

Development and Characterization of Moringa-Chitosan Gel for Gingival and Periodontal Diseases: An Experimental Study

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Abstract

Background: Moringa oleifera is antioxidant and anti-inflammatory, while chitosan is biocompatible and mucoadhesive, making their combination a promising gel for sustained local drug delivery.

Objective: To develop and characterize Moringa-chitosan gels in the concentration 1% and 5%, and to evaluate the physical, rheological, release, antioxidant, and drug content uniformity.

Materials and Methods: Moringa extract was added into chitosan gel at the concentrations of 1% and 5%, by dissolving chitosan in acetic acid and adding the Moringa extract. Physical properties like the color, consistency, and smell were checked. Viscosity was measured using a Brookfield viscometer, the spreadability and swelling were assessed using the glass slide method and immersion in phosphate buffered saline. The total phenolic content (TPC) and invitro drug release were assessed, along with DPPH radical scavenging activity.

Results: The 5% moringa gel reported better antioxidant activity i.e., 63% DPPH inhibition, with IC₅₀ 108µg/mL, compared to the 1% gel with 43.33% DPPH inhibition, and IC₅₀ 125µg/mL. The 5% gel reported a higher drug release, reaching 80% release over 8h, compared to 68% release from the 1% gel. Both gels reported optimal swelling and sustained release, with the 5% gel reporting better spreadability and viscosity.

Conclusion: The 5% Moringa-Chitosan Gel showed better therapeutic properties with higher antioxidant potential and controlled drug release, making it suitable for oral cavity applications like gingivitis and periodontitis as well as an adjunct treatment.

Keywords: Antioxidant activity, Chitosan gel, Drug release, Gel formulation, Moringa oleifera, Oral cavity, Therapeutic application.

Introduction

Gingivitis, common reversible inflammation of the gingiva which arises from dental plaque, food impaction and accumulation of plaque at the gingival margin.¹ Gingivitis is reversible and important because persistent plaque induced inflammation can lead to the initiation and progression to periodontitis, which is aggressive form of gingivitis with significant periodontal and bone loss.² The inflammatory response in gingivitis is mediated by microbial dysbiosis and host immune activation, resulting in excessive cytokine signaling, tissue edema, and inflammatory cell infiltration.³

Interleukin-6 (IL-6) is a pro-inflammatory cytokine in periodontal inflammation and host response regulation, with elevated IL-6 linked to increase inflammatory signaling and may indicate the intensity of gingivitis.⁴ Moringa oleifera is a medicinal plant rich in phenolic compounds and flavonoids with antimicrobial, antioxidant, and anti-inflammatory properties.⁵ Previous studies have reported that Moringa-based products such as mouthwashes and gels, and other experimental work have been explored and has suggested potential down regulation of inflammatory mediators such as IL-6 in bacteria linked periodontitis and gingivitis.⁶⁻⁸ Moreover, recent studies have worked towards locally retained Moringa delivery systems designed to prolong contact time and improve sustained release at the site of inflammation.^{5, 8}

Studies have reported that Moringa oleifera supports tissue repair, wound healing and anti-inflammatory properties in addition to its antioxidant properties, indicating that it can be an important herbal alternate for oral cavity conditions like gingivitis and periodontitis, where inflammation, microbial irritation, and delayed tissue recovery coexist, and may be considered as adjunctive therapy for mucosal and

periodontal applications.⁵ Chitosan is a biocompatible, biodegradable polysaccharide with mucoadhesive and antimicrobial properties.⁹

It is cationic in nature and supports interaction with negatively charged microbial membranes and mucosal surfaces, and chitosan gels/hydrogels have been widely studied for local drug delivery in oral tissues.¹⁰

Moreover, a chitosan matrix improves retention, protect phytochemicals, and modulate the release of the active agents, a property desirable for gingival management where salivary clearance and mastication forces reduce topical residence time of the oral topical medicines.¹¹ Moreover, chitosan itself has antimicrobial, film-forming, and wound-supportive properties, which further reinforce its value as a carrier for bioactive plant extracts.^{10, 12}

Combining Moringa extract with a chitosan gel matrix is a rational strategy to deliver bioactives agents locally while using chitosan mucoadhesive and biofunctional properties.¹³ The pharmacological benefits of Moringa oleifera and the drug delivery of chitosan, combining both into a gel can to be a promising approach, however, limited literature is available on Moringa-loaded chitosan gels, therefore, this can be used as as sustained-release antioxidant gels for gingivitis and periodontitis.^{11, 13}

The present study aimed to develop a Moringa oleifera–chitosan oral gel and evaluated its physical and functional properties in vitro.

Materials and Methods

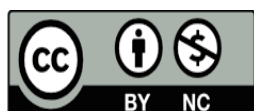
This experimental study was conducted in the animal research laboratories of Rashid Latif College of Pharmacy, Lahore, using specialized units for physicochemical testing, ELISA, and histopathological evaluation. The study was conducted after approval of the Ethical Review Board of Azra Naheed Medical and Dental College (Ref: FRB/BMS/02), from January 2025 to December 2025.

Preparation of Moringa Extract

Fresh Moringa oleifera leaves were washed, shade-dried at 25–30°C, and pulverized. The powdered leaves were extracted with 70% ethanol (v/v) at a 1:10 (w/v) ratio by maceration for 48–72 h with intermittent stirring. The extract was filtered using Whatman No. 1, and the residue was re-extracted twice. Filtrates were pooled and concentrated under reduced pressure at ≤40°C using a rotary evaporator to remove ethanol completely. The remaining concentrate was freeze-dried and lyophilized to obtain a dry extract. The extract was stored in amber

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containers at -20°C , and the extraction yield in (%) was calculated. Prior to gel incorporation, the dry extract was reconstituted in distilled water to achieve the required concentration.

Preparation of Moringa-Chitosan Gel

Chitosan solution (1% w/v) was prepared by dispersing chitosan in 1% (v/v) acetic acid under magnetic stirring at 500 rpm for 2h at room temperature till a clear gel base was formed. The pH was adjusted to 5.5 to 6.5 using 1 M NaOH. Glycerol (1 to 2% w/v) was added as a plasticizer. The standardized Moringa extract was incorporated into the chitosan base at predetermined concentrations 1% and 5%, and the mixture was stirred for 30 min followed by sonication for 5-10 min to remove entrapped air. The gels in Group A (1%) and Group B (5%) were then stored in airtight containers for 24 h before testing (Figure 1).

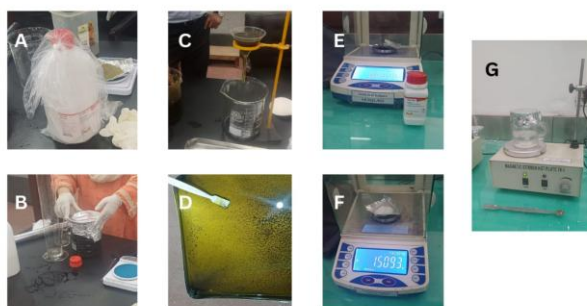


Figure 1: Preparation of Moringa Chitosan Gel (a) Moringa powder for aqueous extraction (b) Ethanol extraction process (c) Filtration of moringa extract (d) Collected moringa extract (e) Weighing chitosan (f) Chitosan solution preparation (g) Sonication for homogenization

Physical and Organoleptic Characterization

The color, odor, texture, smoothness, and presence of grittiness were checked by visual inspection and by gentle rubbing between the fingers wearing gloves. The homogeneity i.e., clumping, phase change and particle aggregate was checked by viewing the gel against a light source. The results were recorded in triplicate.

pH Evaluation

The pH of the formulations was evaluated by dispersing 1 g of gel in 10 mL of distilled water and allowing it to settle for 30 min. The pH was measured using a digital pH meter. All measurements were performed in triplicate and expressed as mean $\pm$ SD.

Rheological Characterization

The viscosity of the gels were assessed using a Brookfield viscometer, where 50g of gel was placed and allowed to settle for 5 min till equilibrium was achieved, and the viscosity was measured at increasing rotational speeds from 5, 10, 20, 50, and 100 rpm with a 30 to 60s stabilization time at rpm. The viscosity (cP) was recorded against shear rate to determine flow, the measurements were conducted in triplicate.

Spreadability Assessment

The spreadability of the gels was done using the glass slide method, where 1g of gel was placed between two clean glass plates, with 20 g weight (M) applied on the upper plate for uniform thickness. The time (T) required for the upper plate to move a specified distance (L, cm) under the applied weight was recorded. Spreadability (S) was calculated using the formula: $S = (M \times L) / T$, and the measurements were done in triplicate.

Swelling Behavior Evaluation

Gel discs of defined weight (W₀) were prepared and immersed in phosphate-buffered saline (PBS, pH 7.4) at $37 \pm 0.5^{\circ}\text{C}$. At

predetermined intervals (0.5, 1, 2, 3, 4, 6, 8 h), discs were removed, gently blotted to remove surface liquid, and weighed (W_t). Swelling index (%) was calculated using the formula: $\text{Swelling Index (\%)} = [(W_t - W_0) / W_0] \times 100$.¹⁴ Triplicate measurements were performed for each formulation.

Total Phenolic Content and Content Uniformity Analysis

Botanical extracts contain multiple active ingredients, the content uniformity was assessed using total phenolic content (TPC). Gel weighing 1 g was dissolved in a measured volume of solvent i.e., hydroethanolic solvent and filtered. TPC was measured using the Folin-Ciocalteu method. Diluted sample was mixed with Folin reagent and sodium carbonate, incubated for 30 to 60 min, and absorbance was read at 765 nm. A gallic acid calibration curve was used, and results were obtained in mg gallic acid equivalents (GAE)/g gel.¹⁵

In-vitro Drug Release Study

In-vitro release was studied using a dialysis membrane (MWCO 12–14 kDa) method. A known amount of gel (1 g) containing standardized extract was placed in the dialysis bag and immersed in 100 mL PBS (pH 7.4) maintained at $37 \pm 0.5^{\circ}\text{C}$ under mild agitation (50 to 100 rpm). At predetermined time points (0.5, 1, 2, 3, 4, 6, 8 h), aliquots were withdrawn and replaced with equal fresh buffer to maintain sink conditions. Released phenolics were quantified using TPC or a validated UV method, and cumulative % release was calculated.¹⁶

DPPH Antioxidant Activity

DPPH solution (0.1 mM) was prepared in methanol. Gel extract was recovered by dissolving gel in solvent and filtering. Various concentrations were mixed with DPPH and incubated in the dark for 30 min at room temperature. Absorbance was measured at 517 nm. Percentage inhibition was calculated using the formula: $\% \text{ inhibition} = [(A_{\text{control}} - A_{\text{sample}}) / A_{\text{control}}] \times 100$. IC₅₀ (concentration producing 50% inhibition) was calculated using a dose-response curve.¹⁷

The data was analyzed using SPSS version 24. The descriptive statistics were used to present means and standard deviations of the triplicate results. The data was presented as graphs and tables.

Results

Physical and Organoleptic Characteristics

Both formulations, Group A (1% Moringa extract) and Group B (5% Moringa extract), showed a greenish-brown appearance. Group A exhibited a lighter greenish shade compared with Group B. Both gels had a smooth and consistent texture, with no visible clumping, phase separation, or particle aggregation observed. A distinct herbal odor was present in both formulations. The physical and organoleptic observations are presented in Table 1. Overall, increasing extract loading from 1% to 5% did not compromise visual stability or homogeneity.

Table 1. Physical and organoleptic properties of A (1%) and B (5%)

Gels	Parameter	Observation	Interpretation
Group A (1%)	Color	Greenish-brown	Uniform dispersion of Moringa extract
	Texture	Smooth, consistent	Stable gel formation; no phase separation
	Odor	Herbal	Presence of active phytochemicals
Group B (5%)	Color	Light Greenish-brown	Uniform dispersion of Moringa extract
	Texture	Smooth, consistent	Stable gel formation; no phase separation
	Odor	Herbal	Presence of active phytochemicals

The pH of both formulations i.e., 1% and 5% remained within 5.5 to 6.5, which is within a range compatible with oral gingival tissues. The pH was in the normal range in the higher concentration group B (5%).

Rheological Characteristics

Group B (5% Moringa extract) showed viscosity ranging from 4416.67 cP at 5 rpm to 2316.67 cP at 100 rpm. Group A (1% Moringa extract) showed viscosity ranging from 4200 cP at 5 rpm to 1800 cP at 100 rpm. The viscosity values decreased with increasing rotational speed in both formulations. The viscosity measurements are presented in Table 2.

Table 2: Mean viscosities for 1% and 5% Moringa Chitosan Gel at different shear rates

Groups	RPM	N	Minimum	Maximum	Mean±SD
1% Moringa Chitosan Gel	5 RPM	3	4150	4250	4200±63.80
	10 RPM	3	3400	4350	3766.6±514.39
	20 RPM	3	2750	2850	2800±67.17
	50 RPM	3	2150	2250	2200±53.91
	100 RPM	3	1750	1850	1800±61.18
5% Moringa Chitosan Gel	5 RPM	3	4350	4500	4416.6±63.80
	10 RPM	3	3750	3900	3816.6±514.39
	20 RPM	3	3150	3300	3216.7±67.17
	50 RPM	3	2650	2800	2716.6±53.91
	100 RPM	3	2250	2400	2316.7±61.18

Spreadability Assessment

Group B (5%) had higher spreadability than A (1%), indicating less force required and uniform mucosal coverage at 5%. The spreadability increased 1.67 times i.e., from 12 to 20gcm/s, in Group B. The spreadability results of both formulations are presented in Table 3.

Table 3: Spreadability of 1% and 5% Moringa Chitosan Gel Formulations

Groups	M(g)	L(cm)	T(s)	Spreadability (g·cm/s)	Mean±SD
1% Moringa Chitosan Gel	20	6.1	10	12.2	12.47±0.68
	20	6.7	10	13.4	
	20	5.9	10	11.8	
5% Moringa Chitosan Gel	20	8.1	8	20.25	20.50±1.34
	20	8.9	8	22.25	
	20	7.6	8	19.0	

Swelling Behavior Evaluation

Both 1% and 5% Moringa-Chitosan gels showed optimal swelling, showing sustained hydration and controlled release, with swelling increasing upto 4 h, and plateaued, indicating equilibrium. For Group A (1% Moringa extract), the swelling index increased from 4.8±0.3% at 0.5 h to 11.2±0.6% at 4 h and was 10.9±0.4% at 8 h. For Group B (5% Moringa extract), the swelling index increased from 9.5±0.4% at 0.5 h to 18.1±1.0% at 4 h and was 17.5±0.8% at 8 h. The time-dependent swelling results are presented in Figure 2.

Total Phenolic Content and Content Uniformity

The TPC of 1% and 5% moringa-chitosan gel was measured to assess the drug content uniformity, and the 1% gel had a mean TPC of 2.11±0.010mg/g, reporting high consistency in the phenolic content, whereas, the 5% gel had a mean TPC of 2.557±0.006mg/g, indicating a similar uniform distribution of phenolic content, but at a slightly higher concentration. The TPC values are presented in Table 4.

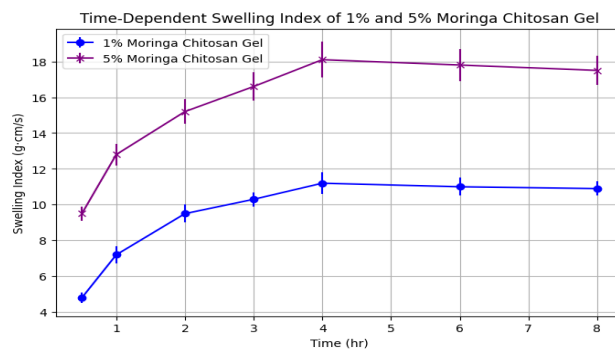


Figure 2: Time dependent swelling of 1% and 5% Moringa-Chitosan gel

Table 4: Total Phenolic Content (TPC) of 1% and 5% Moringa Chitosan Gel Formulation

Groups	TPC (mg/g)	Mean ± SD
1% Moringa Chitosan Gel	2.10	2.110 ± 0.010
	2.12	
	2.11	
5% Moringa Chitosan Gel	2.55	2.557 ± 0.006
	2.56	
	2.56	

In-vitro Drug Release Study

The in-vitro drug release for 1% and 5% Moringa-Chitosan Gel reported a concentration-dependent release profile as the 5% gel released a higher percentage of the active ingredient at each time point compared to the 1% gel. The 1% gel reached 68% release by 8 hours, whereas the 5% reported a cumulative release of 80% over the same period. The drug release values at different time intervals are presented in Figure 3.

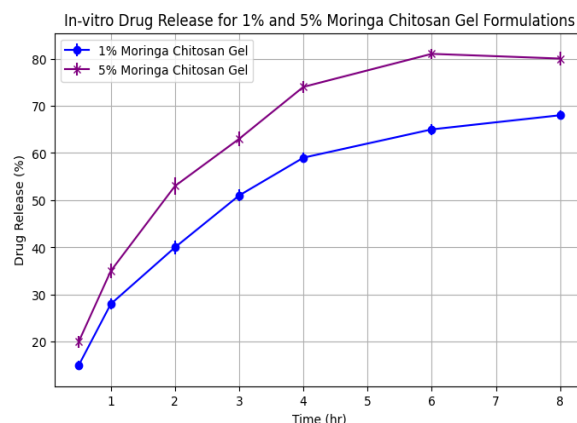


Figure 3: In-vitro release kinetics of 1% and 5% Moringa-Chitosan Gel

DPPH Antioxidant Activity

The antioxidant activity of the Moringa-chitosan gels was evaluated using the DPPH radical scavenging assay. Group A (1% Moringa extract) showed a mean DPPH inhibition of 43.33±2.51% with an IC₅₀ value of 125 ± 5 µg/mL. Group B (5% Moringa extract) showed a mean DPPH inhibition of 63.0±2.0% with an IC₅₀ value of 108±2.64 µg/mL. The antioxidant activity results are presented in Table 5.

Table 5: Antioxidant activity of 1% and 5% moringa-chitosan gels

Groups	DPPH Inhibition (%)	Mean±SD	IC ₅₀ (µg/mL)	Mean±SD
1% Moringa Chitosan Gel	43	43.33±2.51	125	125±5.0
	46		130	
	41		120	
5% Moringa Chitosan Gel	63	63.0±2.0	110	108±2.64
	65		109	
	61		105	

Discussion

In the current study, both 1% and 5% moringa-chitosan gels reported good visual stability and homogeneity with greenish to brown color, indicating incorporation of moringa powder into the chitosan. The 1% gel reported a slightly lighter greenish shade due to the lower concentration of moringa. These findings are consistent with the findings of the study by Naqvi et al.¹⁸ The similar finding was reported in a study by Campos et al., where chitosan effectively retained phytochemicals in gel.¹⁹ The 1% and 5% formulations showed no visible clumping or phase separation, indicating that increasing the Moringa concentration from 1% to 5% did not compromise gel stability, aligning with the findings in Ren and Bashir et al., where moringa-chitosan gels remained stable even with higher phytochemical concentration which confirms the biocompatibility and stability of Moringa-Chitosan gels for oral applications.^{20, 21}

The pH of both Moringa-chitosan gel formulations remained within the range of 5.5–6.5. This pH range is considered appropriate for oral applications because it is compatible with gingival tissues and supports the use of topical formulations within the oral cavity. The maintained pH values may also contribute to formulation stability by preventing excessive acidity or alkalinity that could affect gel performance. Similar pH ranges have been reported in chitosan-based oral and mucosal delivery systems, supporting the suitability of chitosan gels for local oral applications.^{9,10,12}

The viscosity of the gels showed that the 5% moringa-chitosan had a higher viscosity compared to the 1% gel. At 5 RPM, the 5% formulation showed 4416.67cP, while the 1% formulation showed 4200cP and both reported pseudoplastic flow, with viscosity decreasing as the shear rate increased. These findings are consistent with the previous literature reporting similar shear-thinning behavior in chitosan-based gels.²² The 5% gels, with higher viscosity, is expected to adhere better to mucosal surfaces, providing sustained contact and controlled release, which aligns with the findings of Lucero et al., in 2016, reporting higher concentrations of chitosan having increased viscosity and better retention in the oral cavity, making the 5% gel suitable for prolonged effects.^{22, 23} The spreadability test reported that the 5% moringa-chitosan gel showed better spreadability than the 1% gel, with spreadability improving from 12.2 gcm/s in the 1% gel to 20.25 gcm/s in the 5% gel. This finding is consistent with the previous literature which reported that increasing the moringa concentration in gels could improve the spreadability, maybe due to changes in gel viscosity and matrix.^{24, 25} The higher

spreadability in the 5% gel suggests that, despite the increased concentration, the gel was able to spread more uniformly, improving local contact and effectiveness when applied to the gingival tissue, thus improving the potential for gingivitis treatment.²⁶

Both formulations demonstrated time-dependent swelling behavior, with swelling increasing up to 4 h followed by stabilization. The 5% Moringa-chitosan gel showed greater swelling compared with the 1% formulation. Similar findings have been reported by Ahmad et al., where increased polymer content enhanced water uptake and swelling capacity of hydrogel systems.²⁷ The swelling characteristics observed in the current study may support hydration and controlled release properties required for local drug delivery applications.^{28, 29}

The TPC analysis demonstrated uniform distribution of phenolic compounds within both gel formulations. The 1% formulation showed a mean TPC of 2.11 mg/g, whereas the 5% formulation showed a higher mean TPC of 2.55 mg/g. The increased phenolic content in the 5% formulation corresponds with the higher Moringa extract concentration incorporated into the gel matrix. Similar findings have been reported in Moringa-loaded chitosan systems, where chitosan matrices successfully retained bioactive compounds.^{30,31}

The in-vitro drug release study demonstrated a concentration-dependent release pattern, with the 5% Moringa-chitosan gel showing higher cumulative release compared with the 1% formulation, which is consistent with the findings of a study by Naqvi et al., which reported that higher drug concentrations in gels lead to faster and higher release rates due to increase porosity and diffusion.¹⁸ The slower release after initial rapid diffusion, especially in the 5% gel, indicates that both gels reported sustained release, with the 5% gel showing more effective and prolonged release.³²

The antioxidant evaluation demonstrated higher DPPH radical scavenging activity in the 5% Moringa-chitosan gel compared with the 1% formulation. The 5% gel showed 63% inhibition with an IC₅₀ value of 108 µg/mL, whereas the 1% gel showed 43.33% inhibition with an IC₅₀ value of 125 µg/mL. Previous studies have reported that increasing Moringa concentration enhances antioxidant activity due to higher levels of phenolic and flavonoid compounds.^{24, 33, 34} The increased antioxidant activity observed in the present study supports the potential role of Moringa-containing formulations in managing oxidative stress associated with oral inflammatory conditions.

Conclusion

The 1% and 5% moringa-chitosan gels showed physicochemical properties for oral cavity applications. The 5% gel reported better antioxidant activity, greater drug release, and better spreadability while maintaining optimal swelling and drug content uniformity, making the 5% Moringa-Chitosan Gel more effective for prolonged therapeutic use in oral inflammatory conditions like gingivitis and periodontitis.

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CONFLICT OF INTEREST: None

References

- Shafique R, Hassan H, Shakoar A, Aziz S, Aslam K, Najfi NZ. Perception and misconceptions of patients about dental scaling treatment: a cross-sectional study. *Journal of Oral Health and Oral Epidemiology*. 2024;13(3):122-6.
- Abusleme L, Hoare A, Hong BY, Diaz PI. Microbial signatures of health, gingivitis, and periodontitis. *Periodontology* 2000. 2021;86(1):57-78.

3. Neurath N, Kesting M. Cytokines in gingivitis and periodontitis: from pathogenesis to therapeutic targets. *Frontiers in immunology*. 2024;15:1435054.
4. Mazurek-Mochol M, Bonsmann T, Malinowski D, Serwin K, Czerewaty M, Safranow K, et al. Interleukin-6 Receptor Gene rs1800795 Polymorphism and Expression of Interleukin-6 in Gingival Tissue in Patients with Periodontitis. *Microorganisms*. 2024;12(10):1954.
5. Thalib AM, Thalib B, Andrawina W, Eria M, Amelia N. Potential of *Moringa oleifera* as a gingivitis inhibitor. *Makassar Dental Journal*. 2024;13(2):259-62.
6. Buakaew W, Sranujit RP, Noysang C, Sangouam S, Suphrom N, Thongsri Y, et al. Evaluation of mouthwash containing *Citrus hystrix* DC., *Moringa oleifera* Lam. and *Azadirachta indica* A. Juss. leaf extracts on dental plaque and gingivitis. *Plants*. 2021;10(6):1153.
7. Ramírez-Torres V, Torres-León C, Londoño-Hernandez L, Gómez-García R, Ramírez-Guzmán N. Therapeutic Potential of Latin American Medicinal Plants in Oral Diseases: From Dental Pain to Periodontal Inflammation—A Systematic Review. *International Journal of Molecular Sciences*. 2025;26(23):11502.
8. Luetragoon T, Sranujit RP, Noysang C, Thongsri Y, Potup P, Somboonjun J, et al. Evaluation of anti-inflammatory effect of *Moringa oleifera* lam. And *Cyanthillium cinereum* (less) H. Rob. Lozenges in volunteer smokers. *Plants*. 2021;10(7):1336.
9. Jøraholmen MW, Bhargava A, Julin K, Johannessen M, Škalko-Basnet N. The antimicrobial properties of chitosan can be tailored by formulation. *Marine Drugs*. 2020;18(2):96.
10. Alqahtani AS. Topical Drug Delivery in Oral Mucosal Diseases: Challenges, Carriers, and Innovations: A Comprehensive Review. *Biomedical and Pharmacology Journal*. 2025;18(3):1835-48.
11. Priya A, Prasath NH, Malligarjunan N, Pandian SK. In Vitro and In Vivo Efficacy of Phytoactive-Based Oral Care Regimens in the Prophylaxis of Oral Biofilm and Augmentation of Oral Hygiene. *Pharmacological studies in natural oral care*. 2023:723-73.
12. Amin N, Siddiqui U, Muhammad N, Liaqat S, Khan MA, Rahim AJMRF. Advancement of guided tissue regeneration (GTR) membranes for dental applications. 2022;123:155-74.
13. Detsi A, Kavetsou E, Kostopoulou I, Pitterou I, Pontillo ARN, Tzani A, et al. Nanosystems for the encapsulation of natural products: The case of chitosan biopolymer as a matrix. *Pharmaceutics*. 2020;12(7):669.
14. Escamilla-Flores AV, Núñez-Anita RE, Arenas-Aroccena MC, Perez-Duran F, Calderón-Rico F, Santos-Cruz J, et al. Synthesis of biocompatible hydrogel of alginate-chitosan enriched with iron sulfide nanocrystals. *SLAS technology*. 2024;29(4):100158.
15. Ferreira DF, da Silva TM, de Melo RCG, Bastos KA, Ucella-Filho JGM, Severi JA, et al. Development of a gel formulation with pomegranate peel extract (*Punica granatum* L.) for antimicrobial and wound healing action. *South African Journal of Botany*. 2024;173:284-94.
16. Gómez-Lázaro L, Martín-Sabroso C, Aparicio-Blanco J, Torres-Suárez AI. Assessment of in vitro release testing methods for colloidal drug carriers: the lack of standardized protocols. *Pharmaceutics*. 2024;16(1):103.
17. Uddin MN, Roy SC, Mamun AA, Mitra K, Haque MZ, Hossain ML. Phytochemicals and in-vitro antioxidant activities of *Aloe vera* gel. *Journal of Bangladesh Academy of Sciences*. 2020;44(1):33-41.
18. Naqvi SMK, Khan Z, Mirza EH, Chandio A, Manzoor F, Niaz R, et al. Fabrication and characterization of polyvinyl alcohol/chitosan/moringa-extract hydrogel patch for wound-healing applications. *Materials Express*. 2021;11(1):107-15.
19. Campos LM, de Oliveira Lemos AS, da Cruz LF, de Freitas Araújo MG, de Mello Botti GCR, Júnior JLR, et al. Development and in vivo evaluation of chitosan-gel containing *Mitracarpus frigidus* methanolic extract for vulvovaginal candidiasis treatment. *Biomedicine & pharmacotherapy*. 2020;130:110609.
20. Ren M-H, Du Q-H, Li J-M, Liu X-L, Wei L-S, Lan H-X, et al. Emulsion-stabilizing properties of *Moringa oleifera* seed protein and chitosan: impact of molecular weight and protein concentration. *Journal of Food Measurement and Characterization*. 2025:1-11.
21. Bashir S, Iram G, Rafique S, Bashir M, Ghani T, Tanveer A, et al. Encapsulation of *Moringa oleifera* aqueous extract in silver chitosan metallopolymer nanocomposites for anti-cancer activity. *International Journal of Biological Macromolecules*. 2025;297:139683.
22. Vigilato MÁ, Horn M, Martins VCA, de Guzzi Plepis AM. Rheological study of gels based on chitosan and carbon nanotubes. *Brazilian Journal of Thermal Analysis*. 2015;4(1-2):35-8.
23. Lucero M, Ferris C, Sánchez-Gutiérrez C, Jiménez-Castellanos M, De-Paz M-V. Novel aqueous chitosan-based dispersions as efficient drug delivery systems for topical use. Rheological, textural and release studies. *Carbohydrate Polymers*. 2016;151:692-9.
24. Fatmawati A, Fauzi R, Gunawan A, Kurniawati R, Sucianingsih D, Abrari S. Formulation, Evaluation Of Physical Properties And Antioxidant Activity Of Ethanol Extract And Ethyl Acetate Fraction Gel Of *Moringa Oleifera* Leaves. *Medical Sains: Jurnal Ilmiah Kefarmasian*. 2022;7(4):873-80.
25. Sawant T, Behera A, Shetty N, Mathur A, Bali A, Waheed MA. Comparative Evaluation of 4% *Moringa oleifera* Gel with 1% Chlorhexidine Gel as an Adjunct to Scaling and Root Planing in the Treatment of Gingivitis. *Journal of Dental Research and Reviews*. 2023;10(4):247-50.
26. Ida MJ, Shetty B, Khan SF, Yadalam U, Nambiar M. Development and in vitro characterization of a mucoadhesive gel with *Moringa oleifera* extract for periodontal drug delivery. *Journal of Indian Society of Periodontology*. 2023;27(2):146-53.
27. Ahmad S, Manzoor K, Purwar R, Ikram S. Morphological and swelling potential evaluation of *moringa oleifera* gum/poly (vinyl alcohol) hydrogels as a superabsorbent. *ACS omega*. 2020;5(29):17955-61.
28. Sharma G, Setty S, GS K. Efficacy of *moringa oleifera* as a local drug delivery agent in the treatment of chronic periodontitis: A randomized controlled trial. *Journal of Orofacial and Health Sciences*. 2025;12(2):116-21.
29. Kumar J, Purwar R. Self-Healing, Biocompatible Injectable Hydrogel Based on Multialdehyde *Moringa oleifera* Gum and Carboxymethyl Chitosan: A Suitable Platform for Drug Delivery in Wound Healing Application. *ChemistrySelect*. 2024;9(9):e202400309.
30. Kurtulbaş E, Albarri R, Torun M, Şahin S. Encapsulation of *Moringa oleifera* leaf extract in chitosan-coated alginate microbeads produced by ionic gelation. *Food Bioscience*. 2022;50:102158.
31. Ansari S, Srivastava S, Yadav P, Parashar P. *Moringa oleifera*-Loaded Hydrogel: Assessment of Wound Healing Potential in an Animal Model. *Drug Delivery Letters*. 2025.

32. RAMAMURTHY SP, SEKAR P, ULAGANATHAN A, VARGHESE S. Formulation of In-situ Thermoreversible Gel with Moringa oleifera Lam Extract as a Local Drug Delivery System for Adjunct Periodontal Treatment. Journal of Clinical & Diagnostic Research. 2022;16(12).
33. Kabiru H, Ahmad K, Bello N, Paul S. Formulation and evaluation of in vitro antioxidant and antimicrobial activities of herbal hydrogel loaded with Moringa oleifera leaf extract. Science World Journal. 2023;18(1):101-5.
34. J. Hashim F, Vichitphan S, Boonsiri P, Vichitphan K. Neuroprotective assessment of Moringa oleifera leaves extract against oxidative-stress-induced cytotoxicity in SHSY5Y neuroblastoma cells. Plants. 2021;10(5):889.

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