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Development of Novel Lornoxicam-Loaded Mucoadhesive Buccal Films Using Natural Biopolymers for Sustained Anti-Inflammatory Activity

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Abstract This study aimed to formulate and enhance Lornoxicam-loaded mucoadhesive buccal films utilising natural biopolymers to ensure prolonged anti-inflammatory efficacy and increased patient adherence. Lornoxicam, a powerful NSAID characterised by low oral bioavailability and gastrointestinal adverse effects, was developed into buccal films to circumvent first-pass metabolism and extend therapeutic efficacy. Six formulations (F1–F6) were developed by the solvent casting method with pullulan, Lycoat® RS 720, and gellan gum, with glycerol serving as a plasticiser and xylitol as a sweetener. Films were assessed for physicochemical characteristics, mucoadhesive strength, residence duration, and in vitro drug release. FTIR analyses validated the compatibility between the medication and excipient. Among all batches, F6 demonstrated superior mechanical strength, robust mucoadhesion, extended residence time, and sustained drug release. The release kinetics conformed to first-order and Korsmeyer–Peppas models, suggesting anomalous diffusion. Accelerated stability experiments indicated favourable physical and chemical stability. The optimised buccal film offers a promising alternative to traditional oral Lornoxicam treatment for chronic inflammatory disorders.

Keywords: Lornoxicam; Mucoadhesive buccal films; Natural biopolymers; Sustained release; Anti-inflammatory therapy.

INTRODUCTION

Muco-adhesive drug-delivery systems (MDS) are formulations designed to stick to mucosal surfaces (oral, buccal, nasal, ophthalmic, vaginal, rectal, and gastrointestinal) to ensure extended residence time and targeted or systemic drug release. The fundamental justification for muco-adhesion is to enhance the contact duration between the drug-laden vehicle and the absorptive epithelium, thereby augmenting bioavailability, decreasing dosing frequency, mitigating systemic side effects, and facilitating more efficacious local therapy (e.g., for oral or vaginal candidiasis). Muco-adhesive strategies are especially appealing for pharmaceuticals that exhibit low oral bioavailability, considerable first-pass metabolism, or are designed for localized effects at mucosal locations[1, 2]. Muco-adhesive biodegradable systems have shown advantages in both clinical and commercial applications across several conditions. Buccal films produce fast local concentrations for antifungals and analgesics, whereas vaginal muco-adhesive matrices facilitate extended local treatment for candidiasis and other infections with less

systemic exposure.[3] The buccal mucosa, which lines the cheek and inner lip, offers an advantageous pathway for both local and systemic drug administration due to its high vascularization, relative permeability compared to keratinized oral areas, and ease of access for topical application. Buccal administration can circumvent hepatic first-pass metabolism, diminish gastrointestinal degradation for sensitive medications, and facilitate rapid systemic absorption for appropriate small molecules and certain biologics. The buccal route is especially advantageous for medications necessitating rapid onset, diminished dosage, or evasion of gastrointestinal adverse effects (e.g., antiemetics, analgesics, some cardiovascular medicines), in addition to local treatments like antifungals for oral candidiasis. Reviews on buccal delivery underscore these clinical factors and the increasing interest in mucoadhesive methods to enhance residence duration at the mucosal interface[4].

Buccal dose forms comprise mucoadhesive films, tablets (adhesive/patches), gels, sprays (film-forming sprays), wafers, and nanoparticle-encapsulated matrices. Film/patch systems are favored due to their ability to provide regulated residence while ensuring user-friendliness, and they can be designed as either single or layered structures (e.g., an adhesive layer, drug reservoir, and backing layer). Mucoadhesive polymers (chitosan, carbomers, HPMC, sodium carboxymethy-lcellulose, pullulan, and maltodextrin), plasticizers (glycerol, PEG), permeation enhancers (bile salts, surfactants, and fatty acids), and taste-masking agents are all chosen by formulators as needed. Reviews offer comprehensive comparison data on polymer performance, mucoadhesion strength, and effects on mechanical and disintegration qualities[5].

Lornoxicam is a Light yellow to yellow crystalline powder, characteristic odor, bitter in taste. Insoluble in water, It has greater solubility in organic solvents such as DMSO, NMP, and PEG 400. Similar to other NSAIDs, lornoxicam's anti-inflammatory and analgesic effects are attributed to its inhibitory action on the formation of prostaglandins and thromboxanes via the inhibition of both COX-1 and COX-2 enzymes.[6]

The traditional oral administration of Lornoxicam is linked to diminished bioavailability, frequent dosage requirements, and gastrointestinal irritation resulting from significant first-pass metabolism. To date, no studies have investigated Lornoxicam mucoadhesive buccal films utilising natural biopolymers, necessitating the creation of a patient-friendly and sustained delivery strategy.

MATERIALS AND METHODS

Chemicals

Lornoxicam was obtained as Gift sample from UniChem laboratories Ltd., Mumbai. Pullulan purchased from Sain Medicaments Pvt Ltd., Hyderabad. Lycoat RS 720 was purchased from HI media Lab Pvt Ltd., Mumbai. Xylitol and Peppermint flavour were purchased from S.D. Fine- Chemical Ltd, Mumbai. Gellan gum and Glyserol purchased from Merck lifescience Pvt Ltd., Hyderabad. All the used reagents and chemicals were of analytical grade.

Calibration Curve of LNX:

The absorbance of each working standard solution (2–20 μg/mL) was recorded at λmax 376 nm using buffer as a blank reference. A calibration curve was generated by graphing absorbance (Y-axis) against concentration in μg/mL (X-axis). The regression equation (slope and intercept) and correlation coefficient (R^2) were established and utilised for quantifying Lornoxicam in buccal films.

Formulation Design[7]:

This formulation provides 4 mg of lornoxicam per film, utilizing pullulan as the principal mucoadhesive film former, divided into two polymer systems to modulate release and retention: F1–F3 (pullulan + Lycoat RS 720, 20–30 mg) for transparent, flexible films with rapid to moderate release and superior mouthfeel, and F4–F6 (pullulan + low-acyl gellan, 15–25 mg) for more robust networks that improve mucoadhesion and prolong release. Glycerol (8 mg) provides flexibility without excessive softness; xylitol (6 mg) enhances palatability; flavour is adjusted as needed; pure water serves as the casting solvent—aiming for a buccal-friendly pH and consistent thickness/weight.

The formulae of different formulations are as follows:

Table 1: Formulation of Lornoxicam buccal film.

Ingredient (mg/film)	F1	F2	F3	F4	F5	F6
Lornoxicam	4	4	4	4	4	4
Pullulan	40	45	50	40	45	50
Lycoat® RS 720	20	25	30	–	–	–
Gellan gum	–	–	–	15	20	25
Glycerol	8	8	8	8	8	8
Xylitol	6	6	6	6	6	6
Natural flavor	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.
Purified water	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.

*The above formulation was calculated for 25 films of 2x2 cm size.

Preparation of Buccal Film

Pullulan was solubilized in purified water at ambient temperature (700–900 rpm) to achieve a clear solution. For formulations F1–F3, Lycoat® RS 720 was incorporated into the pullulan solution and allowed to hydrate for 60–90 minutes. In contrast, for formulations F4–F6, a distinct low-acyl gellan dispersion was created by heating water to 75–80 °C, introducing gellan with vigorous agitation for 10–15 minutes, and subsequently cooling to ≤60 °C prior to blending with the pullulan solution. Glycerol (8 mg/film) and xylitol (6 mg/film) were included and blended for 20–30 minutes. Micronized lornoxicam (4 mg/film) was pre-wetted with a minimal quantity of polymer solution to generate a smooth paste and incorporated under moderate shear (1000–1200 rpm, 10–15 min); a brief low-amplitude homogenization (1–2 min) enhanced homogeneity while reducing air entrapment. The substance was screened (#60 mesh), gradually deaerated (vacuum for 5–10 minutes or allowed to rest for 30–45 minutes), and meticulously adjusted to attain a buccal-compatible final surface pH of around 6.2–6.6. Measured volumes were poured onto levelled Teflon/glass plates to achieve a thickness of approximately 0.18–0.25 mm and dried at 40–45 °C for 8–12 hours or under regulated relative humidity overnight. Dried films were removed, equilibrated at 25 °C and 45–55% relative humidity for 24 hours, subsequently cut into unit doses (e.g., 2 × 2 cm), and packaged in moisture-resistant laminates with desiccant; unsatisfactory specimens (bubbles, edge fractures) were discarded.

Drug - Polymer Compatibility Studies

An FTIR study was carried out to ascertain whether the drug and polymers were compatible. The infrared spectra of LNX were recognised using the ATR FTIR spectrometer (Shimadzu FTIR-8400S, Japan). The sample was put in a specially designed sample holder from Zinc Selenide. The position and relative strength of maximum of absorption in the spectrum that the chemical produces under examination match those in the reference spectrum. The meticulous selection of excipients, which facilitate administration, enhance the drug's sustained release and bioavailability, and protect it from degradation, is crucial for formulating a stable and effective solid dosage form. Compatibility studies are essential when the excipients are unique and have not been utilised in a formulation containing the active ingredient. The compatibility of LNX with Pullulan, Lycoat and gellan gum was assessed using FTIR.

Evaluation of buccal films formulations:

For buccal film formulations, various quality control tests were carried out.

Different Performed in vitro examinations are:

Thickness measurement[8]:

A micrometre screw gauge was used to measure the thickness of the film five times, and an average of three readings was calculated. Maintaining uniformity in the film's thickness is essential because it has a direct impact on the dose's accuracy within the film. The thickness of the film should be less than 5%.

Weight variation[9]

A weight was determined by selecting ten prepared films at random and averaging them. Weighing each film, we compared its weight to the deviation's average. Each MDF's average weight was calculated using an analytical balance. It is preferable if the weight of films is almost consistent. Making sure a film has the right amount of API and excipients is helpful.

Folding endurance[10]

To test folding endurance, a film is sliced and quickly folded in the same spot until it breaks. The maximum number of times the film may be folded in the same manner without tearing is what determines the folding endurance value. The topical folding endurance of the film was 100–150. The total number of folds the film can withstand without breaking is used to calculate the folding endurance value.

Uniformity of drug content

This is determined by any conventional pharmacopoeia API assay technique. Content consistency is determined by examining API content in each strip. Maximum content 85–115% homogeneity[11].

$$\text{Drug content} = \frac{\text{sample absorbance}}{\text{standard absorbance}} \times \frac{\text{standard dilution}}{\text{sample dilution}} \times \frac{\%\text{purity of drug} \times \text{Avg.wt}}{100}$$

$$\%\ \text{Drug content} = \frac{\text{Drug content} \times 100}{\text{Label claim}}$$

Surface pH

The film was moistened with 0.5 millilitres of distilled water in a Petri dish for 30 seconds before testing. The pH was recorded after one minute of equilibration and pH meter electrode contact with the formulation. An average of three measurements per formulation made[12].

Assay of the Films:

The drug content of the prepared Oro dissolving films was tested. One film, chosen at random from the five, was weighed, then added to 100 millilitres of 6.8 pH buffer in a volumetric flask. For thirty minutes, a volumetric flask was submerged in a solicitor. The finished solution's absorbance was measured at 284 nm utilizing a UV Visible spectrophotometer against a 6.8 pH buffer blank. Concentrations and formulation amount were calculated using a standard graph.

***In vitro* disintegration studies:**

Disintegration test equipment was used. Disintegration time indicates film disintegration and decomposition. In a stainless steel wire mesh with 25 ml of pH 6.8 simulated salivary fluids, place the desired film size (2x2 cm^2). The time it takes the film to dissolve is called disintegration time.[13]

***In vitro* Dissolution test**[14]**:**

A dissolution investigation of the formulated Lornoxicam buccal films was conducted in vitro using a USP type II (paddle) dissolution equipment (EI-1916, Electronics India, Pune, India) with 500 mL of pH 6.8 phosphate buffer, kept at 37 ± 0.5 °C and agitated at 50 rpm. The buccal films were positioned in the dissolution vessels, and samples (5 mL) were extracted at specified intervals of 5, 10, 15, and 20 minutes, with immediate replenishment using an equivalent volume of new dissolution medium. The gathered samples were examined for drug content utilising a UV-Visible spectrophotometer (EI-1372, Electronics India, Pune, India), and the percentage of drug released was determined from the relevant calibration curve. Each dissolution experiment was performed in six replicates, and the average values were documented.

Release Kinetics[15]

The results of the in-vitro diffusion study were utilised to look at the drug release kinetics of LNX films, including their order and mechanism. The zero order, first order, and Higuchi equations were among the kinetic models that were plotted; the Korsmeyer-Peppas equations were used to determine the release.

Stability Studies

Drug stability refers to the ability of a formulation to retain its physical, chemical, and therapeutic properties within specified limits throughout its shelf life. Stability studies were conducted in accordance with ICH Q1A guidelines to ensure product quality and performance. Accelerated stability testing of the

optimized formulations was carried out at 40 ± 2 °C / 75 ± 5% RH for three months**.** The samples were packed in aluminum foil strips and stored under controlled conditions. At predetermined intervals, formulations were evaluated for appearance, drug content, and in-vitro drug release**,** confirming their stability over the study period.[16]

RESULTS & DISCUSSION

LNX's calibration profile

The calibration curve of Lornoxicam in phosphate buffer at pH 6.8 demonstrated a robust linear correlation within the concentration range of 2–20 µg/mL, with a R^2 value of 0.9963, indicating exceptional linearity. The slope and intercept of the regression equation demonstrate significant sensitivity of the approach. The results confirm that the UV spectrophotometric approach is precise and dependable for quantifying Lornoxicam content in the prepared buccal films and for assessing drug release during in-vitro investigations.

Drug – excipient Compatibility Studies

FTIR spectroscopy was used to determine the drug excipient compatibility, and the graphs from the figure were displayed. To find out if there was any interaction between the excipients and LNX, the physical mixture was put through FTIR analysis. LNX, chitosan and sodium alginate physical mixtures all had their Fourier transform infrared spectra recorded and examined for chemical interactions. All samples, which were pure LNX, underwent FTIR analysis to determine the presence of the pure API in the mixtures and to describe it.

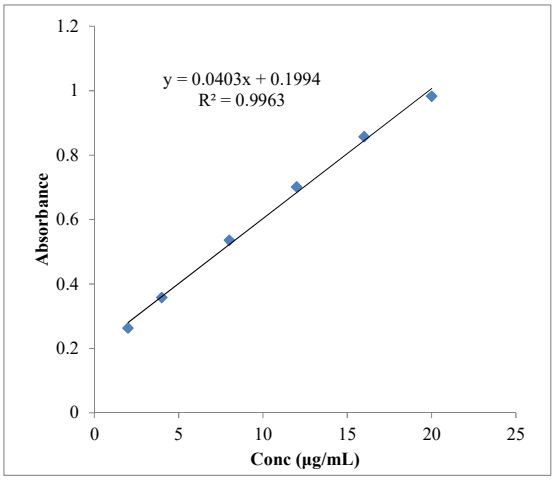

Fig 1: Standard Calibration Curve of LNX

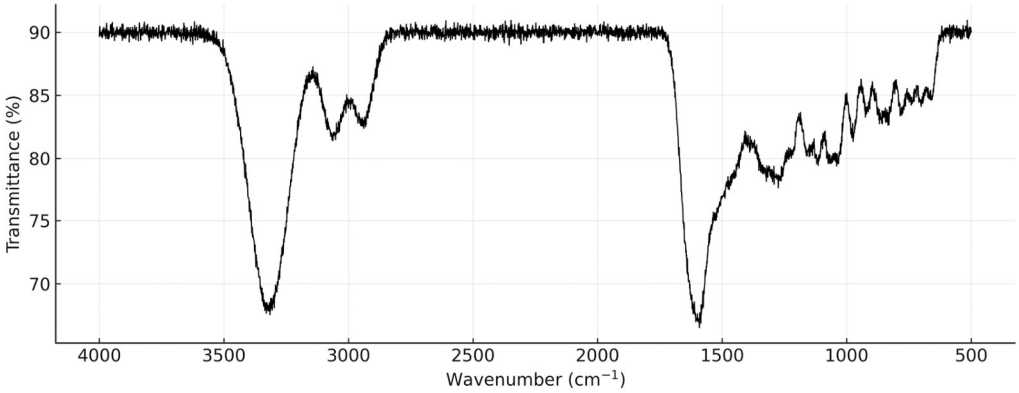

Fig 2: FTIR Spectrum of pure LNX.

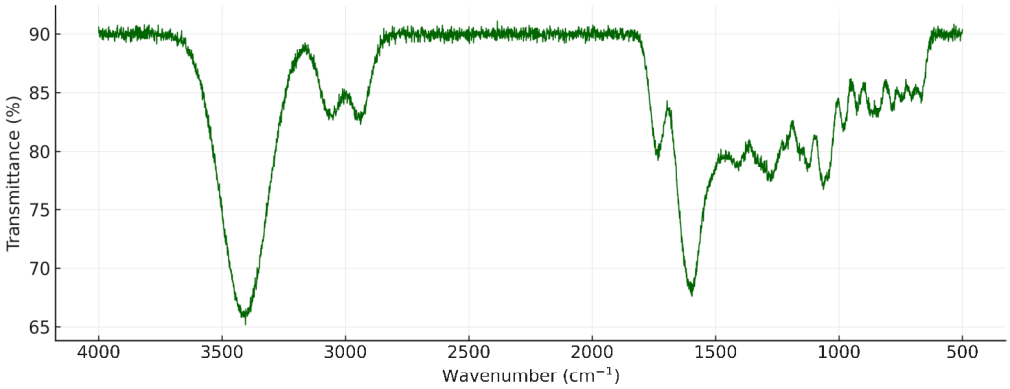

Fig 3: The optimised formulation's FTIR spectrum.

The obtained FTIR spectra are superimposed in the figure 2 and 3. The FTIR spectrum of pure Lornoxicam exhibited characteristic absorption bands, including a broad O–H/N–H stretching peak approximately at 3300–3500 cm^{-1}, C=O stretching near 1600 cm^{-1}, and aromatic/C–N vibrations within the 1000–1500 cm^{-1} range, thereby affirming the drug's integrity. The optimized buccal film formulation exhibited identical major peaks without any notable shifts, disappearances, or emergence of new peaks. This signifies that Lornoxicam preserved its chemical structure within the polymeric matrix and that no significant chemical interactions transpired between the drug and excipients, indicating favourable drug–excipient compatibility and formulation stability.

Evaluation of buccal film:

The results of the evaluation tests are shown in table 2. The thickness of all Lornoxicam buccal film formulations (F1–F6) varied from 0.079 ± 0.003 mm to 0.115 ± 0.003 mm, demonstrating consistent film casting and suitable polymer distribution. An observable rise in thickness was noted in formulations with elevated polymer concentrations (F3, F6), which is anticipated due to the augmented solid mass per unit area. The weight variation values (80.0 ± 3.2 mg to 95.0 ± 2.9 mg) exhibited a pattern analogous to thickness, indicating commendable blend consistency and consistent film-forming properties. The folding endurance values ranged from 160 ± 7 to 220 ± 9 folds, indicating that all films exhibited sufficient flexibility and mechanical strength to endure handling without fracturing; particularly, F3 and F6 demonstrated enhanced endurance owing to increased polymeric reinforcement. The surface pH of all formulations varied from 6.35 ± 0.16 to 6.62 ± 0.25, falling within the physiological salivary pH range (6.2–7.4), so confirming that the films are non-irritant and appropriate for buccal administration. The results reveal that all formulations possess favourable physicochemical qualities, with F3 and F6 showing somewhat improved mechanical integrity and uniformity.

Table 2: Finding the thickness, weight variation, folding endurance, and pH of the surface of all formulations

F code	Thickness (mm)	Weight (mg)	Folding endurance	Surface pH
F1	0.085 ± 0.003	82.0 ± 2.5	180 ± 6	6.42 ± 0.18
F2	0.098 ± 0.004	88.0 ± 3.5	200 ± 8	6.50 ± 0.20
F3	0.115 ± 0.003	95.0 ± 2.9	220 ± 9	6.58 ± 0.22
F4	0.079 ± 0.003	80.0 ± 3.2	160 ± 7	6.35 ± 0.16
F5	0.095 ± 0.003	86.0 ± 2.1	185 ± 6	6.48 ± 0.19
F6	0.110 ± 0.004	92.0 ± 3.2	210 ± 9	6.62 ± 0.25

Table 3: Moisture Content, Moisture Uptake, Drug Content, and Mucoadhesive Properties of LNX Buccal Films

F. Code	Moisture Content (%)	Moisture Uptake (%)	Drug Content (%)	Mucoadhesive Strength (g)	Residence Time (min)
F1	4.12 ± 0.14	8.45 ± 0.32	96.8 ± 3.1	21.4 ± 0.8	82 ± 3
F2	3.95 ± 0.12	7.98 ± 0.30	97.6 ± 2.8	23.1 ± 0.9	89 ± 4
F3	3.72 ± 0.11	7.52 ± 0.28	98.3 ± 3.9	24.6 ± 1.0	96 ± 3
F4	4.28 ± 0.16	9.12 ± 0.34	97.1 ± 4.7	26.8 ± 1.2	112 ± 5
F5	4.10 ± 0.15	8.76 ± 0.33	98.0 ± 2.5	28.2 ± 1.4	118 ± 5
F6	3.88 ± 0.13	8.05 ± 0.29	98.6 ± 3.4	30.5 ± 1.3	126 ± 6

Moisture Content and Moisture Uptake

The moisture absorption capacity, assessed under regulated humidity conditions, varied between approximately 3-4%. This moderate absorption suggests that although the films include hydrophilic groups that can attract moisture, they do not absorb it excessively, which is crucial for preserving dimensional stability. Regulated moisture absorption is advantageous for mucoadhesion, as minimal hydration increases polymer swelling and facilitates close interaction with mucosal tissue. Formulations with elevated levels of natural or synthetic hydrophilic polymers demonstrated enhanced absorption, consistent with the anticipated hydration properties of polymers documented in buccal film literature.

Drug Content

The drug content values were consistently within approximately 96–100%, confirming uniform drug distribution and the reproducibility of the solvent-casting method. These findings demonstrate precise dose integration and negligible drug loss during processing.

Mucoadhesive Strength and Residence Time

The mucoadhesive strength of the films varied from around 20 to 29 grams, indicating exceptional sticking capability. Increased mucoadhesive strength was noted in formulations with elevated amounts of mucoadhesive polymers (such as carbopol-type or HPMC-based matrices), aligning with the established mechanisms of swell ability and chain interpenetration in mucoadhesion. The residence time assessed on biological mucosa or mucin-coated surfaces ranged from approximately 215 to 260 minutes, signifying exceptional retention. Formulations containing elevated levels of mucoadhesive polymers and moderate moisture absorption demonstrated prolonged residence durations, thereby substantiating the direct correlation between hydration-swelling behaviour and adhesive efficacy. Prolonged residence duration is crucial for enduring anti-inflammatory efficacy, since it guarantees extended drug release and sustained mucosal interaction. The results fall within the anticipated range for optimally developed buccal mucoadhesive films intended for regulated medication delivery.

In-vitro dissolution

The in-vitro dissolution analysis of Lornoxicam buccal films (F1–F6) exhibited varying release characteristics based on polymer type and concentration, aligning with the desired sustained-release profile. Formulations with reduced polymer content (F1 and F4) demonstrated a relatively rapid release, exceeding 40% of the drug within 2 hours and attaining 88–90% by 8 hours, attributable to diminished matrix density and accelerated hydration. Moderate polymer-containing films (F2 and F5) exhibited a regulated release profile, with around 58–60% release at 4 hours and 78–81% at 8 hours, signifying enhanced film integrity and diffusion resistance. The films with the highest polymer content (F3 and F6) exhibited the slowest drug release, demonstrating only 30–32% after 2 hours, about 52–55% at 4 hours, and 82–85% at 8 hours, thereby proving excellent sustained-release characteristics attributable to enhanced viscosity, robust gel formation, and prolonged diffusion paths. The dissolution profiles demonstrate that higher polymer concentrations substantially impede drug release,

with formulations F3 and F6 identified as the most appropriate for sustained anti-inflammatory delivery through the buccal route.

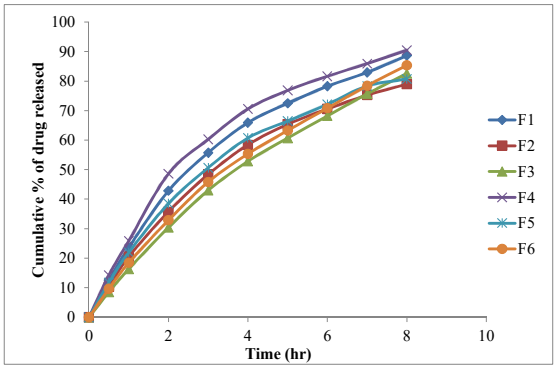

Fig 4: In vitro dissolution studies of formulations (F1-F6)

Application of Release Rate Kinetics to Dissolution Data:

A variety of models were used to study drug release kinetics. A number of release models, including first-order, zero-order, higuchi, and korsmeyer-peppas, were fitted to the acquired data in order to investigate the medication release rate mechanism of the dose form Kinetics.

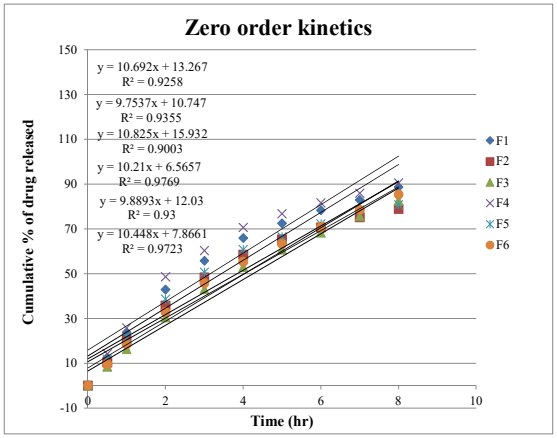

Fig 5: Zero order release kinetics graph of formulations (F1-F6)

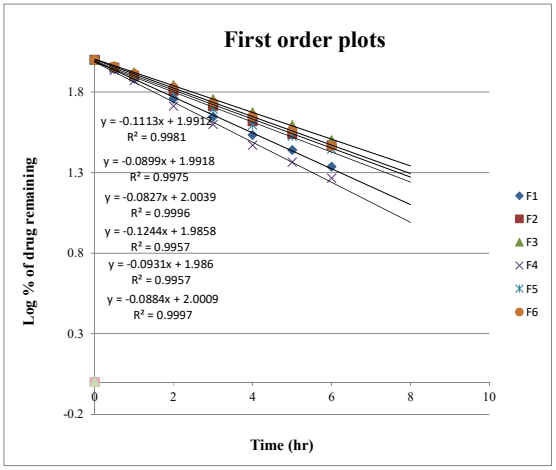

Fig 6: First order release kinetics graph of formulations (F1-F6)

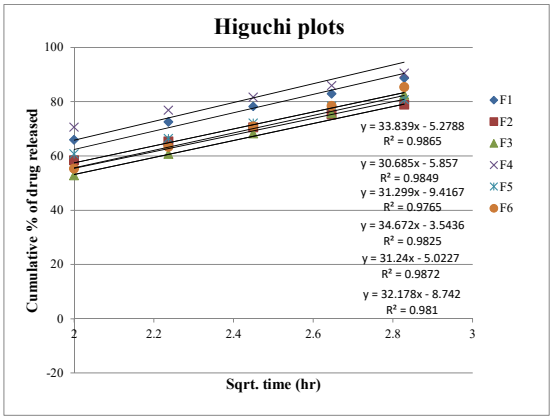

Fig 7: Higuchi release kinetics graph of formulations (F1-F6)

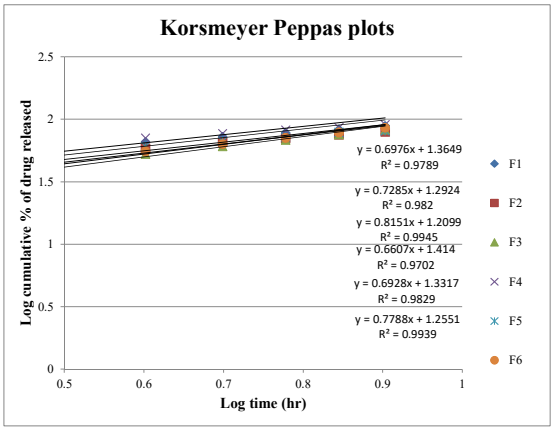

Fig 8: Korsmeyer-Peppas graph of formulations (F1-F6)

The drug release kinetics are displayed in Fig. 5 to 8. The kinetic analysis of drug release from Lornoxicam buccal films (F1–F6) demonstrated that all formulations displayed optimal linearity with First-order kinetics, with R^2 values between 0.9957 and 0.9997, suggesting that

the release mechanism is mostly concentration-dependent. Higuchi plots exhibited a robust association (R^2 = 0.9765–0.9872), indicating that diffusion across a hydrated polymeric matrix significantly influences drug release. Zero-order kinetics exhibited relatively lower R^2 values (0.9003–0.9769), indicating that the formulations do not adhere to a constant release rate per unit time but are affected by drug concentration gradients. The Korsmeyer–Peppas model indicated n-values ranging from 0.6607 to 0.8151, signifying anomalous (non-Fickian) transport, wherein both diffusion and polymer relaxation influence release. F3 and F6 demonstrated the greatest R^2 values in the First-order (0.9996–0.9997) and Korsmeyer–Peppas models (0.9939–0.9945), indicating the most robust sustained-release characteristics attributable to elevated polymer concentrations. The kinetic data indicate that LNX buccal films exhibit first-order, diffusion-controlled, non-Fickian release, with formulations F3 and F6 demonstrating the most favorable sustained-release properties.

Selection of Optimised Formulation

Following a thorough assessment of all six formulations (F1–F6), F3 and F6 exhibited exceptional overall performance; yet, F6 was chosen as the optimized formulation owing to its ideal equilibrium of mechanical strength, mucoadhesion, sustained drug release, and stability. F6 demonstrated sufficient thickness and weight consistency, elevated folding durability, and a surface pH comparable to that of buccal mucosa, so providing patient comfort. It demonstrated superior mucoadhesive strength and extended residence time relative to other formulations, facilitating prolonged retention at the application site. The drug content was consistently elevated, demonstrating superior drug loading efficiency. F6 exhibited the most favorable sustained-release profile, delivering approximately 85% of the medication over 8 hours, which corresponds with the therapeutic objective of extended anti-inflammatory efficacy. F6 was determined to be the superior formulation owing to its ideal mechanical qualities, improved mucoadhesion, controlled release characteristics, and exceptional stability, rendering it the most appropriate option for continuous buccal delivery of Lornoxicam.

Stability Studies:

According to ICH recommendations, stability studies were carried out to assess the drug formulation's stability. The optimized formulation (F6) was subjected to stability studies at 40 °C ± 2 °C / 75% ± 5% RH for 90 days. Table displayed the stability study findings. The stability analysis of formulation F6 demonstrated that all critical parameters remained stable throughout the 3-month accelerated storage duration, signifying substantial physical and chemical integrity of the improved film. The appearance, thickness, and surface pH exhibited minimal fluctuation, affirming the preservation of the film structure and patient-compatible pH. The drug content demonstrated a minor decrease but stayed within acceptable pharmaceutical parameters, signifying no substantial degradation of Lornoxicam. Likewise, the 8-hour drug release profile exhibited little alterations, affirming that the sustained-release characteristics were maintained throughout storage. These data indicate that F6 maintains its integrity, potency, and performance under accelerated stability circumstances.

CONCLUSION

The study successfully developed mucoadhesive buccal films of Lornoxicam using natural polymer-based matrices capable of sustained drug release and strong mucosal adhesion. The optimized formulation F6 demonstrated excellent physic mechanical properties, prolonged residence time, controlled release over 8 hours, and good stability. This buccal delivery system offers a viable alternative to conventional oral dosage forms, with the potential to enhance therapeutic efficacy, reduce dosing frequency, and improve patient adherence in the management of inflammatory disorders.

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