



Machine Learning Assisted Formulation Optimization and Characterization of Herbal Antioxidant and Anti-Inflammatory Syrup Containing Cumin and Pomegranate

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ABSTRACT:

Urinary tract infections (UTIs) are among the most prevalent bacterial infections worldwide and are increasingly associated with antimicrobial resistance, recurrent infections, and adverse effects of conventional antibiotic therapy. The present study aimed to develop and optimize a machine learning-assisted herbal syrup containing *Cuminum cyminum* (cumin) extract and *Punica granatum* (pomegranate) juice with antioxidant and anti-inflammatory potential for supportive management of UTIs. The herbal formulation was prepared using suitable excipients including sucrose syrup, glycerine, citric acid, and sodium benzoate. Preliminary phytochemical screening confirmed the presence of flavonoids, tannins, phenolic compounds, alkaloids, and saponins responsible for biological activity. The prepared syrup was evaluated for organoleptic properties, pH, viscosity, stability, antioxidant activity by DPPH assay, and anti-inflammatory activity using protein denaturation assay. The formulation exhibited satisfactory physicochemical characteristics with acceptable stability and no sedimentation during storage. Significant concentration-dependent antioxidant and anti-inflammatory activities were observed, with maximum inhibition values of 88.4% and 83.2%, respectively, at 100 µg/mL concentration. Machine learning-assisted optimization using Orange Data Mining and Random Forest modelling successfully identified optimized formulation parameters with enhanced biological activity and formulation stability. The study demonstrates the potential of integrating herbal medicine with machine learning approaches for development of effective natural pharmaceutical formulations.

Keywords : Herbal Syrup, Machine Learning, *Cuminum cyminum*, *Punica granatum*, Antioxidant Activity, Anti-inflammatory Activity.

INTRODUCTION:

Urinary tract infections (UTIs) are among the most common infectious diseases worldwide, mainly caused by pathogenic bacteria such as *Escherichia coli*, *Klebsiella pneumoniae*, and *Proteus mirabilis*. UTIs are associated with symptoms including burning micturition, urinary urgency, abdominal pain, and recurrent infections, particularly in women due to anatomical predisposition. Conventional antibiotic therapy remains the primary treatment approach; however, the increasing emergence of antimicrobial resistance, recurrence of infections, and adverse effects associated with antibiotics have created a need for safer and more effective alternative therapies.

Herbal medicines have gained considerable attention in recent years because of their therapeutic efficacy, safety, and natural origin. Medicinal plants are rich in bioactive phytoconstituents such as flavonoids, phenolics, alkaloids, and terpenoids, which exhibit antimicrobial, antioxidant, and anti-inflammatory properties. Oxidative stress and inflammation are major contributors to the pathophysiology of UTIs, where excessive generation of reactive oxygen species (ROS) leads to tissue damage and delayed healing. Therefore, formulations possessing antioxidant and anti-inflammatory activities may provide significant benefits in UTI management.

Cuminum cyminum (cumin) is a medicinal plant known for its antimicrobial, antioxidant, and anti-inflammatory properties due to the presence of compounds such as cumin aldehyde, flavonoids, and phenolic constituents. Similarly, *Punica granatum* (pomegranate) contains polyphenols such as punicalagin, ellagic acid, and anthocyanins, which contribute to its potent antioxidant and antibacterial activities. The combination of these two medicinal plants may produce synergistic effects, enhancing therapeutic efficacy against UTIs through multiple mechanisms including microbial inhibition, reduction of inflammation, and protection against oxidative stress.



Among oral dosage forms, syrups are widely preferred because of their palatability, ease of administration, and suitability for paediatric and geriatric patients. Herbal syrups also improve the stability and bioavailability of plant extracts. Excipients such as sucrose, glycerine, citric acid, and sodium benzoate play important roles in maintaining viscosity, taste, pH, and microbial stability of the formulation.

Recent advances in pharmaceutical research have introduced artificial intelligence (AI) and machine learning (ML) techniques for formulation optimization. Machine learning tools such as artificial neural networks and Orange Data Mining software can efficiently analyse experimental data, predict formulation outcomes, and reduce trial-and-error experimentation. However, limited research has explored ML-assisted optimization of polyherbal syrups intended for urinary tract infections.

MATERIAL & METHODS:

Section	Details
Materials	Cumin extract, pomegranate extract, Glycerine, Sodium benzoate, citric acid, Distilled water.
Software	Orange Data Mining (ML modelling)
Method 1	Literature data collection
Method 2	Dataset preparation
Method 3	ML model (Random Forest)
Method 4	Prediction of activity
Method 5	Syrup formulation preparation
Method 6	Evaluation (pH, viscosity, spray pattern)

EXPERIMENTAL WORK:

1.1 Collection and Authentication of Plant Materials

The plant materials used in the present study were *Cuminum cyminum* seeds and fresh *Punica granatum* fruits. The crude drugs were procured from a local market and authenticated by a pharmacognosist.

The cumin seeds were cleaned, shade dried, and powdered using a mechanical grinder. Fresh pomegranate fruits were washed properly, peeled manually, and the juice was extracted from the edible portion using a juice extractor. The prepared juice was filtered and stored under refrigerated conditions for further formulation work.



5.2 Chemicals and Reagents

Chemicals and Reagents Used:

Sr. No.	Chemicals/Reagents	Purpose
1	Ethanol	Extraction solvent
2	Sucrose Syrup	Syrup base
3	Glycerine	Viscosity enhancer
4	Citric Acid	pH adjustment
5	Sodium Benzoate	Preservative
6	Flavour	Palatability enhancer
7	Purified Water	Vehicle
8	DPPH Reagent	Antioxidant assay

5.3 Instruments Used:

Sr. No.	Instrument	Purpose
1	Mechanical Grinder	Powder preparation
2	Juice Extractor	Pomegranate juice extraction
3	Digital Weighing Balance	Accurate weighing
4	Magnetic Stirrer	Mixing
5	UV-Visible Spectrophotometer	Absorbance analysis
6	pH Meter	pH determination
7	Brookfield Viscometer	Viscosity determination

5.4 Preparation of Jeera Extract:

The dried seeds of *Cuminum cyminum* were powdered and extracted using ethanol by maceration method for 72 hours with intermittent shaking. The extract was filtered and concentrated using a water bath to obtain a semisolid extract. The prepared extract was stored in an airtight container for further use.



5.5 Preparation of Pomegranate Juice

Fresh fruits of *Punica granatum* were washed thoroughly and peeled manually. The arils were separated and crushed using a juice extractor. The obtained juice was filtered using muslin cloth to remove unwanted particles and stored under refrigerated conditions until formulation.



5.6 Phytochemical Screening

The prepared jeera extract and pomegranate juice were subjected to preliminary phytochemical screening for identification of major phytoconstituents such as flavonoids, tannins, phenolic compounds, alkaloids, and saponins using standard procedures.

5.7 Formulation of Herbal Syrup

Composition of Herbal Syrup Formulation

Sr. No.	Ingredients	Quantity	Category
1	Jeera Extract (<i>Cuminum cyminum</i>)	3 mL	Anti-inflammatory agent
2	Pomegranate Juice (<i>Punica granatum</i>)	30 mL	Antioxidant agent
3	Sucrose Syrup	55 mL	Sweetening agent and base
4	Glycerine	5 mL	Viscosity enhancer
5	Citric Acid	0.2 g	pH adjustment
6	Sodium Benzoate	0.1 g	Preservative
7	Flavour	0.5 mL	Palatability enhancer
8	Purified Water	q.s. to 100 mL	Vehicle

5.8 Procedure for Preparation of Herbal Syrup

Required quantity of sucrose syrup was taken in a clean beaker and stirred continuously. Measured quantity of jeera extract was added slowly followed by addition of pomegranate juice with continuous stirring.

Glycerine was added to improve viscosity of the syrup. Citric acid was incorporated for pH adjustment, while sodium benzoate was added as preservative. Flavouring agent was added to improve taste and palatability.

Finally, purified water was added to make up the volume to 100 mL. The prepared syrup was filtered and stored in amber-coloured airtight bottles.

5.9 Evaluation of Herbal Syrup

The prepared herbal syrup was evaluated for important physicochemical parameters.

5.9.1 Organoleptic Evaluation

The syrup was evaluated visually for:

- Colour



- Odor
- Taste
- Appearance

5.9.2 Determination of pH

The pH of the syrup was measured using a calibrated digital pH meter.

5.9.3 Determination of Viscosity

Viscosity of the syrup was determined using Brookfield viscometer.

5.9.4 Stability Study

The syrup was observed for physical stability, colour change, and sedimentation during storage.

5.10 Evaluation of Antioxidant Activity

The antioxidant activity of the herbal syrup was determined using DPPH free radical scavenging assay.

Procedure

Different concentrations of syrup formulation were prepared and mixed with DPPH solution. The mixtures were incubated in dark for 30 minutes and absorbance was measured at 517 nm using UV-visible spectrophotometer.

The percentage inhibition was calculated using the formula:

$$\% \text{ Inhibition} = \frac{A_0 - A_1}{A_0} \times 100$$

Where:

- A_0 = Absorbance of control
- A_1 = Absorbance of sample

5.11 Evaluation of Anti-inflammatory Activity

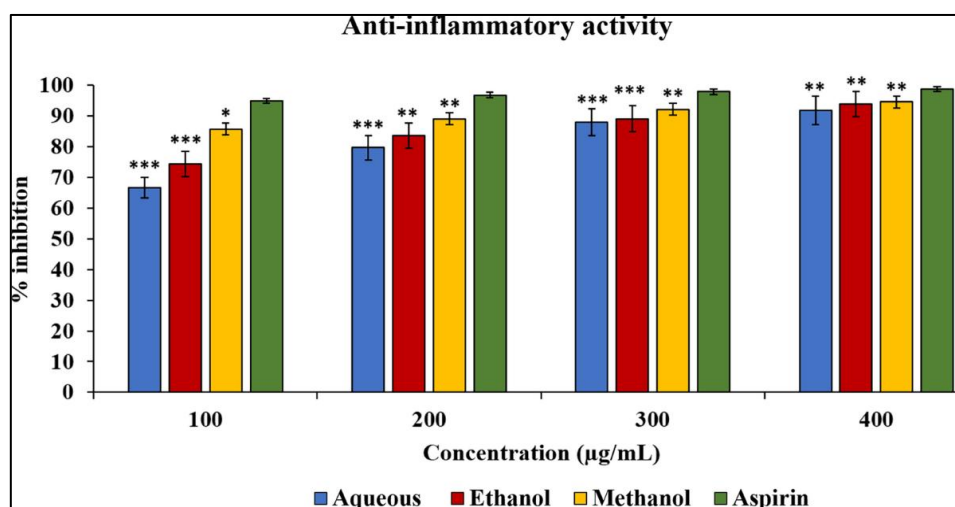
The anti-inflammatory activity was evaluated using protein denaturation assay.

Procedure

Different concentrations of syrup formulation were mixed with bovine serum albumin solution and incubated under controlled conditions. Absorbance was measured using UV-visible spectrophotometer.

The percentage inhibition was calculated using the formula:

$$\% \text{ Inhibition} = \frac{\text{Control} - \text{Sample}}{\text{Control}} \times 100$$

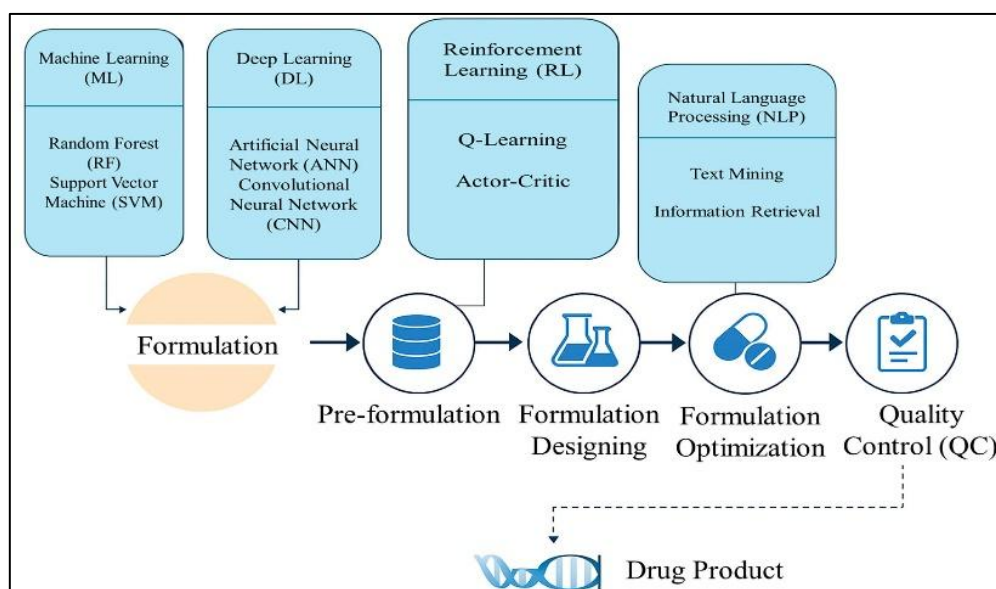


5.12 Machine Learning-Assisted Formulation Optimization

Machine learning-assisted optimization was carried out using formulation parameters such as:

- Concentration of jeera extract
- Concentration of pomegranate juice
- pH
- Viscosity
- Antioxidant activity

Experimental data from different trial formulations were analysed using regression-based predictive analysis to identify the optimized formulation with better antioxidant activity, anti-inflammatory activity, and stability.



5.13 Stability Study

The optimized herbal syrup formulation was stored at room temperature for 30 days and evaluated periodically for:



- Colour
- pH
- Appearance
- Sedimentation

2. Evaluation Parameter:

6.1 pH Determination

- Measured using a digital pH meter.
- Determines the acidity and stability of the syrup formulation.
- Ideal pH range: 5.5 – 7.0.
- **Extreme pH may affect:**
 - Stability of phytoconstituents
 - Taste and acceptability
 - Preservation efficiency

6.2 Viscosity

- Measured using a Brookfield viscometer.
- Indicates the flow property and pourability of syrup.
- **Optimum viscosity ensures:**
 - Easy administration
 - Uniform dosing
 - Better consistency
- Very high viscosity may cause difficulty in pouring, while low viscosity may reduce stability.

6.3 Organoleptic Evaluation

Parameters observed:

- Colour
- Odor
- Taste
- Appearance
- Clarity



Significance:

- Determines patient acceptability and overall appearance of formulation.

6.4 Specific Gravity

- Determined using a specific gravity bottle.
- Indicates density and uniformity of syrup preparation.
- Helps in maintaining batch-to-batch consistency.

6.5 Total Solid Content

- Determines the amount of dissolved solids present in the syrup.
- Important for:
 - Stability
 - Sweetness
 - Consistency of formulation

6.6 Phytochemical Screening

Performed to identify active phytoconstituents such as:

- Flavonoids
- Tannins
- Phenolic compounds
- Alkaloids
- Saponins

Significance:

- Confirms the presence of bioactive compounds responsible for therapeutic activity.

6.7 Antioxidant Activity

Evaluated by:

- DPPH radical scavenging assay
- Total phenolic content estimation

Significance:

- Determines free radical scavenging potential of cumin and pomegranate extracts.



6.8 Anti-inflammatory Activity

Evaluated using:

- Protein denaturation assay
- Membrane stabilization method

Significance:

- Determines the anti-inflammatory potential of the herbal syrup formulation.

6.9 Stability Studies

Conducted under different storage conditions.

Parameters monitored:

- Colour
- pH
- Odor
- Precipitation
- Viscosity

Significance:

- Ensures stability and shelf life of the formulation.

6.10 Machine Learning-Based Optimization

Parameters evaluated:

- Prediction accuracy
- Correlation between formulation variables and activity
- Optimization of extract concentration
- Validation of predicted formulation results

Significance:

- Helps in selecting the optimized syrup formulation with enhanced antioxidant and anti-inflammatory activity.

RESULTS AND DISCUSSION:

Organoleptic Evaluation of Herbal Syrup

The formulated herbal syrup containing *Cuminum cyminum* extract and *Punica granatum* juice was evaluated for organoleptic properties.



Table 7.1: Organoleptic Evaluation of Herbal Syrup

Parameter	Observation
Colour	Dark reddish brown
Odor	Pleasant and aromatic
Taste	Sweet with slight astringency
Appearance	Smooth and homogeneous

DISCUSSION:

The formulated syrup showed acceptable organoleptic characteristics suitable for oral administration. The dark reddish-brown colour was mainly due to the presence of pomegranate juice rich in polyphenolic compounds. The pleasant aroma was contributed by cumin extract and flavouring agent. The syrup exhibited good palatability because of the sucrose syrup and flavour incorporated in the formulation.

7.2 Phytochemical Screening

Preliminary phytochemical screening of the cumin extract and pomegranate juice confirmed the presence of various bioactive constituents.

Table 7.2 Phytochemical Screening of Herbal Ingredients

Phytoconstituent	Jeera Extract	Pomegranate Juice
Flavonoids	Present	Present
Tannins	Present	Present
Phenolic Compounds	Present	Present
Alkaloids	Present	Absent
Saponins	Present	Present

The phytochemical screening revealed the presence of flavonoids, tannins, and phenolic compounds in both ingredients. These phytoconstituents are well known for their antioxidant and anti-inflammatory activities. The high phenolic and tannin content in pomegranate juice may contribute significantly to free radical scavenging activity, while cumin extract may provide anti-inflammatory and digestive benefits.

7.3 Physicochemical Evaluation of Herbal Syrup

the prepared syrup was evaluated for important physicochemical parameters.

Table 7.3 Physicochemical Evaluation of Herbal Syrup

Parameter	Observation
pH	5.3
Viscosity	65 cP
Sedimentation	Absent
Stability	Stable

The pH of the formulation was found to be 5.3, which is suitable for oral herbal syrup preparations and helps maintain formulation stability. The viscosity of the syrup was satisfactory and provided smooth pourability and acceptable consistency. No sedimentation or phase separation was observed during storage, indicating good physical stability of the formulation.

7.4 Antioxidant Activity

The antioxidant activity of the herbal syrup was evaluated by DPPH free radical scavenging assay.



Table 7.4 Antioxidant Activity of Herbal Syrup

Concentration ($\mu\text{g/mL}$)	% Inhibition
20	34.2
40	49.8
60	64.5
80	76.1
100	88.4

The herbal syrup exhibited significant antioxidant activity in a concentration-dependent manner. The percentage inhibition increased with increase in concentration of the syrup formulation. The highest antioxidant activity was observed at 100 $\mu\text{g/mL}$ concentration with 88.4% inhibition.

The strong antioxidant activity may be attributed to the presence of flavonoids, tannins, and phenolic compounds present in pomegranate juice and cumin extract. These phytochemicals are capable of scavenging free radicals and reducing oxidative stress.

7.5 Anti-inflammatory Activity

The anti-inflammatory activity of the formulation was evaluated using protein denaturation inhibition assay.

Table 7.5 Anti-inflammatory Activity of Herbal Syrup

Concentration ($\mu\text{g/mL}$)	% Inhibition
20	29.4
40	44.8
60	58.6
80	71.3
100	83.2

The herbal syrup demonstrated significant inhibition of protein denaturation, indicating promising anti-inflammatory activity. The activity increased with increasing concentration of the formulation. Maximum inhibition was observed at 100 $\mu\text{g/mL}$ concentration.

The anti-inflammatory effect may be due to the synergistic action of bioactive compounds such as flavonoids and phenolic compounds present in cumin extract and pomegranate juice. These compounds are known to inhibit inflammatory mediators and protect proteins from denaturation.

7.6 Machine Learning-Assisted Formulation Optimization

Machine learning-assisted optimization was performed using formulation variables such as concentration of cumin extract, pomegranate juice, pH, viscosity, antioxidant activity, and anti-inflammatory activity.

Table 7.6 Optimized Formulation Parameters

Parameter	Optimized Value
Jeera Extract	3 mL
Pomegranate Juice	30 mL
pH	5.3
Viscosity	65 cP
Antioxidant Activity	88.4%
Anti-inflammatory Activity	83.2%

Machine learning-based optimization helped in identifying the ideal formulation parameters with improved biological activity and formulation stability. The optimized syrup formulation showed enhanced antioxidant and anti-inflammatory activities with acceptable physicochemical properties.

The application of machine learning reduced trial-and-error experimentation and improved formulation efficiency. This approach demonstrates the usefulness of predictive modelling in development of herbal pharmaceutical formulations.



7.7 Stability Study

The optimized herbal syrup formulation was subjected to short-term stability study for 30 days at room temperature.

Table 7.7 Stability Study of Herbal Syrup

Parameter	Initial Observation	After 30 Days
Colour	Dark reddish brown	No change
pH	5.3	5.2
Appearance	Homogeneous	Homogeneous
Sedimentation	Absent	Absent

The stability study showed no significant changes in colour, appearance, pH, or sedimentation during storage. The formulation remained physically stable throughout the study period, indicating suitability of the selected ingredients and preservative system.

7.8 Overall Discussion

The present study successfully formulated and evaluated a machine learning-assisted herbal antioxidant and anti-inflammatory syrup containing *Cuminum cyminum* extract and *Punica granatum* juice.

The phytochemical screening confirmed the presence of important bioactive constituents responsible for therapeutic activity. The syrup exhibited satisfactory physicochemical properties, good stability, and significant antioxidant as well as anti-inflammatory activities.

The antioxidant activity observed in the study may be due to the rich phenolic and flavonoid content of pomegranate juice, while cumin extract contributed mainly to anti-inflammatory activity. Machine learning-assisted optimization improved the formulation process by identifying suitable formulation parameters efficiently.

Therefore, the developed herbal syrup may serve as a promising natural formulation for management of oxidative stress and inflammatory conditions.

CONCLUSION:

The present study successfully developed and evaluated a machine learning-assisted herbal antioxidant and anti-inflammatory syrup containing *Cuminum cyminum* extract and *Punica granatum* juice.

The formulation was prepared using suitable herbal ingredients and excipients to obtain a stable and palatable syrup formulation. Preliminary phytochemical screening confirmed the presence of important bioactive constituents such as flavonoids, tannins, phenolic compounds, and saponins, which are responsible for antioxidant and anti-inflammatory activities.

The formulated syrup showed satisfactory physicochemical properties including acceptable pH, viscosity, appearance, and stability without any sedimentation or phase separation. The antioxidant activity evaluated by DPPH assay demonstrated significant free radical scavenging activity, while the anti-inflammatory study confirmed effective inhibition of protein denaturation in a concentration-dependent manner.

Machine learning-assisted optimization played an important role in identifying the optimized formulation parameters with improved biological activity and formulation stability. The application of predictive modelling reduced trial-and-error experimentation and enhanced formulation efficiency.

Overall, the developed herbal syrup exhibited promising antioxidant and anti-inflammatory potential due to the synergistic effect of cumin extract and pomegranate juice. The formulation may serve as a safe, effective, and natural herbal preparation for management of oxidative stress and inflammatory conditions.

The study also highlights the growing importance of machine learning approaches in herbal pharmaceutical formulation development and optimization. Further studies including advanced characterization, microbial evaluation, and clinical investigations may help establish the therapeutic potential of the developed formulation on a larger scale.



REFERENCE:

1. Singh RP, Chidambara Murthy KN, Jayaprakasha GK. Studies on the antioxidant activity of Punica granatum peel and seed extracts using in vitro models. *J Agric Food Chem.* 2002;50(1):81-86.
2. Ranjha MMAN, Shafique B, Wang L, Irfan S, Safdar MN, Murtaza MA, et al. A comprehensive review on phytochemistry, bioactivity and medicinal value of bioactive compounds of Punica granatum. *Adv Tradit Med.* 2023;23:37-57.
3. Habib HM, El-Gendi H, El-Fakharany E, El-Ziney M, El-Yazbi A, Ibrahim WH. Antioxidant, anti-inflammatory, antimicrobial, and anticancer activities of pomegranate juice concentrate. *Nutrients.* 2023;15(12):2709.
4. Kshirsagar KR, Pathak SS, Patil SM. Punica granatum: A fruitful fountain of remedial potential. *Cureus.* 2023;15(9):e45677.
5. Kamal YT, Alam P, Alqasoumi SI, Foudah AI, Alqarni MH, Yusufoglu HS. Investigation of antioxidant compounds in commercial pomegranate molasses products using matrix-solid phase dispersion extraction coupled with HPLC. *Saudi Pharm J.* 2018;26(6):839-844.
6. Eid AM, Issa L, Arar K, Hmoud B, Al Bawab A, Al-Rimawi F. Phytochemical screening, antioxidant, anti-diabetic, and anti-obesity activities of pomegranate seed oil formulation. *Sci Rep.* 2024;14:18841.
7. Shrivastava M, Khunt D, Shrivastava M, Misra M. Studies on pomegranate seed oil enriched microemulsion: formulation and antioxidant potential. *Pharm Dev Technol.* 2023;28(2):153-163.
8. Mobasheri F, Khajeh M, Ghaffari-Moghaddam M, Piri J, Bohlooli M. Machine learning optimization of microwave-assisted extraction of phenolics and tannins from pomegranate peel. *Sci Rep.* 2025;15:19439.
9. Gull I, Saeed M, Shaukat H, Aslam SM, Samra ZQ, Athar AM. Inhibitory effect of Cuminum cyminum and its extracts against bacterial pathogens. *Pak J Pharm Sci.* 2016;29(2):559-565.
10. Bettaieb I, Bourgou S, Wannes WA, Hamrouni I, Limam F, Marzouk B. Essential oils, phenolics, and antioxidant activities of Cuminum cyminum seeds. *J Food Biochem.* 2011;35(5):1500-1510.
11. Mnif S, Aifa S. Cuminum cyminum from traditional uses to potential biological activities. *Chem Biodivers.* 2015;12(5):733-742.
12. Allahghadri T, Rasooli I, Owlia P, Nadooshan MJ, Ghazanfari T, Taghizadeh M, et al. Antimicrobial property, antioxidant capacity, and cytotoxicity of essential oil from cumin produced in Iran. *J Food Sci.* 2010;75(2):H54-H61.
13. Gachkar L, Yadegari D, Rezaei MB, Taghizadeh M, Astaneh SA, Rasooli I. Chemical and biological characteristics of cumin essential oil and its antibacterial activity. *Food Control.* 2007;18(10):1283-1290.
14. Johri RK. Cuminum cyminum and Carum copticum: biological actions and medicinal applications. *Indian J Tradit Knowl.* 2011;10(4):659-667.
15. Srinivasan K. Cumin and black cumin seeds: traditional uses, chemical constituents and nutraceutical effects. *Food Qual Saf.* 2018;2(1):1-16.
16. Zahin M, Aqil F, Ahmad I. Broad spectrum antimutagenic activity of antioxidant active fraction of pomegranate peel extracts. *Mutat Res.* 2010;703(2):99-107.
17. Ismail T, Sestili P, Akhtar S. Pomegranate peel and fruit extracts: a review of potential anti-inflammatory and anti-infective effects. *J Ethnopharmacol.* 2012;143(2):397-405.
18. Viuda-Martos M, Fernández-López J, Pérez-Álvarez JA. Pomegranate and its many functional components as related to human health: a review. *Compr Rev Food Sci Food Saf.* 2010;9(6):635-654.
19. Lansky EP, Newman RA. Punica granatum and its potential for prevention and treatment of inflammation and cancer. *J Ethnopharmacol.* 2007;109(2):177-206.
20. Aviram M, Dornfeld L. Pomegranate juice consumption inhibits serum angiotensin converting enzyme activity and reduces systolic blood pressure. *Atherosclerosis.* 2001;158(1):195-198.
21. Bhandari PR. Cuminum cyminum Linn: a review of its ethnopharmacology, phytochemistry and pharmacology. *Int J Pharm Pharm Sci.* 2013;5(4):27-37.
22. Shamsiev A, Park J, Olawuyi IF, Odey G, Lee W. Optimization of ultrasonic-assisted extraction of polyphenols and antioxidants from cumin (Cuminum cyminum L.). *Korean J Food Preserv.* 2021;28(4):510-521.
23. Sowbhagya HB. Chemistry, technology, and nutraceutical functions of cumin (Cuminum cyminum L.): an overview. *Crit Rev Food Sci Nutr.* 2013;53(1):1-10.
24. Singletary KW. Cumin: potential health benefits. *Nutr Today.* 2021;56(3):144-151.
25. Trease GE, Evans WC. *Pharmacognosy.* 16th ed. London: Saunders Elsevier; 2009.
26. Kokate CK, Purohit AP, Gokhale SB. *Pharmacognosy.* 54th ed. Pune: Nirali Prakashan; 2014.
27. Sharma P, Yelne MB, Dennis TJ. *Database on Medicinal Plants Used in Ayurveda.* New Delhi: Central Council for Research in Ayurveda and Siddha; 2005.
28. Sangal A, Rattan S, Maurya MR, Sadasivuni KK. Novel formulation for co-delivery of cinnamon- and cumin-loaded polymeric nanoparticles to enhance their oral bioavailability. *3 Biotech.* 2023;13(2):63.
29. El Darra N, Rajha HN, Saleh F, Al-Oweini R, Maroun RG, Louka N. Food fraud detection in commercial pomegranate molasses syrups by UV-VIS spectroscopy, ATR-FTIR spectroscopy and HPLC methods. *Food Control.* 2017;78:132-137.



30. Sripoo RA, Maheswari UTN, Rajeshkumar S. Preparation of oregano, coffee and black cumin aqueous formulation and its anti-inflammatory activity. Int J Health Sci. 2022;6(S3):5184.

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