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COMPOSITE ORAL FILM BASED ON STARCH/POLY(VINYL ALCOHOL)/CHITOSAN CONTAINING Garcinia mangostana PEEL EXTRACT FOR RECURRENT APHTHOUS STOMATITIS

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Abstract

Recurrent aphthous stomatitis affects approximately 5–25% of the global population, and the limited residence time of conventional topical formulations often reduces therapeutic efficacy at oral mucosal lesions. Polymeric films have emerged as promising localized oral drug delivery systems because they prolong mucosal retention and enable sustained release of bioactive compounds. Garcinia mangostana peel, an abundant agricultural by-product, is rich in xanthones, flavonoids, tannins, and phenolic compounds with antibacterial potential, although its application in oral films remains limited. This study aimed to fabricate and characterize a composite oral film based on starch/poly(vinyl alcohol)/chitosan containing Garcinia mangostana peel extract and evaluate its physicochemical properties and antibacterial activity against Streptococcus mutans. Mangosteen peel extract was prepared by maceration using 70% ethanol, cassava starch was isolated by wet extraction, and composite films containing 0%, 1%, and 2% extract were fabricated using the solvent-casting method. Mangosteen peel extraction and cassava starch isolation yielded 10% and 25%, respectively, while phytochemical screening confirmed the presence of flavonoids, saponins, tannins, and phenolic compounds. All formulations produced intact films with uniform thickness (0.260–0.268 mm), neutral pH (6.410–7.393), and folding endurance exceeding 300 cycles. Increasing extract concentration significantly enhanced antibacterial activity ($p = 0.009$), with inhibition zones increasing from 5.31 ± 0.19 mm (F1) to 6.66 ± 0.38 mm (F2). The 2% extract-loaded formulation exhibited the most balanced physicochemical properties and antibacterial performance, highlighting the potential of starch/poly(vinyl alcohol)/chitosan composite films as naturally derived platforms for localized oral drug delivery in recurrent aphthous stomatitis.

Keywords: Garcinia mangostana peel extract; composite oral film; recurrent aphthous stomatitis; recurrent aphthous stomatitis

INTRODUCTION

Polymeric films have emerged as promising oral drug delivery platforms because they adhere to the oral mucosa, protect ulcerated tissues, prolong drug residence time, and reduce systemic exposure (Dubashynskaya et al., 2024). Among natural polymers, cassava starch offers excellent film-forming ability and biodegradability but has limited mechanical strength. Chitosan provides antimicrobial and mucoadhesive properties, while poly(vinyl alcohol) (PVA) improves flexibility and structural stability. Their combination produces a biocompatible polymeric matrix with enhanced physicochemical performance suitable for oral biomaterial applications (Arpa et al., 2023) (Mitantsoa et al., 2021).

Incorporating natural bioactive compounds further enhances the therapeutic potential of polymeric films. Garcinia mangostana peel, an abundant agricultural by-product comprising 60–62% of the fruit mass, is rich in xanthones, flavonoids, tannins, and phenolic compounds. Its major bioactive constituent, α-mangostin, exhibits antibacterial, antioxidant, and anti-inflammatory activities through inhibition of NF-κB signaling, suppression of reactive oxygen species, and modulation of pro-inflammatory cytokines (Janadharma, 2017), making mangosteen peel extract a promising candidate for localized treatment of inflammatory oral lesions (Soontornwat et al., 2025) (Garcia et al., 2021). Despite previous studies on starch-based films, chitosan, and mangosteen-derived extracts, the integration of starch/PVA/chitosan with Garcinia mangostana peel extract for localized oral drug delivery has been scarcely investigated. Therefore, this study developed a solvent-cast starch/poly(vinyl alcohol)/chitosan composite

oral film containing mangosteen peel extract and evaluated its extraction yield, phytochemical profile, organoleptic characteristics, physicochemical properties, and antibacterial activity against Streptococcus mutans. The findings provide a basis for developing a natural composite biomaterial for localized treatment of recurrent aphthous stomatitis.

METHOD

This study employed a laboratory-based experimental design to develop and evaluate a film based on starch/poly(vinyl alcohol)/chitosan containing Garcinia mangostana peel extract for localized oral drug delivery. The experimental workflow consisted of mangosteen peel extraction, cassava starch isolation, qualitative phytochemical screening, fabrication of composite films with different extract concentrations, physicochemical characterization, antibacterial activity evaluation against Streptococcus mutans, and statistical analysis. Three formulations were prepared, namely F0 (without extract), F1 (1% extract), and F2 (2% extract), to investigate the influence of extract concentration on film characteristics and antibacterial performance. Fresh mangosteen peels were sorted, washed, cut into small pieces, oven-dried at 65°C to constant weight, ground into powder, and sieved through a 60-mesh sieve. Extraction was performed by maceration using 70% ethanol at a sample-to-solvent ratio of 1:10 (w/v) for 72 h at room temperature with intermittent stirring. The filtrate was concentrated using a rotary evaporator and stored in an amber container until use. Extraction efficiency was calculated using Eq. (1).

$$\text{Extraction Yield (\%)} = \frac{\text{Weight of dried extract}}{\text{Initial dry sample}} \times 100 \quad (1)$$

Cassava starch was isolated by the conventional wet extraction method. Fresh cassava tubers were washed, peeled, blended with distilled water (1:4, w/v), filtered, and allowed to sediment for 12–24 h. The starch precipitate was collected, washed, oven-dried at 50–60°C, ground, sieved (60 mesh), and the starch yield was calculated from the dried starch weight relative to the initial fresh cassava weight.

Qualitative phytochemical screening of Garcinia mangostana peel extract was performed to detect flavonoids (Shinoda test), tannins and phenolics (ferric chloride), xanthones (sodium hydroxide/ferric chloride), and saponins (foam test). Results were recorded qualitatively as positive (+) or negative (−).

Composite oral films were prepared by the solvent-casting method. Cassava starch, chitosan, and poly(vinyl alcohol) (PVA) were dissolved separately under appropriate conditions before blending into a homogeneous solution. Three formulations were prepared: F0 (without extract), F1 (1% extract), and F2 (2% extract). Glycerol was used as a plasticizer, and peppermint oil was added to improve the organoleptic properties. The detailed composition of each formulation is presented in Table 1.

Composite oral films were prepared by the solvent-casting method. Cassava starch, chitosan, and poly(vinyl alcohol) (PVA) were prepared separately and blended into a homogeneous polymer solution. Garcinia mangostana peel extract was added according to the formulation (Table 1), followed by glycerol (2 mL) as a plasticizer and peppermint oil (1 mL) as a flavoring agent. The casting solution was homogenized, degassed, poured into silicone molds, and dried at 45°C. The dried films were removed from the molds and stored in airtight containers at 4°C until further analysis.

Table 1. Formulation of starch/PVA/chitosan composite oral films.

Materials	F0	F1	F2	Function
Garcinia mangostana peel extract	–	1 g	2 g	Active ingredient
Cassava starch	2.5 g	2.5 g	2.5 g	Natural polymer
Chitosan	1.0 g	1.0 g	1.0 g	Natural polymer
Poly(vinyl alcohol) (PVA)	1.5 g	1.5 g	1.5 g	Synthetic polymer
Glycerol	2 mL	2 mL	2 mL	Plasticizer
Peppermint oil	1 mL	1 mL	1 mL	Flavoring agent
Distilled water	ad 100 mL	ad 100 mL	ad 100 mL	Solvent

Organoleptic properties (color, odor, surface appearance, and texture) were evaluated by 20 volunteers using a structured questionnaire. Film weight, thickness, folding endurance, and surface pH were measured using standard analytical methods.

Antibacterial activity against Streptococcus mutans was assessed using the agar diffusion method. Film specimens, pure mangosteen peel extract, gentamicin (positive control), and F0 (negative control) were tested after incubation at 37°C for 24 h, and inhibition zones were measured. All experiments were performed in triplicate and expressed as mean ± standard deviation (SD). Statistical analysis was conducted using the Kruskal–Wallis test ($p < 0.05$), followed by pairwise comparisons when significant differences were observed.

RESULTS AND DISCUSSION

Extraction Yield of Garcinia mangostana Peel Extract and Cassava Starch

The extraction efficiency of both the bioactive component (Garcinia mangostana peel extract) and the polymeric matrix (cassava starch) was first evaluated to ensure that sufficient raw materials were obtained for the fabrication of the composite oral films. Extraction yield is an important parameter because it reflects the effectiveness of the extraction process and determines the availability of bioactive compounds and polymeric materials for subsequent formulation. The extraction yields obtained in the present study are summarized in Table 2.

Table 2. Extraction yield of Garcinia mangostana peel extract and cassava starch.

Raw material	Extraction method	Initial weight (g)	Solvent volume	Final product (g)	Yield (%)
Garcinia mangostana peel powder	Maceration (70% ethanol)	100	1 L	10	10
Fresh cassava tuber	Wet extraction	2000	8 L	500	25

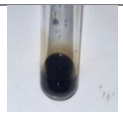
As presented in Table 2, the extraction yield of mangosteen peel represents the proportion of soluble constituents recovered from the raw material after extraction. Although a higher yield indicates greater recovery of extractable compounds, it does not necessarily reflect higher concentrations of bioactive constituents because crude extracts also contain non-pharmacologically active compounds. Therefore, extraction yield mainly indicates extraction efficiency, which is influenced by factors such as solvent polarity, extraction time, solvent-to-solid ratio, particle size, temperature, and extraction technique (Rizki et al., 2023).

The 10% extraction yield obtained in this study is consistent with previous reports of ethanolic extraction of Garcinia mangostana peel, which generally range from 9% to 15%, indicating effective recovery of secondary metabolites. Variations among studies are expected due to differences in plant maturity, geographical origin, drying conditions, solvent composition, extraction duration, and evaporation conditions. Thus, the extraction protocol was considered suitable for preparing mangosteen peel extract for composite oral film fabrication. The wet extraction process produced a cassava starch recovery of 25%, demonstrating efficient isolation of starch granules. This value falls within the reported range of 19%–25% for cassava starch extraction. Starch recovery is influenced by cultivar, washing and sedimentation efficiency, grating, and drying conditions. The relatively high yield suggests minimal material loss during processing. Overall, both extraction procedures provided sufficient mangosteen peel extract and cassava starch for composite oral film fabrication, with extraction efficiencies comparable to previous studies (Dewi et al., 2023) (Armanto, 2023).

Phytochemical Screening

Prior to incorporation into the composite oral film, qualitative phytochemical screening was conducted to verify the presence of major bioactive secondary metabolites in the ethanolic extract of Garcinia mangostana peel. The qualitative screening results are summarized in Table 3.

Table 3. Qualitative phytochemical profile of Garcinia mangostana peel extract.

Phytochemical group	Qualitative observation	Result	Biological significance
Flavonoids	 Red coloration	Positive (+)	Antioxidant, anti-inflammatory
Saponins	 Stable foam formation	Positive (+)	Antibacterial, immunomodulatory
Tannins	 Dark green/blue-black coloration	Positive (+)	Antibacterial, astringent
Phenolic compounds	 Dark blue coloration	Positive (+)	Antioxidant activity

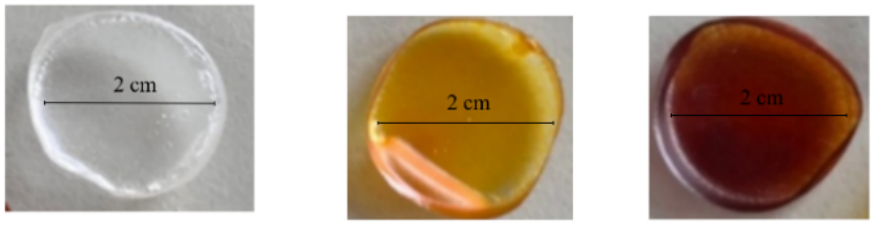
The positive reactions observed for all tested metabolite groups indicate that the extraction procedure successfully preserved the major secondary metabolites naturally present in mangosteen peel (Table 3). These findings confirm that the extract contains a chemically diverse composition suitable for incorporation into the composite film. The presence of multiple phytochemical classes suggests that the biological activity of the formulation may result from synergistic interactions among these compounds rather than a single active constituent. Thus, qualitative phytochemical screening provides an important preliminary assessment of the extract's therapeutic potential.

Among the detected metabolites, flavonoids and phenolic compounds are the primary contributors to the antioxidant activity of mangosteen peel. Their ability to donate hydrogen atoms or electrons neutralizes free radicals, reducing oxidative stress associated with delayed healing and prolonged inflammation in recurrent aphthous stomatitis. Therefore, preserving these compounds during extraction is expected to support tissue repair and reduce inflammatory responses (Pratiwi et al., 2025). Tannins further enhance therapeutic potential through antimicrobial and astringent properties by disrupting bacterial cell functions and promoting tissue contraction, thereby supporting wound healing.

Saponins, another major metabolite identified, exhibit antibacterial, anti-inflammatory, and immunomodulatory activities by increasing bacterial membrane permeability and regulating inflammatory mediators. Together with flavonoids, tannins, and phenolic compounds, they may provide complementary biological effects that improve the therapeutic performance of the composite film. This phytochemical profile agrees with previous reports identifying Garcinia mangostana peel as a rich source of xanthones, flavonoids, tannins, saponins, and phenolic compounds responsible for its antioxidant, antimicrobial, anti-inflammatory, and wound-healing properties (Ortega et al., 2025) (Pratiwi et al., 2025). The agreement with previous studies indicates that the extraction protocol effectively preserved the characteristic phytochemical composition of mangosteen peel.

Formulation and Fabrication of Composite Oral Films

Three formulations of starch/PVA/chitosan composite films were successfully fabricated using the solvent casting technique to evaluate the influence of Garcinia mangostana peel extract concentration on the physical characteristics of the resulting films. Formulation F0 served as the control without extract incorporation, whereas F1 and F2 contained 1% and 2% (w/w) mangosteen peel extract, respectively.



(a) (b) (c)

Fig 1. Representative photographs of the fabricated composite oral films based on starch/PVA/chitosan (a) F0 (without mangosteen peel extract), (b) F1 (1% mangosteen peel extract), and (c) F2 (2% mangosteen peel extract).

The control formulation (F0) was transparent and colorless, whereas increasing concentrations of mangosteen peel extract progressively changed the film to a yellowish-brown color and reduced its transparency. This color change is attributed to naturally occurring pigments and polyphenolic compounds, particularly xanthones, which become increasingly incorporated into the starch/PVA/chitosan matrix as extract concentration increases. Similar effects have been reported in starch- and PVA-based films containing phenolic-rich plant extracts due to enhanced light absorption by polyphenolic pigments (Abedi-Firoozjah et al., 2023). All formulations formed continuous films, demonstrating good compatibility among cassava starch, poly(vinyl alcohol), and chitosan. Starch provides the structural matrix, PVA improves flexibility and mechanical strength, and chitosan reinforces the network while contributing mucoadhesive properties. This combination enables efficient entrapment of bioactive compounds without disrupting film formation, consistent with previous reports on starch/PVA composite films (Saini et al., 2025).

Several air bubbles were observed on some film surfaces, most likely due to air entrapment during vigorous stirring and incomplete deaeration before casting. Similar defects are common in solvent-cast starch- and chitosan-based films (Santhosh et al., 2024), and can be minimized by optimizing stirring, heating, or applying vacuum degassing before casting (Singh et al., 1987). The absence of phase separation despite increasing extract concentrations indicates good compatibility between mangosteen peel phytochemicals and the starch/PVA/chitosan matrix. Uniform incorporation of the extract is expected to improve the physicochemical consistency of the films and support sustained release of bioactive compounds during buccal application (Yağmur et al., 2026).

Organoleptic and Physical Evaluation

Organoleptic evaluation was performed to investigate the visual and sensory characteristics of the fabricated composite oral films. The organoleptic assessment results are summarized in Table 4.

Table 4. Organoleptic characteristics of the fabricated composite oral films.

Parameter	F0	F1	F2
Colour	Transparent (95.7%)	Yellowish-brown (100%)	Dark brown (95.7%)
Texture	Slight air bubbles (87.0%)	Slight air bubbles (69.6%)	No air bubbles (87.0%)
Odor	Odorless (73.9%)	Extract odor (43.5%)	Extract odor (78.3%)

Based on the organoleptic evaluation (Table 4), clear differences were observed among the formulations after incorporation of Garcinia mangostana peel extract. F0 was transparent, odorless, and exhibited slight surface bubbles, whereas F1 appeared yellowish-brown with a mild extract odor. F2 showed a darker brown color, a stronger characteristic odor, and a smoother surface without visible bubbles. These findings indicate that increasing extract concentration progressively altered the sensory characteristics of the films while maintaining successful film formation.

The gradual darkening from transparent to dark brown is attributed to the increasing incorporation of phenolic compounds, flavonoids, and xanthones, which contain chromophoric structures that absorb visible light. This observation is consistent with the phytochemical screening results, indicating that the bioactive compounds remained preserved after incorporation into the polymer matrix. Likewise, the stronger herbal odor in F1 and F2 reflects the presence of volatile and semi-volatile constituents from mangosteen peel extract, with the more pronounced odor in F2 suggesting greater retention of these compounds. Differences in surface morphology were also observed. Slight bubbles remained in F0 and F1, whereas F2 exhibited a smoother surface without obvious bubbles. Air bubbles commonly result from vigorous stirring, incomplete deaeration, or uneven heating during solvent casting. The

absence of visible bubbles in F2 suggests improved dispersion of the extract within the polymer matrix, producing a more homogeneous film surface that may enhance drug distribution, mechanical integrity, and release uniformity. These findings agree with previous studies showing that plant extracts influence the color, surface homogenity, and internal polymer structure of edible films (Kalaka et al., 2022) (Widyasti et al., 2025).

Table 5. Weight, thickness, folding endurance of composite oral films.

Formulation	Physical Evaluation			
	Weight (g) ± SD	**Thickness (mm) ± SD**	**Folding ± SD**	**pH ± SD**
F0	0,073 ± 0,012[a]	0,262 ± 0,055[a]	>300 ± 0	7,393 ± 0,012[a]
F1	0,107 ± 0,006[a]	0,260 ± 0,046[a]	>300 ± 0	6,410 ± 0,010[a]
F2	0,107 ± 0,012 g[a]	0,268 ± 0,045[a]	>300 ± 0	7,220 ± 0,026[ab]

The physical properties of pharmaceutical films influence their handling, administration, and drug release. Therefore, weight uniformity, thickness, folding endurance, and pH were evaluated to determine whether incorporation of mangosteen peel extract affected the physicochemical characteristics of the starch/PVA/chitosan composite films (Table 5).

Although F1 and F2 showed slightly higher average weights than F0, the differences were not statistically significant, indicating uniform mass distribution and reproducible solvent casting. Uniform film weight reflects homogeneous dispersion of polymers and bioactive compounds, ensuring consistent drug loading (Arinjani and Ariani, 2019). Likewise, film thickness remained consistent (0.260–0.268 mm) with no significant differences among formulations, indicating that extract incorporation did not affect polymer network formation. These values also met the Japanese Industrial Standard (JIS) requirement for edible films (0.25–0.29 mm)

All formulations exhibited folding endurance values above 300 folds without cracking, demonstrating excellent flexibility and mechanical integrity. This performance is attributed to the synergistic interaction of starch, PVA, and chitosan within the polymer network and meets the recommended standard for pharmaceutical films (Maraie and Wannas, 2026). Film pH ranged from 6.410 ± 0.010 to 7.393 ± 0.012. Although F1 showed a significantly lower pH than F0, likely due to acidic phenolic compounds from the extract, all formulations remained within the physiological range for buccal application (pH 5.6–7.4), minimizing the risk of mucosal irritation (Firmansya et al., 2022) (Abdella et al., 2022). Overall, incorporation of mangosteen peel extract did not adversely affect the fundamental quality attributes of the composite films. All formulations maintained uniform weight, appropriate thickness, excellent flexibility, and physiologically acceptable pH, indicating that the starch/PVA/chitosan matrix effectively accommodated the extract while preserving desirable pharmaceutical properties for localized treatment of recurrent aphthous stomatitis.

Antibacterial activity against Streptococcus mutans

The antibacterial activity test was conducted to evaluate the ability of the composite oral film containing Garcinia mangostana peel extract to inhibit the growth of Streptococcus mutans. The tested samples included F0 (without extract), F1 (1% extract), F2 (2% extract), 2% Garcinia mangostana peel extract as the natural positive control, and gentamicin as the positive control. The inhibition zone diameters are presented in Table 6.

The incorporation of Garcinia mangostana peel extract enhanced the antibacterial activity of the films, as shown by the inhibition zones produced by F1 and F2. F1 (1% extract) exhibited a mean inhibition zone of 5.31 ± 0.19 mm, while F2 (2% extract) showed a larger inhibition zone of 6.66 ± 0.38 mm. Both formulations demonstrated moderate antibacterial activity, with greater inhibition observed at the higher extract concentration (Eiselt et al., 2025) (Rahmawati, 2026).

Tabel 6. Antibacterial activity test result against Streptococcus mutans

Sample	Mean Inhibition Zone (mm)	±SD	Category
F0	0	0,00	None
F1 (1% extract)	5,31	0,19	Medium
F2 (2% extract)	6,66	0,38	Medium
2% Garcinia mangostana peel extract	7,65	0,10	Medium
Gentamicin	12	0,53	High

Although the antibacterial activity of F1 and F2 was lower than that of the pure extract and gentamicin, the results indicate that the bioactive compounds retained their antibacterial properties after incorporation into the film. This activity is attributed to secondary metabolites such as xanthones, flavonoids, tannins, and saponins, which inhibit bacterial growth by disrupting cell membranes and interfering with bacterial metabolism (Rahmawati, 2026). The Kruskal–Wallis test showed a significant difference among treatment groups ($p = 0.009$), confirming that extract concentration significantly influenced antibacterial activity. Despite producing smaller inhibition zones than gentamicin, the starch/PVA/chitosan composite film containing Garcinia mangostana peel extract shows potential as an antibacterial drug delivery system for recurrent aphthous stomatitis. Sustained release of the bioactive compounds may prolong their contact with the oral mucosa and enhance therapeutic efficacy (Ariani et al., 2024).

CONCLUSION

Composite oral films based on starch/poly(vinyl alcohol)/chitosan containing Garcinia mangostana peel extract were successfully fabricated using the solvent-casting method. The extraction process yielded 10% mangosteen peel extract and 25% cassava starch, while phytochemical screening confirmed the presence of flavonoids, saponins, tannins, and phenolic compounds, indicating successful preservation of the major bioactive constituents. Incorporation of mangosteen peel extract altered the organoleptic properties of the films by increasing color intensity and odor without compromising film formation. All formulations exhibited favorable physicochemical properties, including uniform thickness (0.260–0.268 mm), near-neutral pH (6.410–7.393), and excellent flexibility with folding endurance exceeding 300 cycles. Antibacterial evaluation demonstrated a significant concentration-dependent effect against Streptococcus mutans ($p = 0.009$), with the 2% extract formulation (F2) producing the largest inhibition zone (6.66 ± 0.38 mm) while maintaining the most favorable physicochemical characteristics. Overall, the starch/poly(vinyl alcohol)/chitosan composite matrix effectively served as a carrier for Garcinia mangostana peel extract, preserving its physicochemical stability and antibacterial activity. These findings support the potential of the developed composite film as a natural mucoadhesive drug delivery system for recurrent aphthous stomatitis and provide a basis for further studies on drug release, mucoadhesion, cytocompatibility, and in vivo therapeutic efficacy.

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