cost-effective system for developing modified-release tablets of curcumin in an effort to increase the duration of drug release. Because curcumin has a shorter elimination half-life, reducing the frequency of doses can increase its bioavailability.

**Methods:** For improved drug retardation in the stomach environment, modified-release tablets were made utilizing the wet granulation method with various grades of high-potassium chloride (HPC) as the extended-release matrix-forming agent and katira gum as the viscosity-modifying agent. Combining the use of HPC and katira gum slows the drug's release in the stomach. The sustained-release tablets had the highest rate of medication release for up to 24 hours with almost no stomach absorption. The medication and excipients did not interact, according to the fourier-transform infrared spectroscopy (FTIR) spectra. There was no evidence of drug-excipient incompatibility, according to differential scanning calorimetry (DSC) tests. Optimal formulation batch F2 modified release tablets showed no outward signs of deterioration after three months of storage, according to stability analysis. Further evidence that F2 was steady is the lack of variation in drug content and percentage of drug release.

**Conclusion:** This study accomplished its stated goal of creating a modified-release tablet formulation that is both cost-effective and does not make use of coating technology.

**Keywords:** Curcumin, Katira gum, Modified release tablet, Hydroxy propyl cellulose, Colon.

International Journal of Drug Delivery Technology (2024); DOI: 10.25258/ijddt.14.2.54

**How to cite this article:** Nikam V, Suryawanshi S, Rathod N, Kadam S. Formulation, Development and *In-vitro* Characterization of Modified Release Tablets of Curcumin. International Journal of Drug Delivery Technology. 2024;14(2):961-968.

**Source of support:** Nil.

**Conflict of interest:** None

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### INTRODUCTION

The increasing incidence of colonic disorders in recent decades has become a worldwide health concern, necessitating more effective and safer pharmacological treatments for colonic diseases at the local level.<sup>1</sup> Among male-predominant cancers, colon cancer is high in Western and European nations and ranks third globally in terms of cancer diagnoses.<sup>1,2</sup> There were 883,200 fatalities due to cancer, making it one of the prominent causes of death globally.<sup>3</sup> New cases of colon cancer (104,610) and rectal cancer (43,340) will bring the total number of colorectal cancer (CRC) cases in the United States to 147,950 in 2020. Despite the fact that the majority of these cases occur in those aged 50 and up, 17,930 new cases of CRC (12%) will be identified in individuals under the age of 50.<sup>4</sup> Researchers have explored drug targeting to the colon and its problems extensively over the past few decades. Research into CDDs is heavily focused on creating formulations that are more tailored to the colon.<sup>5</sup> The main methods for treating colon cancer are chemotherapy and radiation therapy. For

this cancer, researchers have created and tested a plethora of chemotherapeutic drugs that can be taken orally. In order to reduce the likelihood of tumor recurrence, patients may be prescribed surgery in addition to chemotherapy. Chemotherapy is not very effective in preventing CRC from progressing to an advanced level, even when medications are taken at the maximum allowed doses in an effort to destroy as many malignant cells as possible. This is due to the fact that anticancer agents are unable to reach cancer cells in effective quantities. When a medicine is injected intravenously (i.v.), it travels through the bloodstream to major organs like the liver, lungs, heart, and kidneys. This causes the drug to be widely distributed throughout the body, which means that its concentration in the target tissues is lower, which might lead to side effects. Additional reduction in drug distribution to the colon can occur as a result of drug metabolism.<sup>6</sup> There has been a significant uptick in interest in the use of oral colon-specific drug delivery systems (OCDDS) to treat disorders affecting the large intestine. Topical treatments for

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\*Author for Correspondence: vikrantnikam@gmail.com

colon disorders, including ulcerative colitis, colorectal cancer, Crohn's disease, and others, benefit from colon drug-targeting.<sup>7</sup> Improved therapeutic efficacy is achieved through the use of colon-specific drug delivery, which directs treatment at sick regions, reduces drug absorption to the system, and avoids liver metabolism (due to first-pass metabolism).<sup>8</sup> When it comes to preventing and treating colorectal cancer, the effectiveness of an oral OCDDS is directly impacted by the rate and amount of drug absorption.<sup>9</sup>

The hydrophobic polyphenol curcumin, formally known as diferuloylmethane, is derived naturally from the rhizome of the *Curcuma longa* (turmeric) plant.<sup>10</sup> It is a naturally occurring phenol with a characteristic yellow hue. It dissolves readily in acetic acid, chloroform, alkali, and ketone but remains insoluble in water at neutral and acidic pH. Since it is hydrophobic, it can pass through cell membranes with ease and exercise its effects in the nucleus, endoplasmic reticulum, and mitochondria.<sup>11</sup> An antioxidant, curcumin is. Additionally, it is used as a chemotherapeutic agent and chemosensitizer to effectively control colon cancer and other disorders.<sup>12</sup> One of the main reasons why colorectal cancer starts is thought to be chronic inflammation. Also, immune cells can penetrate tumors (a process called tumor-elicited inflammation) and promote tumor growth by encouraging the expansion of cancer cells. Due to its influence on many signaling pathways, curcumin has been shown to be significant in the prevention and treatment of CRC, and as a result, many consider it one of the most effective natural remedies for future inflammation. The anticancer benefits of curcumin have been extensively studied, but the spice is not widely used due to its rapid metabolism, low absorption, and degradation.<sup>13</sup>

This study's overarching goal is to produce a formulation that can inhibit drug release in upper GIT while simultaneously directing drug release to colon. Organic solvents are commonly employed in coating technology despite their flammability and toxicity. Any equipment that contains leftover solvents poses a danger of poisoning. Therefore, modified-release tablets of curcumin, a model drug, were created using HPC as an extended-release matrix forming and katira gum as a release-modifying polymer. So, curcumin-modified release tablets were made utilizing various amounts of HPC and katira gum. The non-toxic, widely-used gum katira was chosen as the viscosity-modifying agent due to its well-documented biocompatibility and safety for use in the food and pharmaceutical industries.<sup>14</sup> The primary goal of this approach was to produce a cost-effective alternative to enteric coating polymers that would increase the bioavailability and extend the drug release of curcumin while decreasing the frequency of dose. Using a variety of state-of-the-art analytical methods, including powder X-ray diffraction (P-XRD), differential scanning calorimetry (DSC), UV spectroscopy, and fourier-transform infrared spectroscopy (FTIR), we have investigated the many physicochemical features of curcumin. In addition, we have studied how different mixtures of HPC and katira gum, as well as different types of polymers, affected the swelling index and percentage of drug release in the final formulations.

## MATERIALS AND METHOD

### Materials

Complimentary sample of curcumin was provided by SciTech Pharma. LobaChem Laboratory supplied the isopropyl alcohol, hydrogen peroxide, lactose, and magnesium stearate. The supplier of katira gum was Yarro Chemicals.

### Methods

#### *Preformulation study*

- *Melting point*

The capillary technique was used to determine the melting points of curcumin, HPC, Katira gum, lactose, and magnesium stearate. It suggests the degree of chemical purity.<sup>15,16</sup>

- *Loss on drying*

After adding 1 g of curcumin to a petri dish, the weight of the dish and the curcumin were then measured. The following formula was used to compute Loss on drying (LOD) after heating a petri dish containing curcumin to 105°C for 1-hour in an oven. Then, the weight of the petri dish and curcumin were measured again.<sup>17</sup>

$$\text{LOD} = \text{Initial weight} - \text{Final weight} / \text{Initial weight} \times 100$$

- *IR spectroscopy*

FT-IR spectra were obtained by Bruker Optics for curcumin, hpc, katira gum, lactose, and magnesium stearate. Our spectroscopic analysis of the medicine and its excipients was carried out within the 4000 to 400 cm<sup>-1</sup> frequency range. Various peaks were observed in the spectra that were acquired. After that, the spectra were compared to the drug's and excipient's standard spectra in order to determine which functional groups were present in the drug's and excipient's structures<sup>18</sup>.

- *Differential scanning calorimetry*

Two milligrams of each substance were subjected to differential scanning calorimetry (DSC) tests in an aluminum container subjected to a temperature gradient ranging from 10 to 300°C at a rate of 10°C/minute. The samples were then analyzed in a nitrogen-free environment with a flow rate of 100 mL/minute.<sup>19</sup>

- *X-ray diffraction study*

The drug's P-XRD properties were investigated.<sup>20</sup> Analysis of curcumin diffraction patterns was carried out using Bruker AXS D8 Advance equipment, which is located in Karlsruhe, Germany.

#### *UV-Visible spectrophotometric method*

- *Determination of  $\lambda_{max}$*

The UV spectrophotometer was used to scan the standard solution of curcumin in a mixture of ethanol, phosphate buffer (pH 6.8), and hydrochloric acid between 200 and 400 nm.

- *Calibration curve of curcumin in ethanol*

About 100 mL of ethanol (100 µg/mL) was used to dissolve 10 mg of curcumin. To make it up to 100, 10 mL of this solution was taken out and studied at 413 nm of  $\lambda_{max}$ .<sup>21</sup>

### Solubility study

To determine which solvents are suitable for the formulation of dosage forms and to determine which solvents the drug dissolves in is the primary goal of a solubility study. To test curcumin's solubility, 10 mg of the medication were dissolved in various solvents, including chloroform, methanol, dimethyl sulfoxide, and ethanol (Table 1).<sup>21</sup>

### Compatibility study

Practical investigations aim to identify actual and potential interactions between drugs and excipients as fast as feasible, whereas the primary objective of this study is to consider drug/excipient compatibility. The stability of the medicine may be compromised due to the close proximity of the drug to one or more excipients in solid dosage form. Using FTIR (BRUCKER OPTICS), we were able to record the spectra of curcumin, Curcumin:HPC, Curcumin:Katira Gum, Curcumin:Lactose, and a physical mixture of Curcumin:HPC, Katira gum, lactose, and magnesium stearate in a 1:1 ratio, as well as Curcumin:Magnesium stearate in a 20:1 ratio. Granules produced with Curcumin:HPC:katira gum, lactose, and magnesium stearate were also studied in detail using the FTIR method. For 15 days at 55°C and 40% relative humidity, all of the samples mentioned above were kept before the FTIR spectrum was taken. Physical inspections for caking, liquefaction, discoloration, odor, or gas generation were performed on all samples on a regular basis during storage.<sup>22</sup>

### Determination of Precompression Parameters

#### Bulk density

Bulk density is mass-to-volume ratio of the powder bed, including the pores and gaps, to a total volume of the powder bed.

Approach: a 25 mL measuring cylinder was filled with the granules, and their volumes were measured straight from the cylinder. Bulk density was subsequently determined by dividing weight of granules by their volume.<sup>23</sup>

$$\text{Bulk Density} = \frac{\text{Mass of Granule}}{\text{Bulk Volume}}$$

#### Tapped density

Tapped density is defined ratio of the mass of the powder bed to the tapped volume. It was determined by using a bulk-density apparatus (Electrolab).

Method: the granules were weighed and filled into a 25 mL measuring cylinder. Then it was placed in a bulk-density apparatus. The capacity of the cylinder was determined after tapping it approximately 100 times. We next used the following calculation to determine tapped density.<sup>23</sup>

$$\text{Tapped Density} = \frac{\text{Mass of granule}}{\text{Bulk volume}}$$

#### Compressibility index (Carr's index)

It was determined using following formula

$$\text{Carr's Index} = \frac{\text{Tapped Density} - \text{Bulk Density}}{\text{Tapped Density}} \times 100$$

#### Angle of repose

The capacity of the cylinder was determined after tapping it approximately 100 times. We next used the following calculation to conclude tapped density.

#### Fixed funnel method

Graph paper laid out flat on a horizontal surface was used in conjunction with the funnel, which had its tip set at a specific height, H. With great care, granules were poured into the funnel until the conical pile's apex was within touching distance of the funnel's tip. Next, in order to estimate the angle of repose, the diameter of base of the conical pile was measured.<sup>23</sup>

$$\text{Tan } \theta = \frac{h}{r}$$

Where, h = height of pile

R = radius of the base pile

θ = angle of repose

### Development of Modified Release Tablet

#### Formulation of preliminary patches

First formulations were made with 20% HPC, Klucel LF, and Klucel EF. We created these batches to help to choose the right polymer concentration and range (Table 2).<sup>24,25</sup>

#### Formulation of tablet

Each component was measured out and strained through a #60 mesh sieve. After 30 minutes of thorough mixing on a butter paper with a spatula, the ingredients – Curcumin, HPC, and katira gum – were properly combined. Afterward, the lactose was crumbled into the aforementioned mixture using a pestle and mortar for ten minutes. IPA, a non-aqueous granulating liquid, was added to the damp mass-preparation process. Next, moist material was passed through a mesh #18 filter in order to get granule-ready. To achieve desired uniform size, granules were dried at 60°C and then passed through a mesh #12 sieve once more. Lastly, Mg stearate was added and thoroughly mixed for one to two minutes. In order to create a 250 mg tablet, the granules were subjected to compression using 8 mm concave punches on a JAGUAR JMD-4-8 rotary tablet compression machine.

### Characterization of Developed Modified Release Tablets

#### Thickness

Tablets' thickness was determined using a Vernier Caliper (AEROSPACE), a tool that not only allows for precise measurements but also gives data on the variation among tablets. The thickness of three randomly chosen tablets each formulation batch was measured, and the average and standard deviation of those values were computed.<sup>26</sup>

#### Hardness

This is the required hardness or strength of the tablets so that they can withstand mechanical shocks that happen during

**Table 1:** Melting point, solubility and LOD of curcumin

Test	Observed result	Standard limit
Melting point (°C)	181	179–183
Solubility (mg/mL)		
Water	29.35	26
Phosphate buffer pH 7.4	88.72	-
Phosphate buffer pH 6.8	79.37	-
0.1 N HCl pH 1.2	65.24	-
%Loss on drying (LOD)	0.39	0.5

**Table 2:** Composition of the formulation batches

Ingredients (mg)	F1	F2	F3	F4	F5	F6
Curcumin	50	50	50	50	50	50
HPC	15%	20%	--	--	--	--
Klucel LF (HPCLF)	--	--	15%	20%	--	--
Klucel EF (HPCEF)	--	--	--	--	15%	20%
Katira Gum	2.5	2.5	2.5	2.5	2.5	2.5
Lactose	157.5	157.5	157.5	157.5	157.5	157.5
Mg. Sterate	2.5	2.5	2.5	2.5	2.5	2.5
IPA	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.
Total	250	250	250	250	250	250

the manufacturing, packaging, and related procedures. Using a Monsanto hardness tester (Omega Scientific Company, Ecolab), we randomly selected three tablets from each batch to find the mean and standard deviation of their hardness. Kilograms per square centimeter is a unit of hardness measurement.

#### Friability

To test tablet's friability, ELECTROLABEF2W ver.1.45, a friabilator manufactured by Roche, was utilized. Ten tablets were selected from each formulation batch for the sample weight (W) of the tablets. The tablets were placed in the drum and then spun at 25 rpm (100 rpm) for 4 minutes. Once taking the tablets out of the drum, dusted them, and weighed them again once the test was complete (w0), we continued. A one percent reduction in body weight is considered healthy. Triplicate runs of the test were performed and the mean was determined. A formula was used to determine the friability.

$$F = \frac{W - W_0}{W} \times 100$$

Where, W- Initial weight

W0- Final weight

#### Weight variation

Twenty tablets were randomly selected from every batch to conduct a weight variation test. When each tablet was measured, the SHIMADZU AUX220 digital electronic balance was used. We compared the average weight to the individual weights.

#### Content uniformity

Picking three tablets at random from each batch allowed us to study the consistency of drug content. A powder was produced by crushing and homogenizing the tablets in a glass mortar. By precisely dissolving 10 mg of curcumin powder in 100 mL of phosphate buffer at a pH of 6.8, a 100 µg/mL stock solution was created. To get a clear solution, the mixture was sonicated for 30 minutes and then filtered using Whatman filter paper. A volumetric flask was used to dilute the stock solution to a final volume of 10 mL after 1-mL was removed. Above, we see the UV spectroscopic approach in action, which allowed us to determine the drug concentration at 413 nm.<sup>27</sup>

#### Swelling index

To observe how tablets swelled, researchers used a small petri dish filled with the experimental media and a piece of plastic paper that had been folded twice. The weight of each of these randomly chosen tablets was recorded separately (W1). After placing tablets on a piece of paper in the petri dish, they were immersed in several different solutions: 0.1 N HCL (45 mL), phosphate buffer (pH 6.8) for 5 hours, and finally, phosphate buffer (pH 7.4) for as long as 1-hour. Using tissue paper, we delicately drained the petri dishes of any extra surface water after the specified time interval, and then we removed the tablets. The second and last weight of these bloated tablets was noted as final weight (W2). We used the following equation to determine the percentage swelling index, which was determined after triplicate testing.<sup>28</sup>

$$\text{Swelling Index} = \frac{W_2 - W_1}{W_2} \times 100$$

Where, W<sub>1</sub> = initial weight of tablet

W<sub>2</sub> = weight of tablet after 12 h

#### In-vitro drug release study

For the *in-vitro* drug release investigation, we utilized the ELECTROLAB TDT-08L, a device recognized by USP as a category 2 dissolution device. The standard operating procedure was followed.

#### Kinetic data treatment

Collected data on drug release were examined using various mathematical models to learn more about how the drugs were released from the newly created tablets. Numerous kinetic models were used in this research, such as first-order kinetic, zero-order kinetic, the Higuchi equation, the Hixson-Crowell equation, and the Korsmeyer-Peppas equation.

#### Stability studies of formulation

Curcumin tablets with a changed release formula were put through a short-term stability study that lasted three months. For stability tests, tablets were first wrapped in aluminum foil and then put in a stability room that was kept at a high temperature (40 ± 2° C) and a relative humidity of 75 ± 5%. Once the 3 months were up, the tablets were taken out of the stability room and looked at for their look, drug content, and an *in-vitro* drug release study.

## RESULTS AND DISCUSSION

### Preformulation Study

A study was done on the curcumin drug and its fillers before they were made (Table 3).

### Quantification of Curcumin by UV Spectroscopy

It was found that curcumin's  $\lambda_{\text{max}}$  was 415.2 nm in 0.1N HCL, 412.4 nm in PBS 6.8 pH, and 420.5 nm in PBS 7.4 pH. It was used to study drug release to look at the wavelength of curcumin in different dissolving mediums.

### Drug-Excipient Compatibility Studies

The FTIR spectrum that was recorded shows that curcumin has main peaks, which means that curcumin, polymers, and excipients did not interact with each other (Figure 1). So, it was proven that curcumin, polymers, and the excipient did not react badly with each other. Which was backed by the FTIR spectrum "F" that was put on top of it. The DSC test was done on pure curcumin, curcumin mixed with polymers, and curcumin mixed with other substances. A sharp endothermic peak can be seen on the DSC thermogram of curcumin at 124.16°C. The physical mixture of the medication, polymer, and excipients similarly exhibited this peak at 118.35°C. The fact that these high values were relatively unchanged between the curcumin polymers and excipients demonstrated that there was little to no adverse interaction between the two.

### Differential Scanning Calorimetry

There was a sharp endothermic peak at 181.4°C on the DSC thermogram of pure curcumin (Figure 2), which was the melting point of curcumin. This was very similar to the sharp endothermic peak at 149.6°C on the DSC thermogram of the improved tablet formulation (Figure 3). The findings showed that the crystalline structure of the curcumin stayed the same after the tablets were pressed together. This thermogram also proved that the curcumin did not change into any other form after the tablets were compressed.

### X-Ray Diffraction (XRD)

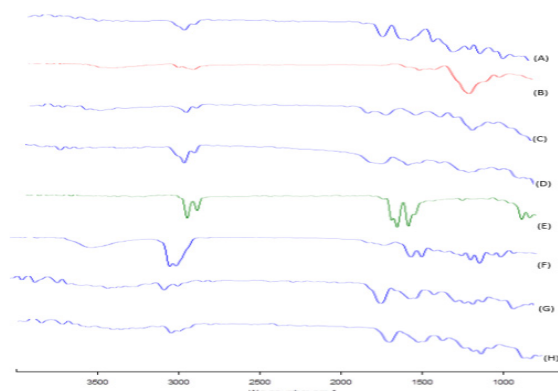
An X-ray diffractometer (XRD) was used to look at the pattern of diffraction in pure curcumin. P-XRD pattern of curcumin shows very strong and sharp peaks, which also shows that chemical is crystallized (Figure 4). The P-XRD analysis of the best batch mixture shows that there were no changes in the powder blend's polymers after it was compressed (Figure 5).

### Determination of Precompression Parameters

Before the curcumin-modified release tablet was compressed, the granules were checked for their angle of repose and Carr's index to learn more about how they move. These studies looked at all six formulation types and found that the angle of repose was between 32 and 34% and the Carr's index was between 11 and 14%. These findings met the standards set in the literature. Based on this finding, it was clear that all of the formulations had good flow properties, which were needed when tablets were compressed.

**Table 3:** Study of flow properties as a part of preformulation studies

Batch code	Bulk density (gm/cm <sup>2</sup> )	Tapped density (gm/cm <sup>2</sup> )	Carr's index	Angle of repose( $\theta$ )
F1	0.352	0.426	11.23	32.30
F2	0.355	0.425	12.59	32
F3	0.370	0.398	11	32.78
F4	0.341	0.412	11.20	33.24
F5	0.312	0.400	11.90	34
F6	0.330	0.440	11.55	33.26



**Figure 1:** FTIR spectra of (A) Curcumin (B) HPC (C) Katira gum (D) Lactose (E) Magnesium stearate (F) Curcumin with HPC (G) Curcumin with klucel LF (H) Curcumin with Klucel

### Characterization of Tablets of Curcumin

#### *In process quality control test for preliminary batches*

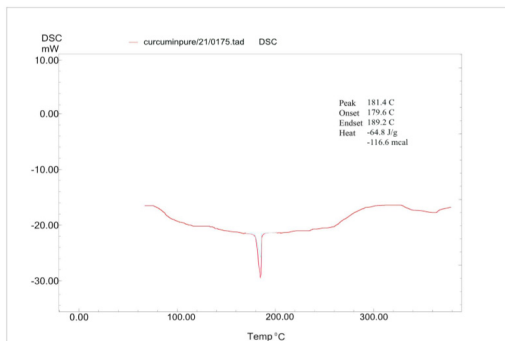
Curcumin-modified release tablets were manufactured for the process quality control test using the non-aqueous wet granulation method in conjunction with two release retardants, HPC and Katira gum. We made six separate batches of recipes. Table 5 shows the results of the physical characterization tests conducted on the formed tablets. The measured thicknesses for all the formulas fell somewhere between 4.01 and 4.12 mm. The tablet hardness ranged from 12.10 to 12.24 kg/cm<sup>2</sup>. As far as the literature was concerned, it was in line with the conventional values. About 4kg/cm<sup>2</sup> is the bare requirement for tablet manufacturing. Across all formulations, the average weight of the tablets fell somewhere between 250 and 250.2 mg. Hence, according to USP, the weight variation test was passed by all six formulations. There was a range of 98.02 to 99.68% drug concentration across all six formulations. Therefore, each tablet met the requirements of IP 2010 (a curcumin tablet must contain between 90 and 110% of the listed amount of curcumin) (Table 4).

#### *Swelling index*

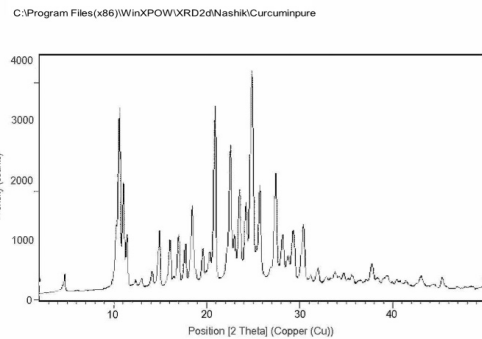
Katira gum and hydrophilic polymers are similar. The swelling behavior of modified-release tablets of curcumin is greatly affected by the concentration and ratio of both of these polymers, according to the current study. The batches F1 and

**Table 4:** Quality control of formulated modified-release tablets of curcumin

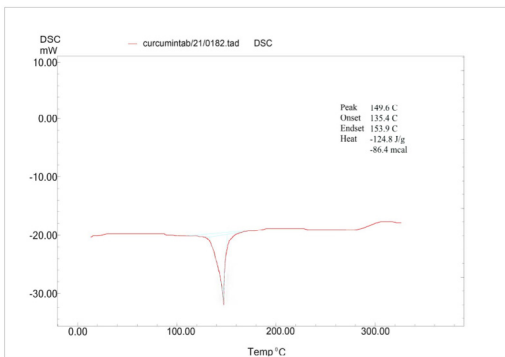
Batch code	Thickness (mm)	Hardness (kg/Cm <sup>2</sup> )	Friability (%)	Weight variation (mg)	Drug content (%)
F1	4.1 ± 0.1	12.12 ± 0.5	0.21 ± 0.022	250.2	98.32 ± 0.59
F2	4.1 ± 0	12.15 ± 0.27	0.21 ± 0.023	250.1	99.68 ± 0.02
F3	4.03 ± 0.05	12.10 ± 0.52	0.20 ± 0.0057	250.01	98.20 ± 0.62
F4	4.01 ± 0	12.12 ± 0.55	0.21 ± 0.022	250.0	98.22 ± 0.49
F5	4.12 ± 0.02	12.26 ± 0.15	0.22 ± 0.023	250.03	98.03 ± 0.16
F6	4.1 ± 0.1	12.24 ± 0.12	0.21 ± 0.021	250.2	98.65 ± 0.12



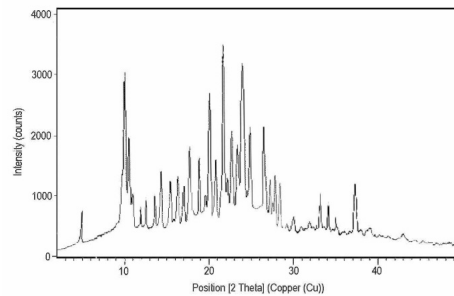
**Figure 2:** DSC thermogram of pure curcumin



**Figure 4:** X-ray diffractogram of Curcumin



**Figure 3:** DSC thermogram of optimized formulation



**Figure 5:** X-ray diffractogram of optimized tablet

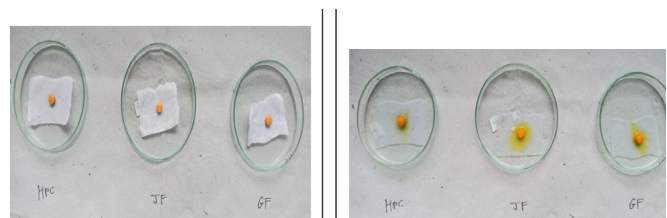
**Table 5:** Swelling index

Batch Code	Swelling index (%) in 0.1 N HCL (pH 1.2) (2 h)	Swelling index (%) in phosphate buffer pH 7.4 (12 h)
F1	38.75 ± 0.10	91.92 ± 0.08
F2	38.70 ± 0.15	92.90 ± 0.46
F3	38.72 ± 0.12	90.12 ± 0.42
F4	38.71 ± 0.11	90.22 ± 0.12
F5	37.98 ± 0.15	89.02 ± 0.32
F6	37.96 ± 0.16	82.06 ± 0.12

F3 exhibit the highest swelling index values; after 2 hours in 0.1 N HCL (pH 1.2) and 91.92% in phosphate buffer pH 7.4 after 12 hours, respectively (Figure 6, Table 5).

*In-vitro drug release study*

Hydrophilic polymeric matrix systems are basis of the curcumin modified release tablets that have been created. Here, the medication is released into the body when it dissolves in a



**Figure 6:** Swelling Index of the tablet (a) initial tablet (b) tablet after 24 hours.

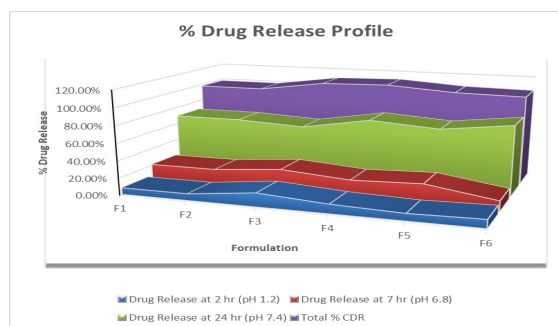
hydrophilic polymeric matrix that contains the drug particles. Erosive matrix degradation and diffusion over the gel layer. Drug release% in 0.1 N HCl (pH 1.2) after 2 hours. In this order: F1 = 7.82, F2 = 7.8, F3 = 15.92, F4 = 10.71, F5=8.28, F6= 9.81. In comparison to F1 and F2, formulations F3, F4, F5, and F6 exhibit extremely high drug release (Figure 7). The medication was able to become trapped in the polymer matrix because of the milling gelling feature of katira gum, which is pH dependent. Entrapped medication within the polymer matrix was not released as katira gum shrank at stomach pH.

**Table 6:** Kinetic release study of formulation

Batch code	Zero order		First order		Higuchi		Krosmejaer-peppas		Hixon-Crowell	
	$R^2$	$K_0$	$R^2$	$K_1$	$R^2$	$K_H$	$R^2$	$n$	$R^2$	$K_S$
F1	0.9966	4.1305	0.8453	0.0551	0.9354	23.899	0.9958	0.994	0.9355	-0.1468
F2	0.9970	4.1471	0.8346	0.0556	0.9416	24.059	0.9977	1.009	0.9247	-0.1452
F3	0.9782	4.395	0.9113	0.0453	0.8906	25.046	0.7608	0.876	0.9322	-0.1273
F4	0.9954	4.5955	0.8588	0.0521	0.9308	26.062	0.9908	0.930	0.9414	-0.1388
F5	0.9901	4.4187	0.8204	0.0557	0.9468	25.69	0.9989	1.020	0.961	-0.1178
F6	0.9745	4.395	0.8994	0.054	0.8861	25.029	0.9464	0.919	0.9415	-0.1129

**Table 7:** Stability study of F2 formulation

S. No	Parameter	Observation	
		Before stability study	After stability study
1	Physical appearance	Yellow	Yellow
2	Drug content (%)	99.68	98.62
3	Drug release (%)	98.17	97.89

**Figure 7:** *In-vitro* drug release study of different formulation batches.

Due to its greater swelling capacity in aqueous media, katira gum is able to release less medication when exposed to acid. Additionally, the matrix-forming agents HPC, Klucel JF, and Klucel GF were utilized for extended-release applications. The drug release rate is reduced by increasing the thickness of the diffusional layer, which is achieved when an anionic agent, such as katira gum, is added to the matrix former (HPC, Klucel JF, and Klucel GF), which in turn raises its viscosity.

#### Kinetic data treatment

Kinetic study was done by using a Korsmeyer-Peppas kinetic model. Twenty milligrams of HPC is the lowest concentration seen in any of these formulations. Drug release was delayed for up to 18, 19, and 18 hours, respectively, after these formulations were exposed to the dissolution media, and they exhibited the least swelling. The diffusional exponent, abbreviated as “n,” is what controls the device’s drug release mechanism.<sup>29</sup> According to Table 7, the values of “n” for F2 were 1.0092 and 1.0202, respectively, suggesting that these formulations followed the protocol of Anomalous transport.<sup>30</sup> The medication is released from the device in anomalous transport through a combination of the diffusion and erosion mechanisms.<sup>31</sup>

F1, F3, F4, and F6 were the other four formulations that showed zero-order kinetics. The highest concentration of HPC, around 15 to 20%, is present in all of these formulations. So, when these formulations were mixed with the dissolving liquid, the swelling was at its highest. The inflated polymeric matrix is the route via which the medication diffuses. These dose formulations have a delayed onset of action of up to 24 hours (Table 6).

#### Short-term stability study

Following a three-month storage period, the F2 curcumin formulation was assessed. Physical appearance, drug content, and %drug release research were all factors considered while evaluating the tablets. At the conclusion of the three-month storage period, the results demonstrated that the appearance of the modified-release curcumin tablet had not changed noticeably. Additionally, the drug content percentage and drug release were not different, suggesting that the F2 formulation was stable (Table 7).

## CONCLUSION

The curcumin-modified-release tablet formulations were a success. Formulation F2, which showed sustained drug release for up to 24 hours, also had the highest swelling characteristics. In addition, the data show that less than 10% of the medicine was released in the stomach environment when gastric-resistant or enteric-coating polymers were not used. By utilizing the shrinking property of katira gum, we can inhibit the drug’s release in stomach conditions with low pH. The combination of HPC, an extended-release matrix-forming agent, with katira gum, a prolonged-release agent with minor gelling capabilities, results in better retardation of drug release characteristics. The swelling and gelling properties of hydrophilic polymers like HPC and katira gum caused the delayed drug release. This layer is created to surround the tablet matrix and is dependent on the formation of a hydrated viscous substance. Results from differential scanning calorimetry and powder X-ray diffraction analyses showed that compressing the enhanced formulation batch had no effect on curcumin crystallinity. Crystalline molecules make up curcumin. F2 was thus chosen as the optimal formulation. This study accomplished its stated goal of creating modified-release tablets at a reasonable cost without the use of expensive coating technology or enteric coating polymer.

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