Khalij Libya Journal of Dental and Medical Research. 2026;10(4):398-410
https://doi.org/10.47705/kjdmr.26412
eISSN:2708-888X

Original article

Development and Pharmaceutical Characterization of Ginger Extract-Loaded Fast-Dissolving Oral Films Based on Pectin–Gelatin Blends

Aref Taleb, Nagla Layas*, Heba Masoud

Department of Industrial Pharmacy, Faculty of Pharmacy, University of Tripoli, Tripoli, Libya
Corresponding email. *N.Layas@uot.edu.ly*

Abstract
Ginger (*Zingiber officinale*) is widely used against nausea and vomiting, but conventional preparations are pungent and inconvenient for patients who are nauseated or have difficulty swallowing. Fast-dissolving oral thin films (OTFs) are a water-free, patient-friendly alternative. The Objective of this study is to formulate ginger ethanolic extract-loaded OTFs from pectin, gelatin, and their blends and to evaluate the effect of polymer ratio on film properties. Films were prepared by solvent casting from pectin (F1), gelatin (F2), and pectin–gelatin blends of 75:25 (F3), 50:50 (F4), and 25:75 (F5), plasticized with glycerol (33% w/w of polymer). Films were evaluated for appearance, thickness, weight uniformity, surface pH, disintegration time, moisture content and uptake, mechanical properties (tensile strength, elongation at break, folding endurance), and adhesion to agar gel as a model of mucoadhesion. Extract content (UV, 282 nm), in vitro dissolution (USP apparatus 1), and polymer–extract interactions (ATR-FTIR spectroscopy) were also determined. Pectin and gelatin films cracked, whereas the blends (F3–F5) formed continuous films. For F3–F5, mean thickness ranged from 0.105 to 0.140 mm, mean weight of 1 × 1 cm^2 strips from 14.8–22.1 mg, surface pH from 6.75–7.00, and disintegration time from 33–51 s. Moisture content ranged from 15–26%, moisture uptake (72 h, 75% RH) from 18.8–20.0%, tensile strength ranged from 0.53–0.70 N/mm^2, elongation from 34–50%, and folding endurance from 449–602. F5 (highest gelatin) released 86.1% of the extract within 1 min, and all blends released more than 94% within 5 min. F3 and F4 showed higher adhesion to agar gel (tensiometer readings of 80 and 75 mN/m) than F5 (60 mN/m). Extract content ranged from 63.8 –97% of the theoretical value, and only F4 (97%) met the 85–115% acceptance criterion. ATR-FTIR spectra of the films showed the characteristic bands of all components and suggested hydrogen bonding within the matrix. Pectin–gelatin blends produced flexible, fast-disintegrating films that adhered to agar gel and could incorporate ginger extract, although content uniformity requires optimization. The highest gelatin proportion (F5) gave the fastest disintegration and release, whereas the pectin-richer blends (F3 and F4) showed stronger adhesion. F4 (50:50) showed the most favorable overall profile, and these findings indicate that the polymer ratio influenced film performance, while further optimization is needed to improve ginger extract standardization and content consistency.
Keywords. Zingiber officinale, Oral Thin Films, Pectin, Gelatin, Solvent Casting, Oral Drug Delivery.

Received*: 16/09/26*
Accepted*: 14/11/26*
Published*: 23/11/26*

Copyright *© Khalij-Libya Journal (KJDMR) 2026. Open Access. Some rights reserved. This work is available under the CC BY-NC-SA*

Introduction

Ginger (Zingiber officinale Roscoe) is a widely used medicinal plant that has attracted considerable scientific interest because of its potential therapeutic and nutraceutical properties. Ginger contains several bioactive constituents, including gingerols, shogaols, and zingerone, which have been associated with various biological activities. Among its traditional and investigated applications, ginger has been particularly studied for its potential effects on nausea and vomiting [1]. An overview of systematic reviews and meta-analyses reported evidence supporting the beneficial effects of ginger in managing chemotherapy-induced, postoperative, and pregnancy-related nausea and vomiting, although the methodological quality of the included meta-analyses was generally low to critically low [2]. These findings have contributed to increasing interest in developing suitable dosage forms for incorporating ginger-derived bioactive compounds.

Oral thin films (OTFs), also known as orodispersible films, are thin polymeric dosage forms designed to hydrate, disintegrate, or dissolve rapidly upon contact with saliva, thereby releasing their incorporated active compounds. They offer several advantages, including ease of administration, portability, and administration without the need for water. These characteristics may be particularly beneficial for individuals who have difficulty swallowing conventional tablets or capsules [3,4]. To ensure acceptable performance, oral films should possess adequate flexibility and mechanical strength to withstand handling, packaging, and transportation while maintaining suitable disintegration and release characteristics [5]. A disintegration time of approximately one minute or less is commonly reported as a target for fast-disintegrating oral films, although the required time depends on the intended dosage form and its application [6].

The composition of an oral film generally includes an active pharmaceutical ingredient or other bioactive compound, a film-forming polymer, and a plasticizer to improve flexibility and reduce brittleness. Additional ingredients, such as sweeteners and flavouring agents, may be incorporated to improve palatability, while other excipients may be used to

Khalij Libya Journal of Dental and Medical Research. 2026;10(4):398-410
https://doi.org/10.47705/kjdmr.26412
eISSN:2708-888X

modify disintegration, stability, and overall film characteristics [5]. Several manufacturing techniques have been investigated for oral film production, including solvent casting and hot-melt extrusion, with solvent casting being a commonly used approach in formulation development [7]. The selection of suitable film-forming polymers is particularly important because the polymer matrix influences the mechanical, physicochemical, and release properties of the prepared films.

Natural polymers have received considerable attention in oral film development because of their availability, biodegradability, and film-forming potential [5]. Among these materials, pectin is a natural polysaccharide composed predominantly of α-(1→4)-linked galacturonic acid units, with varying degrees of methyl esterification. It is commonly obtained from plant sources, particularly citrus peels and apple pomace. Pectin possesses hydrophilic and film-forming characteristics, making it a potential material for developing oral films. Its ability to absorb water may facilitate film hydration and disintegration, while its mucoadhesive characteristics may contribute to interactions with mucosal surfaces [8,9].

Gelatin, a protein-based polymer obtained through the partial hydrolysis of collagen, is also widely investigated in film formulation because of its film-forming ability and mechanical characteristics. Gelatin films can provide structural integrity and flexibility, while the incorporation of plasticizers such as glycerol may improve elasticity and reduce brittleness. However, the properties of gelatin-based films depend on formulation composition and processing conditions [10]. Combining gelatin with pectin may therefore provide an opportunity to modify the properties of the resulting polymeric matrix. The balance between the hydrophilic characteristics of pectin and the film-forming and mechanical properties of gelatin makes their combination worthy of investigation for oral film development.

Previous studies have demonstrated the potential of gelatin–pectin combinations in developing functional films. Bhatia et al. prepared gelatin–pectin-based active films incorporated with Styrax benzoin oleo gum resin and evaluated their mechanical, physicochemical, morphological, thermal, and antioxidant properties [11]. Similarly, Azizah et al. investigated fish gelatin–pectin composite films containing lemongrass essential oil at different gelatin-to-pectin ratios. Their findings demonstrated that polymer composition and essential oil incorporation influenced several film characteristics, including thickness, water content, tensile strength, elongation at break, and antioxidant activity [12]. Although these studies focused on active food packaging, they provide supporting evidence that the composition of gelatin–pectin polymer blends can influence the characteristics of the resulting films.

The application of pectin in ginger-containing oral films has also been investigated. Costa et al. developed pectin-based orally disintegrating films containing jambolan juice (*Syzygium cumini*) and ginger oleoresin at different concentrations. The prepared films were evaluated for their physicochemical, mechanical, mucoadhesive, swelling, and functional properties. The incorporation of ginger oleoresin influenced the characteristics of the films, while the developed systems demonstrated antioxidant activity and retained a substantial proportion of their phenolic content during stability testing [13]. This study demonstrates the feasibility of incorporating ginger-derived materials into pectin-based oral films. However, investigating the use of ginger extract in combination with pectin and gelatin, and determining how different polymer ratios affect the resulting film properties, remains relevant for further formulation development.

Therefore, the present study aimed to formulate and characterize ginger extract-loaded oral films using pectin and gelatin as film-forming polymers. Five formulations containing different pectin-to-gelatin ratios, including individual polymer systems, were prepared and evaluated. The influence of polymer composition on the physicochemical, mechanical, extract-content, disintegration, release, and mucoadhesive properties of the prepared films was investigated. The study seeks to establish the relationship between polymer composition and film performance and to identify a formulation exhibiting a favorable overall profile for further development.

Materials and Methods

Materials and Reagents

Low-methoxyl (LM) pectin (RedMan, Singapore), gelatin powder (Merck, Germany), and analytical reagent-grade ethanol 96% (Carlo Erba Reagents, France).

Equipment

Equipment comprised a digital analytical balance (KERN ABS 220-4N, Germany), pH meter (Schott CG 825, Netherlands), UV–Vis spectrophotometer (Jenway 6305, UK), ultrasonic bath (Sonorex, Bandelin, Germany), a magnetic stirrer (IKA RH basic, Germany), USP apparatus 1 (IKA, Germany), micrometer screw gauge (Crownmen, DIN 863, Germany), ATR-FTIR spectrometer (Agilent Cary 630, Canada), tensiometer with du Noüy ring (KRÜSS GmbH, Germany), and a hot-air oven (Ollmann & Co. KG, Germany).

Plant Material and Authentication

Fresh rhizomes of *Zingiber officinale* Roscoe were obtained from a local market in Tripoli, Libya. The plant material was authenticated by Dr. Mohammed Maklof, Faculty of Science, University of Tripoli, on 5 January 2026.

Khalij Libya Journal of Dental and Medical Research. 2026;10(4):398-410
https://doi.org/10.47705/kjdmr.26412
eISSN:2708-888X

Preparation of Ginger Extract

Fresh rhizomes of Zingiber officinale Roscoe were washed thoroughly, cut into small pieces, and dried at 40–45 °C for 48 h until a constant weight was obtained. The dried material was pulverized, and 100 g of the resulting powder was extracted with 500 mL of 70% ethanol by maceration for 72 h with occasional stirring. The mixture was subsequently sonicated for 1 h while maintaining the temperature below 45 °C and filtered through Whatman No. 1 filter paper. The residue was re-extracted for an additional 24 h, and the filtrate was combined with the initial extract. The combined filtrate was allowed to evaporate at room temperature and was subsequently dried in an oven at 35 °C for 1 h to obtain the dried ginger extract. The extraction yield was 15%, corresponding to approximately 15 g of dried extract from 100 g of dried ginger powder. The dried extract was stored in an amber container at 4 °C until further use.

Preparation of Oral Thin Films

Films were prepared using the solvent-casting method (Figure 1). Five formulations were prepared: pectin (F1), gelatin (F2), and pectin–gelatin blends of 75:25 (F3), 50:50 (F4), and 25:75 (F5). Each contained glycerol (33 % w/w polymer), ginger extract, stevia, and vanilla flavor (Table 1).

Table 1. Composition of the casting solutions (per 100 mL).

Ingredient	F1	F2	F3	F4	F5
Pectin (g)	3.0	–	3.0	2.0	1.0
Gelatin (g)	–	3.0	1.0	2.0	3.0
Glycerol (g)	1.0	1.0	1.0	1.0	1.0
Ginger extract (mg)	250	250	250	250	250
Stevia (g)	0.30	0.30	0.20	0.20	0.20
Flavour (g)	0.20	0.20	0.20	0.20	0.20
Distilled water (mL)	q.s. 100	q.s. 100	q.s. 100	q.s. 100	q.s. 100

Pectin was dispersed in distilled water and allowed to hydrate at 40–50 °C for 30 min. Gelatin was soaked in cold water for 20 min and then heated at 45–50 °C until a clear and homogeneous solution formed. The polymer solutions were combined in the proportions given in Table 1, and glycerol, ginger extract, stevia, and vanilla flavor were added under continuous magnetic stirring for one hour to obtain a homogeneous film-forming dispersion. The dispersion was left to stand for 30 min to remove entrapped air.

20 mL of each formulation was cast onto a levelled 10 cm Petri dish and dried in a hot air oven at 40 °C for 24 h to evaporate the solvent, resulting in clear, flexible oral thin films. The dried films were carefully removed and cut into 2 × 2 cm^2 pieces. The films were stored in airtight containers containing a desiccant at room temperature until further evaluation.

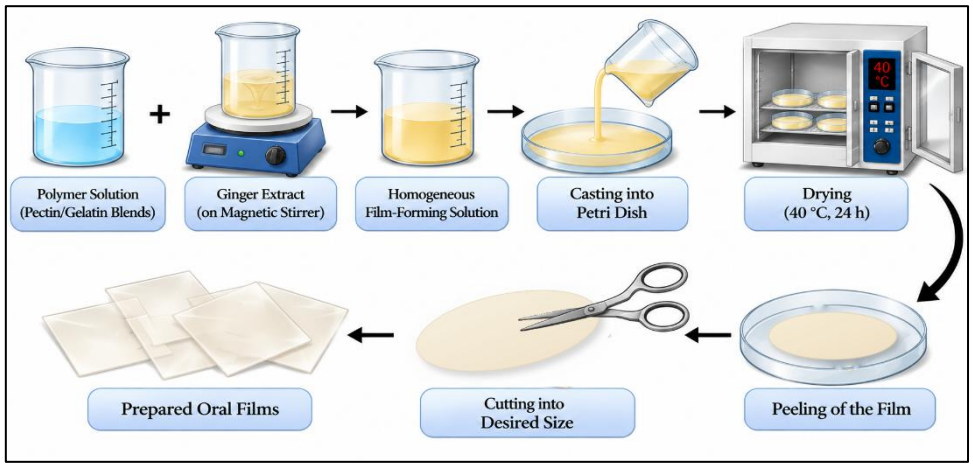

Figure 1. Diagrammatic Representation Solvent Casting Method

Evaluation Test for Oral Thin Film

Physical Appearance

The physical appearance of the OTFs, including color, homogeneity, transparency, and surface texture, was visually examined [14].

Khalij Libya Journal of Dental and Medical Research. 2026;10(4):398-410
https://doi.org/10.47705/kjdmr.26412
eISSN:2708-888X

Physicochemical Characterization

Thickness of Film

Film thickness is a vital parameter as it directly influences the uniformity of the drug content and the comfort of application. The thickness of five films from each formulation was measured at five different points (center and four corners) using a screw gauge micrometer with a least count of 0.01 mm. Acceptable thickness for buccal films is reported as 50-1000 µm [15]. The results are expressed as mean ± standard deviation (SD).

Surface pH

The surface pH should lie within the oral cavity range (5.5–7.4) to avoid mucosal irritation [16]. A film measuring 2 × 2 cm^2 was placed in a Petri dish and moistened with 2mL of distilled water. After 1 min, the electrode of a calibrated pH meter was brought into contact with the film surface and left to equilibrate for 1 min. The pH value was then recorded [17]. Three films from each formulation were evaluated, and the results were expressed as mean ± standard deviation (SD).

Film Weight

Film weight was determined to assess the uniformity of the prepared oral films. Six strips measuring 1 × 1 cm^2 were randomly selected from each formulation and weighed individually using a high-precision analytical balance. The mean weight and standard deviation (SD) were calculated for each formulation [18].

Moisture Content

The moisture content was determined by measuring the weight loss after drying to constant weight [19]. Three film strips (2 × 2 cm^2) per formulation were individually weighed to obtain their initial weights and then dried in a hot-air oven at 50 °C to constant weight. The dried strips were reweighed, and the percentage moisture content was calculated using the following equation:

$$\% \text{ Moisture Contents} = [(W_o - W_d) / W_o] \times 100 \qquad (1)$$

Where W_o is the initial weight of the film strip, and W_d is its weight after drying.

Moisture Uptake Study

The moisture uptake of the oral films was evaluated to assess their hygroscopicity and physical stability under high-humidity conditions. Pre-weighed film strips measuring 2 × 2 cm^2 were placed in a desiccator maintained at approximately 75% relative humidity (RH) using a saturated sodium chloride (NaCl) solution at room temperature. The films were exposed to these conditions for 72 h and then reweighed. The percentage of moisture uptake was calculated using the following equation [20]:

$$\% \text{ Moisture Uptake} = [(W_f - W_i) / W_i] \times 100 \qquad (2)$$

Where W_i is the initial weight of the film, and W_f is the final weight after exposure to approximately 75% RH.

Tensile Strength (TS) and Percentage Elongation (%E)

The mechanical properties of the oral thin films (OTFs) were evaluated using a custom-built longitudinal loading apparatus (Figure 2). Film strips measuring (2 × 5 cm^2) were secured between a fixed upper clamp and a movable lower clamp. Weights were added incrementally to the lower clamp in 50 g steps, with a 30 s pause between additions, until the film ruptured. The total breaking load (g) was recorded and converted to force (N = g × 9.81/1000). Tensile strength (TS) was calculated using the following equation:

$$TS = [F / (w \times t)] \qquad (3)$$

Where F is the breaking force N, w is the film width, and t is the film thickness. The units used for width and thickness determine the final unit of tensile strength.

Percentage elongation %E was calculated using the following equation:

$$\% E = [(L_f - L_i) / L_i] \times 100 \qquad (4)$$

Where L_f is the gauge length at the point of film rupture and L_i is the initial gauge length.

Khalij Libya Journal of Dental and Medical Research. 2026;10(4):398-410
https://doi.org/10.47705/kjdmr.26412
eISSN:2708-888X

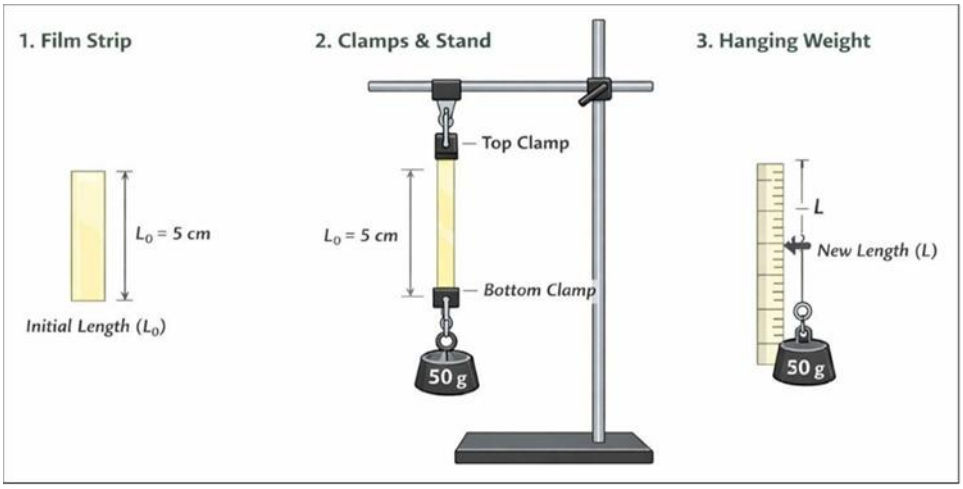

Figure 2. Diagram of determination of mechanical properties of oral film

Folding Endurance

The flexibility and resistance of the oral thin films (OTFs) to repeated folding were evaluated using the folding endurance test. Film specimens measuring 2 × 2 cm^2 were manually folded along the same central line through 180°, bringing the two halves together, and then unfolded to their original position. This cycle was repeated until visible cracking or film breakage occurred. The number of completed folding cycles before failure was recorded as the folding endurance value [21].

In Vitro Disintegration Time

The in vitro disintegration time of the oral thin films (OTFs) was determined using a simple method. A film specimen measuring 2 × 2 cm^2 was placed in a glass Petri dish containing 10 mL of phosphate buffer (pH 6.8) to simulate the pH of saliva at 37 ± 0.5 °C with gentle swirling, and the time to complete breakup was recorded (n = 3). A time of ≤60 s was taken as rapid disintegration [22].

In Vitro Adhesion to Agar Gel

The in vitro detachment of the films from a 2% (w/v) agar gel as a simulated mucosal surface was measured with a KRÜSS ring tensiometer [23,24]. The use of a tensiometric approach for assessing the tensile adhesive strength of hydrated polymers was previously reported by Esposito et al., who employed a modified Du Noüy tensiometer [25].

Agar gel (2% w/v) was prepared by dissolving agar powder in distilled water with heating until a clear solution formed. The solution was poured into Petri dishes and allowed to cool and form a uniform gel layer. Before testing, the gel surface was moistened with 0.5 mL of phosphate buffer (pH 6.8) at 37 °C. A film specimen measuring 2 × 2 cm^2 was attached to the lower surface of the tensiometer ring using adhesive tape. The film was brought into contact with the agar gel surface under a consistent applied pressure and maintained in contact for approximately 1–2 min. The ring was then gradually lifted until the film detached from the gel surface, and the tensiometer reading (mN/m) and residence time were recorded. Measurements were performed for each formulation under the same experimental conditions.

Calibration Curve of the Ginger Extract

A calibration curve was constructed using UV–visible spectrophotometry to quantify the ginger extract in the prepared oral thin films (OTFs). A stock solution was prepared by accurately weighing 100 mg of ginger extract and dissolving it in 100 mL of phosphate buffer (pH 6.8) in a volumetric flask to obtain a concentration of 1000 µg/mL. Working standard solutions were prepared by appropriate dilution of the stock solution to obtain concentrations of 2, 4, 6, 8, 10, and 20 µg/mL. The absorbance of each standard solution was measured at 282 nm using a UV–visible spectrophotometer, with phosphate buffer (pH 6.8) as the blank. This wavelength was selected based on the experimentally determined absorption maximum of the ginger extract and previous spectrophotometric studies [26]. A calibration curve was constructed by plotting absorbance against concentration. The linearity was evaluated using linear regression (y = mx + c) and the coefficient of determination (R^2). All standard measurements were performed in triplicate.

Extract Content and Content Uniformity

To determine the ginger extract content, individual film specimens measuring 2 × 2 cm^2 were randomly selected and dissolved in 100 mL of phosphate buffer (pH 6.8) [27]. The samples were subjected to ultrasonication for 15–20 min to facilitate extraction of the ginger extract from the pectin–gelatin matrix. The resulting solutions were filtered through a 0.45-µm membrane filter and appropriately diluted, when necessary, to ensure that their absorbance values fell within the

Khalij Libya Journal of Dental and Medical Research. 2026;10(4):398-410
https://doi.org/10.47705/kjdmr.26412
eISSN:2708-888X

established calibration range. The absorbance of each sample was measured at 282 nm, and the ginger extract concentration was calculated using the calibration curve equation.

The theoretical ginger extract content per film was calculated based on the casting composition. Each 10 cm diameter Petri dish contained 20 mL of casting solution containing 50 mg of ginger extract. Based on the plate surface area (78.5 cm^2), approximately 19.63 theoretical film units of 2 × 2 cm^2 could be obtained per plate, corresponding to a theoretical extract content of approximately 2.55 mg per film.

The percentage of ginger extract content was calculated using the following equation:

$$Extract\ content\ (\%) = M_m/M_t \times 100 \quad (5)$$

Where M_m is the measured extract content in the film (mg) and M_t is the theoretical extract content in the film (mg). Content uniformity was assessed against an acceptance range of 85–115% of the theoretical content, as used for oral dissolving films [28].

In vitro Dissolution Study

The in vitro release of ginger extract from the prepared oral thin films (OTFs) was evaluated using USP dissolution apparatus type I (basket method) [29, 30]. The dissolution medium consisted of 500 mL of phosphate buffer (pH 6.8), maintained at 37 ± 0.5 °C. Each film specimen cut (2 x 2 cm2) dimensions was placed inside the dissolution basket, and the apparatus was operated at a rotation speed of 50 rpm.

At predetermined time intervals (1, 2, 3, and 5 min), 10 mL samples were withdrawn from the dissolution medium and immediately replaced with an equal volume of fresh phosphate buffer maintained at the same temperature. The withdrawn samples were filtered through a 0.45-µm membrane filter and analyzed using a UV–visible spectrophotometer at 282 nm. The concentration of ginger extract in each sample was determined using the previously established calibration curve.

The cumulative percentage of ginger extract released at each sampling time was calculated by accounting for the extract present in the dissolution medium and the amount removed in previous samples, according to the following equation:

$$Cumulative\ release\ (\%) = \frac{VC_n + V_s \sum_{i=1}^{n-1} C_i}{M_0} \times 100 \quad (6)$$

Where:

V = total dissolution medium volume (500 mL)

V_s= sample withdrawal volume (10 mL)

C_n= concentration at the current sampling time (mg/mL)

C_i= concentration at each previous sampling time (mg/mL)

M_0 = theoretical ginger extract content in the film (mg)

All dissolution experiments were performed in triplicate, and the results were expressed as mean ± standard deviation (SD).

ATR-FTIR spectroscopy

ATR-FTIR spectroscopy was performed to characterize the functional groups of the ginger extract and the prepared oral thin films and to investigate potential interactions between the formulation components. Spectra were recorded using a Cary 630 FTIR spectrometer (Agilent Technologies) equipped with a diamond attenuated total reflectance (ATR) sampling accessory. Measurements were conducted over the spectral range of 650–4000 cm^{-1}. Prior to spectral acquisition, the instrument was purged with nitrogen for 40 min to minimize interference from atmospheric carbon dioxide and water vapor. Sample handling and cleaning followed the manufacturer's guidelines [31]: samples were placed directly onto the diamond crystal, and sufficient contact was ensured using the instrument's sample press. The crystal was cleaned with ultrapure acetone followed by absolute ethanol between measurements to prevent sample carryover. All spectra were recorded at room temperature (25 °C). The obtained spectra were subsequently examined to identify characteristic absorption bands and assess possible changes in functional groups following film formulation.

Statistical Analysis

Results were expressed as mean ± standard deviation (SD). Statistical significance was assessed using one-way analysis of variance (ANOVA). A p-value of less than 0.05 was considered statistically significant. Correlation coefficients were calculated to assess the relationships between the evaluated parameters.

Results and Discussion

Khalij Libya Journal of Dental and Medical Research. 2026;10(4):398-410
https://doi.org/10.47705/kjdmr.26412
eISSN:2708-888X

Film Formation and Physical Appearance

The physical appearance of the prepared films varied with polymer composition. The films prepared from pectin alone (F1) or gelatin alone (F2) fractured during drying and could not be peeled off as intact strips; they were therefore excluded from further testing. The blends (F3–F5) formed continuous, crack-free, peelable films, with a transparent and smooth surface (Figure 3). Similar improvement in film formation on blending pectin with gelatin has been reported [32, 33].

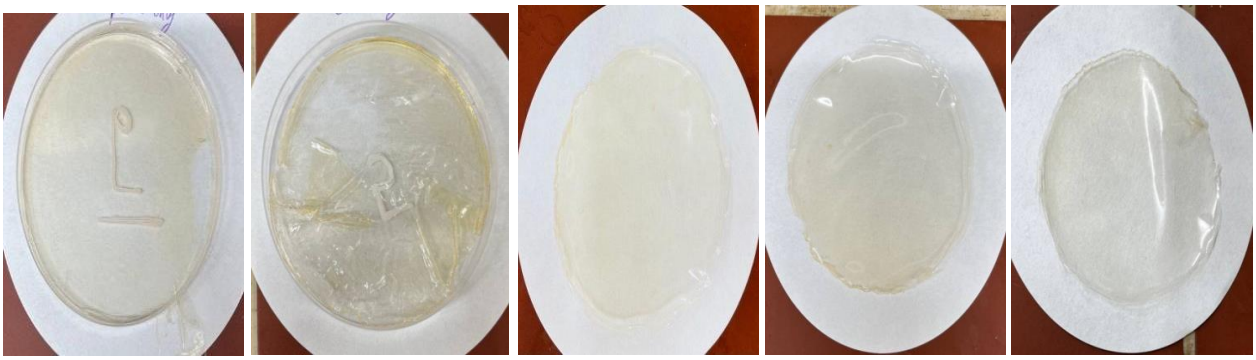

Figure 3. Physical appearance of ginger extract-loaded oral films prepared with different pectin: gelatin ratios: (A) F1, pectin only; (B) F2, gelatin only; (C) F3, 75:25; (D) F4, 50:50; and (E) F5, 25:75.

Physicochemical Characteristics

The physicochemical characteristics of the prepared ginger extract-loaded oral films F3, F4, and F5 are presented in (Table 2 and Figure 4). Film thickness, weight, surface pH, and disintegration time were evaluated. These properties are commonly used to assess film uniformity and suitability for oral administration [12].

Table 2. Physicochemical characteristics of ginger extract-loaded oral films

Formula Code	Thickness (mm) Mean ± SD	Weight (mg) Mean ± SD	Surface pH Mean ± SD	Disintegration Time (s) Mean ± SD
F3	0.126 ± 0.006	17.4 ± 0.67	6.75 ± 0.022	47 ± 3.3
F4	0.140 ± 0.006	22.06 ± 0.75	6.79 ± 0.019	51 ± 2.7
F5	0.105 ± 0.0087	14.8 ± 1.71	7.00 ± 0.013	33 ± 3.0

Film thickness

Mean thickness of the prepared films ranged from 0.105 mm (F5) to 0.140 (F4). F4 was the thickest film, followed by F3, whereas F5 was the thinnest ($p < 0.05$) (Table 2). The differences in film thickness may reflect the effect of pectin–gelatin ratios on the viscosity of the casting solutions, although viscosity was not measured; thickness did not vary monotonically with ratio, so casting variability cannot be excluded. Film thickness influences mechanical properties, drug loading per unit area, and disintegration behavior [14]. The coefficient of variation (CV) was below 9% (highest for F5, 8.3%), indicating acceptable thickness uniformity.

Film Weight

The mean film weights were 17.4 ± 0.67, 22.06 ± 0.75, and 14.8 ± 1.71 mg for F3, F4, and F5, respectively. F4 had the highest mean weight, and F5 the lowest ($p < 0.05$). Weight followed the same order as thickness (F4 > F3 > F5). This is expected for films of equal area (2 × 2 cm2). The CV was below 4% for F3 and F4 but 11.6% for F5, indicating poor weight uniformity for F5. This variability may reflect differences in casting, spreading, or drying and suggests that reproducibility of the casting procedure for F5 needs improvement.

Surface pH

All formulations had a near-neutral surface pH, which is desirable because strongly acidic or alkaline films may irritate the oral mucosa [16]. The surface pH ranged from 6.75 to 7.00, indicating that all formulations maintained a relatively narrow and near-neutral pH range. Although statistically significant differences were observed among the formulations ($p < 0.05$), the small absolute variation in pH suggests that changes in the pectin–gelatin ratio had a limited practical effect on the surface pH of the films.

Khalij Libya Journal of Dental and Medical Research. 2026;10(4):398-410
https://doi.org/10.47705/kjdmr.26412
eISSN:2708-888X

Disintegration Time

All films disintegrated in less than 60 s (33 ± 3.0 to 51 ± 2.7 s). Disintegration was fastest for F5, followed by F3 and F4. All films met the predefined criterion of disintegration within 60 s [22]. The faster disintegration of F5 may reflect its lower film thickness and weight, which allow penetration of the medium, as well as its higher gelatin content. Likewise, F4 was the thickest and heaviest film and had the longest disintegration time. The pectin–gelatin ratios may also affect hydration and matrix integrity, and hence disintegration, but their effect cannot be separated from that of thickness in this study.



A B C

Figure 4. Physicochemical properties of ginger extract-loaded oral thin film: (A) thickness; (B) surface pH and (C) disintegration time.

Moisture Content and Moisture Uptake

The moisture content and moisture uptake of films results are presented in (Table 3). Moisture content and uptake were measured because water influences the physical stability and mechanical performance of oral films [34].

Table 3. Moisture content and moisture uptake of films.

Formula Code	Moisture content (%)	Moisture uptake (%)
F3	25.72	20.00
F4	26	19.28
F5	15	18.77

The moisture content ranged from 15 % to 26% (Table 3). Moisture content was highest for F4 (26%) and F3 (25.7%) and considerably lower for F5 (15%). The higher moisture content of the pectin-richer F3 and F4 may reflect the strong water-binding capacity of pectin hydroxyl and carboxyl groups. The lower moisture content of F5 may favor storage stability, although 15% remains high. Water can act as a plasticizer, yet F5, the driest film, was the most elastic, as shown by the mechanical properties results, suggesting that polymer composition outweighed water content.

After 72 h at 75% relative humidity, moisture uptake was 20.0%, 19.3%, and 18.8% for F3, F4, and F5, respectively. Uptake was highest for F3 and lowest for F5. F3 and F4 contain more pectin than F5, and the hydroxyl and carboxyl groups of pectin bind water through hydrogen bonds; glycerol also retains water in all three formulations [9]. The narrow range of moisture uptake (18.8–20.0%) indicates similar hygroscopicity for the three films under these conditions.

Mechanical Properties

All three films were sufficiently flexible and withstood handling and cutting (Table 4). Folding endurance exceeded 400 folds for all formulations, above the 300 folds generally considered good [14]; elongation at break ranged from 34% to 50%. F5 showed the highest elongation at break, suggesting greater extensibility of the polymer network. This behavior may be related to differences in the structural organization and intermolecular interactions between pectin and gelatin [35].

Table 4. Mechanical properties of the films.

Formula Code	Tensile strength (N/mm^2)	Elongation (%)	Folding endurance (folds)
F3	0.66	40	602
F4	0.53	34	538
F5	0.70	50	449

Khalij Libya Journal of Dental and Medical Research. 2026;10(4):398-410
https://doi.org/10.47705/kjdmr.26412
eISSN:2708-888X

F5 had the highest tensile strength and elongation but the lowest folding endurance, whereas F4 had the lowest tensile strength and elongation. Because film thickness differed among the formulations and folding endurance depends on local defects as well as on polymer composition, differences in folding endurance should be interpreted cautiously. The tensile values are also limited by the resolution of the loading method. F3, F4, and F5 ruptured at a load of 150 g, corresponding to tensile strengths of 0.53-0.70 N/mm^2.

In Vitro Mucoadhesive Strength Measurement

Mucoadhesive behavior was evaluated by measuring the detachment of the films from a 2% (w/v) agar gel using a KRÜSS ring tensiometer (Figure 5). The detachment readings were 80, 75 and 60 mN/m for F3, F4, and F5, respectively, and the in vitro residence times were 90, 60 and 12 s (Table 5). The higher readings and longer residence times of the pectin-rich F3 and F4 may reflect greater hydration, which can promote wetting and polymer-chain interpenetration at the gel interface [9], although differences in moisture uptake between formulations were small. In contrast, the short residence time of the gelatin-rich F5 (12 s) may reflect its rapid hydration and dissolution, which reduce structural integrity and lead to early loss of contact with the gel. However, because agar contains no mucin, these results reflect relative adhesion to a hydrated polysaccharide gel rather than true mucoadhesion to the oral mucosa.

Table 5. Tensiometer readings and in vitro residence time of oral thin films.

Formula Code	Tensiometric reading (mN/m)	Residence time (s)
F3	80	90
F4	75	60
F5	60	12



Figure 5. Krüss tensiometer set-up for the in vitro detachment test.

Drug content

The calibration curve of the ginger extract in phosphate buffer (pH 6.8) was linear at 282 nm over 2–20 µg/mL (absorbance = 0.007 × concentration + 0.0011; R^2 = 0.9961; Figure 6, Table 6).

The extract content ranged from 63.8% to 97.0% of the theoretical loading of 2.55 mg per film (Table 7). Only F4 fell within the 85–115% range required for content uniformity [28]. The low values for F3 and F5 may be due to incomplete recovery of the extract from the film matrix, uneven dispersion of the ethanolic extract in the aqueous polymer solution, or loss of volatile and thermolabile constituents during drying (24 h at 40 °C).

Table 6. Calibration Data of Ginger Extract at λmax 282 nm

Concentration (µg/mL)	Mean Absorbance ± SD
Blank 0	0.000 ± 0.000
2	0.018 ± 0.001
4	0.032 ± 0.00
6	0.040 ± 0.001
8	0.055 ±0.002
10	0.073 ± 0.003
20	0.144 ± 0.000

Khalij Libya Journal of Dental and Medical Research. 2026;10(4):398-410
https://doi.org/10.47705/kjdmr.26412
eISSN:2708-888X

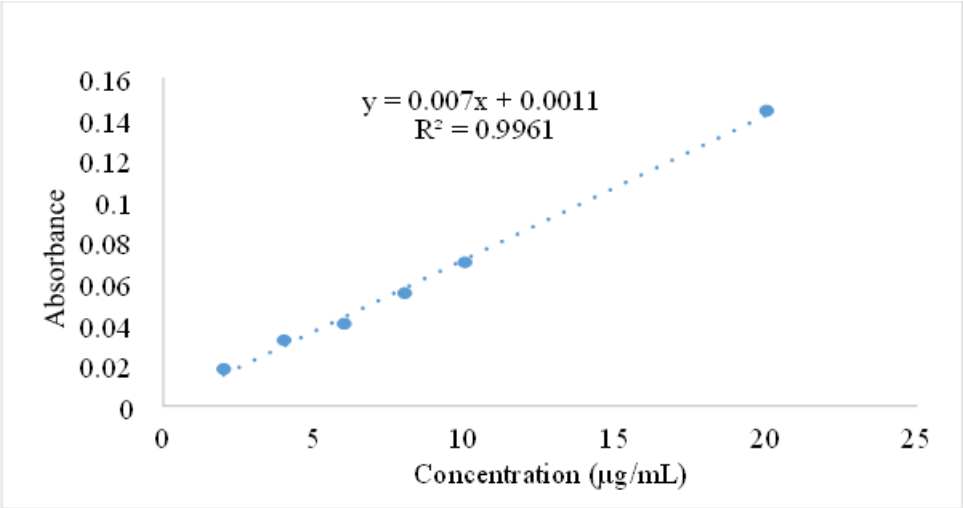

Figure 6. Calibration curve of ginger extract in phosphate buffer (pH 6.8) at 282 nm.

Table 7. Extract content of ginger-loaded oral thin films

Formula Code	Drug Content (%)
F3	63.8%
F4	97%
F5	67%

In vitro dissolution

All films released the extract rapidly (Table 8). F5 released 86.1% and 95.2% of the extract at 1 and 2 min, respectively. F3 and F4 released 63.5% and 68.3% at 1 min, and all three formulations exceeded 94% at 5 min. F5 released the extract fastest, which agrees with its shortest disintegration time and highest gelatin content; faster hydration and break-up probably expose the extract to the medium sooner, whereas F3 and F4 did not follow their disintegration order. The release profiles of F3 and F4 crossed twice, between 1 and 2 min and between 2 and 3 min (F3 76.7% vs F4 73.1% at 2 min; F3 83.7% vs F4 90.8% at 3 min).

Table 8. Cumulative release of ginger extract (%) from the films in phosphate buffer (pH 6.8)

Time (min)	F3	F4	F5
1	63.5	68.3	86.1
2	76.7	73.1	95.2
3	83.7	90.8	96.8
5	94.9	98.2	99.5

ATR-FTIR spectroscopy

ATR-FTIR spectra of the ginger extract, gelatin, pectin, and films F3–F5 are shown in (Figure 7), and the band assignments are summarized in (Table 9). The O–H/N–H stretching band of the films appeared at 3265–3280 cm^{-1}, at a higher wavenumber than in gelatin (3254 cm^{-1}), pectin (3250 cm^{-1}), and the extract (3235 cm^{-1}), which suggests a changed hydrogen-bonding environment after blending. This agrees with Mishra et al. [36], who attributed changes in the hydroxyl stretching region of pectin/gelatin hydrogel membranes to hydrogen bonding and intermolecular interactions between the two polymers. C-H stretching appeared at 2915-2933 cm^{-1} in all samples.

The films showed amide I (1629–1630 cm^{-1}) and amide II (1543 cm^{-1}) bands, confirming the presence of gelatin in the matrix. The amide I band changed little from that of pure gelatin (1625 cm^{-1}), whereas the amide II band shifted by about 22 cm^{-1} to a higher wavenumber (1521 to 1543 cm^{-1}). A similar amide II shift was reported by Mishra et al. [36] (1540 cm^{-1} in gelatin to 1560-1575 cm^{-1} in the blended membranes). Together, these shifts are consistent with electrostatic and hydrogen-bond interactions between the protonated amino groups of gelatin and the carboxylate groups of pectin. The amide I region also overlaps with the asymmetric COO^- stretching of pectin (1588 cm^{-1}) and the aromatic C=C stretching of the ginger (1595 cm^{-1}), and these contributions could not be resolved. The pectin ester C=O band (1722 cm^{-1}) was not distinct in the films, possibly because of its low intensity, the low degree of esterification of the pectin, or dilution within the matrix.

Khalij Libya Journal of Dental and Medical Research. 2026;10(4):398-410
https://doi.org/10.47705/kjdmr.26412
eISSN:2708-888X

Bands at 1401 and 1446–1450 cm^{-1} (CH_2 bending and symmetric COO^- stretching), 1237 cm^{-1} (amide III) and 1032–1036 cm^{-1} (C–O/C–O–C of pectin and phenolic groups) were present in all films, together with a band at 1103-1107 cm^{-1} corresponding to the pectin (1103 cm^{-1}) and extract (1100 cm^{-1}) bands. The C-O bands at 1032-1036 cm^{-1} fell within the range reported by Mishra et al. [36] (1018-1052 cm^{-1}). Although the absolute band positions differed from those in that study, which may reflect differences in the gelatin and pectin used and in film composition, the overall pattern supports polymer-polymer interaction.

No new bands appeared, which suggests that the extract is held in the matrix by physical interactions rather than covalent bonding. F3, F4, and F5 showed nearly identical band positions, indicating that the pectin–gelatin ratio did not change the chemical composition detectable by FTIR.

Table 9. ATR-FTIR band positions (cm^{-1}) of the individual components and films F3–F5.

Assignment	Ginger extract	Pectin	Gelatin	F3	F4	F5
O–H / N–H stretching	3235	3250	3254	3280	3280	3265–3280
C–H stretching	2922	2919	2926	2933	2915	2930
C=O (ester)	–	1722	–	–	–	–
Amide I / C=C / COO^-	1595	1588	1625	1629	1629	1630
Amide II	1510	–	1521	1543	1543	1543
CH_2 bending / COO^- sym.	1398	1390	1398, 1439	1401, 1450	1401, 1446	1401, 1450
Amide III	–	–	1234	1237	1237	1237
C–O–C / C–O stretching	1032, 1100	1066, 1103	1081	1036, 1103	1032, 1103	1034, 1107

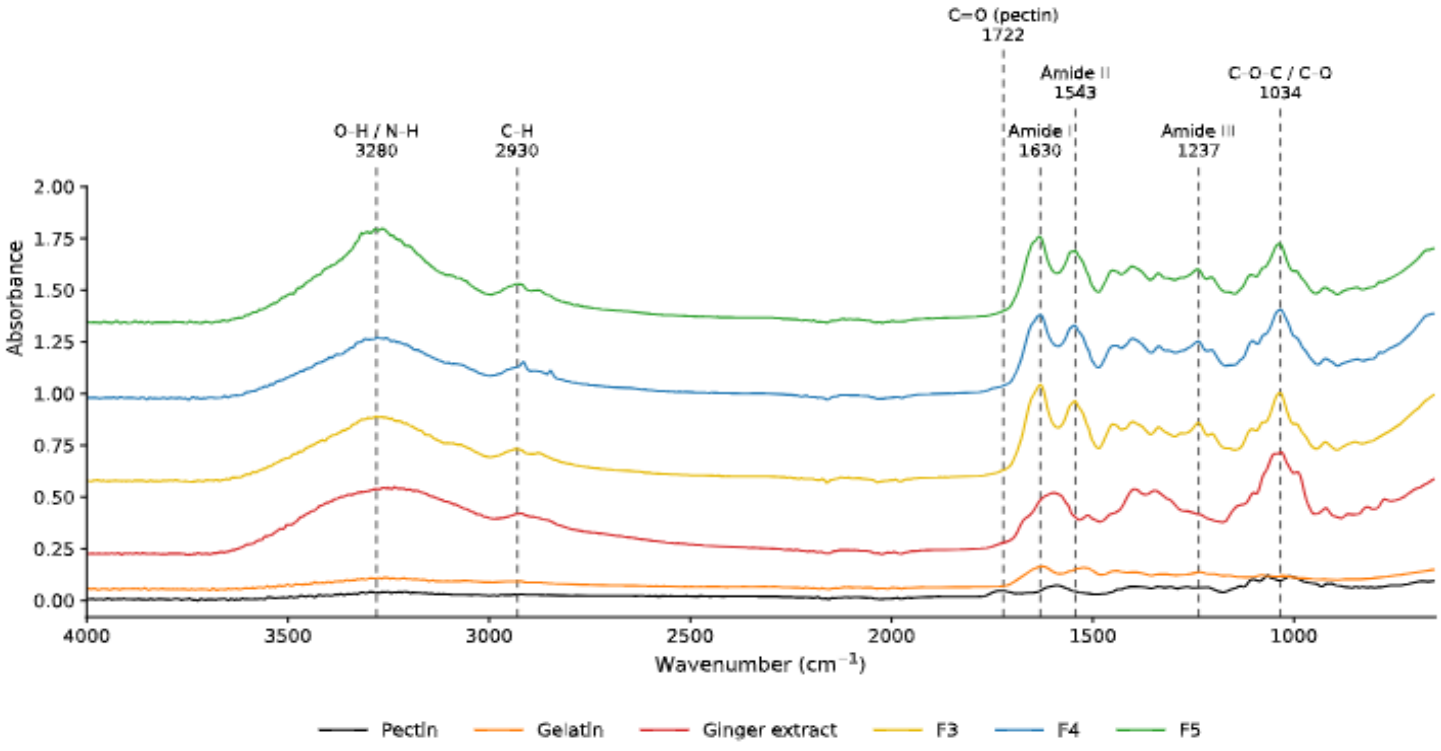

Figure 7. ATR-FTIR spectra of pectin, gelatin, ginger extract, and films F3-F5.

Conclusion

Neither pectin nor gelatin alone produced intact films under the casting and drying conditions used (F1, F2), whereas the pectin–gelatin blends F3–F5 (75:25, 50:50 and 25:75) formed continuous, flexible films with a near-neutral surface pH (6.75–7.00), disintegration times of 33–51 s and folding endurance above 400 folds. The polymer ratio shifted the balance of properties: the gelatin-rich blend F5 disintegrated fastest (33 s), showed the highest elongation (50%) and released 86.1% of its extract within 1 min, whereas the pectin-richer blends F3 and F4 adhered more strongly to an agar-gel model (80 and 75 mN/m versus 60 mN/m for F5) and stayed in contact longer. FTIR spectra showed no new bands, consistent with physical rather than covalent interactions between the extract and the polymer matrix.

No single formulation was best on every criterion. F4 (50:50) was the only film whose extract content (97%) fell within the 85–115% acceptance range, and it combined strong adhesion (75 mN/m) with more than 98% release within 5 min, which makes it the most promising candidate based on the present data. The low extract contents of F3 and F5 (63.8% and 67%) show that uniform loading of the ethanolic extract has not yet been achieved.

Conflict of Interest

There are no financial, personal, or professional conflicts of interest to declare.

References

1. Ali BH, Blunden G, Tanira MO, Nemmar A. Some phytochemical, pharmacological and toxicological properties of ginger (Zingiber officinale Roscoe): a review of recent research. Food Chem Toxicol. 2008 Feb;46(2):409-20.
2. Li Z, Wu J, Song J, Wen Y. Ginger for treating nausea and vomiting: an overview of systematic reviews and meta-analyses. Int J Food Sci Nutr. 2024 Feb;75(2):122-33.
3. Garcia VA dos S, Borges JG, Vanin FM, Carvalho RA de. Orally disintegrating films of biopolymers for drug delivery. In: Biopolymer Membranes and Films. 2020. p. 289-307.
4. Borges AF, Silva C, Coelho JFJ, Simões S. Oral films: current status and future perspectives: I—Galenical development and quality attributes. J Control Release. 2015 May 28;206:1-19. doi: 10.1016/j.jconrel.2015.03.006.
5. Pacheco MS, Barbieri D, da Silva CF, de Moraes MA. A review on orally disintegrating films (ODFs) made from natural polymers such as pullulan, maltodextrin, starch, and others. Int J Biol Macromol. 2021 May 1;178:504-13. doi: 10.1016/j.ijbiomac.2021.02.180.
6. Choudhary DR, Patel VA, Chhalotiya UK, Patel HV, Kundawala AJ. Development and characterization of pharmacokinetic parameters of fast-dissolving films containing levocetirizine. Sci Pharm. 2012 Jul-Sep;80(3):779-87.
7. Irfan M, Rabel S, Bukhtar Q, Qadir MI, Jabeen F, Khan A. Orally disintegrating films: a modern expansion in drug delivery system. Saudi Pharm J. 2016 Sep;24(5):537-46.
8. Roy S, Priyadarshi R, Łopusiewicz L, Biswas D, Chandel V, Rhim JW. Recent progress in pectin extraction, characterization, and pectin-based films for active food packaging applications: a review. Int J Biol Macromol. 2023 Jun 1;239:124248. doi: 10.1016/j.ijbiomac.2023.124248.
9. Sriamornsak P, Wattanakorn N, Nunthanid J, Puttipipatkhachorn S. Mucoadhesion of pectin as evidence by wettability and chain interpenetration. Carbohydr Polym. 2008 Nov 4;74(3):458-67.
10. Ahmed JM, Boya DA, Kamal H. Formulation of a fast-dissolving oral film using gelatin and sodium carboxymethyl cellulose. Zanco J Med Sci. 2020 Dec 24;24(3):338-46.
11. Bhatia S, Jawad M, Chinnam S, et al. Preparation and characterization of gelatin-pectin-based active films incorporated with Styrax benzoin oleo gum resin. Polym Adv Technol. 2024 Aug;35(8):e6539. doi: 10.1002/pat.6539.
12. Azizah F, Nursakti H, Ningrum A, Supriyadi. Development of edible composite film from fish gelatin–pectin incorporated with lemongrass essential oil and its application in chicken meat. Polymers (Basel). 2023 Apr 27;15(9):2075. doi: 10.3390/polym15092075.
13. Costa BS, Pires CTGVM, Chambi HNM, Schmidt FL. Pectin orally disintegrating films containing jambolan juice (Syzygium cumini) and ginger: functional properties. Ind Crops Prod. 2025;226:120590. doi: 10.1016/j.indcrop.2025.120590.
14. Sevinç Özakar R, Özakar E. Current overview of oral thin films. Turk J Pharm Sci. 2021 Feb;18(1):111-21. doi: 10.4274/tjps.galenos.2020.76390.
15. Karki S, Kim H, Na SJ, Shin D, Jo K, Lee J. Thin films as an emerging platform for drug delivery. Asian J Pharm Sci. 2016 Oct;11(5):559-74.
16. Zaman M, Hassan R, Razzaq S, Mahmood A, Amjad MW, Raja MAG, et al. Fabrication of polyvinyl alcohol based fast dissolving oral strips of sumatriptan succinate and metoclopramide HCL. Sci Prog. 2020 Oct-Dec;103(4):36850420964302. doi: 10.1177/0036850420964302. PubMed PMID: 33151131; PubMed Central PMCID: PMC10358599.
17. Singh H, Kaur M, Verma H. Optimization and evaluation of desloratadine oral strip: an innovation in paediatric medication. ScientificWorldJournal. 2013;2013:395681.
18. Rajagopalan S, et al. Fast dissolving oral thin films: an innovative herbal drug delivery system. Int J Res Med Sci. 2024 Aug;12(8):3085-90. doi: 10.18203/2320-6012.ijrms20242250.
19. Bala R, Pawar P, Khanna S, Arora S. Orally dissolving strips: a new approach to oral drug delivery system. Int J Pharm Investig. 2013 Apr;3(2):67-76. doi: 10.4103/2230-973X.114897. PubMed PMID: 24015378; PubMed Central PMCID: PMC3757902.
20. Suksaeree J, Chaichawawut B, Srichan M, Tanaboonsuthi N, Monton C, Maneewattanapinyo P, et al. Applying design of experiments (DoE) on the properties of buccal film for nicotine delivery. e-Polymers. 2021;21(1):566-74. doi: 10.1515/epoly-2021-0064.

21. Jelvehgari M, Montazam SH, Soltani S, Azar K, Montazam SA. Fast dissolving oral thin film drug delivery systems consist of ergotamine tartrate and caffeine anhydrous. Pharm Sci. 2015 Jun;21(2):102-10.
22. Bhattarai M, Gupta AK. Fast dissolving oral films: a novel trend to oral drug delivery system. Sunsari Tech Coll J. 2016;2(1):58-68. doi: 10.3126/stcj.v2i1.14802.
23. Ofokansi KC, Kenechukwu FC, Ogwu NN. Design of novel miconazole nitrate transdermal films based on Eudragit RS100 and HPMC hybrids: preparation, physical characterization, in vitro and ex vivo studies. Drug Deliv. 2015 Nov;22(8):1078-85. doi: 10.3109/10717544.2013.875604.
24. Müller L, Rosenbaum C, Krause J, Weitschies W. Characterization of an in vitro/ex vivo mucoadhesiveness measurement method of PVA films. Polymers (Basel). 2022 Nov 28;14(23):5146. doi: 10.3390/polym14235146.
25. Esposito P, Colombo I, Lovrecich M. Investigation of surface properties of some polymers by a thermodynamic and mechanical approach: possibility of predicting mucoadhesion and biocompatibility. Biomaterials. 1994 Feb;15(3):177-82. doi: 10.1016/0142-9612(94)90064-7.
26. Promdam N, Panichayupakaranant P. Quantitative HPLC method and alternative green solvents for extraction of [6]-gingerol from ginger. Pak J Pharm Sci. 2022 May;35(3):851-7. PubMed PMID: 35791487.
27. Salehi S, Boddohi S. New formulation and approach for mucoadhesive buccal film of rizatriptan benzoate. Prog Biomater. 2017 Dec;6(4):175-87. doi: 10.1007/s40204-017-0077-7. PubMed PMID: 29110144; PubMed Central PMCID: PMC5700911.
28. United States Pharmacopeial Convention. Uniformity of dosage units. In: The United States Pharmacopeia. Rockville (MD): United States Pharmacopeial Convention; 2011.
29. Speer I, Preis M, Breitkreutz J. Dissolution testing of oral film preparations: experimental comparison of compendial and non-compendial methods. Int J Pharm. 2019 Apr 20;561:124-34. doi: 10.1016/j.ijpharm.2019.02.042.
30. Shukla R. Formulation and evaluation of fast dissolving oral films of anti-epileptic drug. Int J Pharm Drug Res. 2019;7(2):60-5.
31. Agilent Technologies. Agilent Cary 630 FTIR Spectrometer User's Guide. Edition 7. Manual No. G8043-90001. Mulgrave, Victoria, Australia: Agilent Technologies; 2024.
32. Olaru G, Rapa M, Popa ME. Experimental research on biopolymers obtaining based on chitosan, gelatin and pectin. Sci Bull Ser F Biotechnol. 2020 Jul;24(2):117-22.
33. Akhter R, Masoodi FA, Wani TA. Chitosan, gelatin and pectin based bionanocomposite films with rosemary essential oil as an active ingredient for future foods. Int J Biol Macromol. 2024 Jun;272:132813.
34. Takeuchi Y, Hayakawa F, Tahara K, Takeuchi H. Orally disintegrating films: the effects of water content on disintegration and mechanical properties. J Drug Deliv Sci Technol. 2021 Dec;66:102893. doi: 10.1016/j.jddst.2021.102893.
35. Athanasopoulou E, Bigi F, Maurizzi E, Karellou EIE, Pappas CS, Quartieri A, et al. Synthesis and characterization of polysaccharide- and protein-based edible films and application as packaging materials for fresh fish fillets. Sci Rep. 2024 Jan 4;14(1):517. doi: 10.1038/s41598-024-51163-y. PubMed PMID: 38177403; PubMed Central PMCID: PMC10767132.
36. Mishra RK, Majeed AB, Banthia AK. Development and characterization of pectin/gelatin hydrogel membranes for wound dressing. Int J Plast Technol. 2011 Jun;15(1):82-95.