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Formulation and Evaluation of Anti-Inflammatory Herbal Hydrogel Containing Carissa Carandas Leaves Extract and Curcuma Amada Rhizomes Extract

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Abstract:

Inflammation is a fundamental physiological response triggered by tissue injury, infection or irritation, often characterized by redness, swelling, pain and loss of function. Although the widespread use of traditional anti-inflammatory medications, long term use may have negative consequences, underscoring the need for safer and more potent substitutes. The current research attempted to create and assess an herbal anti-inflammatory hydrogel using ethanolic extracts of the rhizomes of Curcuma Amada and the Carissa Carandas leaves. The anti-inflammatory and antioxidant qualities of these medicinal plants are attributed to their abundance of bioactive phytoconstituents, including flavonoids, phenolic compounds alkaloids and terpenoids. To improve topical distribution and patient compliance, the extracts were produced by cold maceration using ethanol and then added to a hydrogel foundation made using Carbopol 940 and Hydroxypropyl Methylcellulose (HPMC). Numerous physicochemical criteria, such as pH, viscosity, spreadability, extrudability, homogeneity, washability and skin irritation, were assessed for the produced formulations. According to the findings, every formulation showed respectable stability and topical application appropriateness. Batch B5 exceeded the other batches, exhibiting ideal pH, greater spreadability and desired extrudability. The hydrogel had a smooth, non-gritty texture was easily cleaned and showed no symptoms of irritation. Because of its natural composition, low risk of side effects and high patient compliance, the created herbal hydrogel exhibits great potential as a safe and effective substitute for traditional anti-inflammatory treatments. Its therapeutic efficacy, stability and convenience of use point to the necessity for more thorough research, including sophisticated pharmacological and clinical studies.

Key words: topical drug delivery system; hydrogel; anti-inflammatory; carissa carandas leaves; curcuma amada rhizomes

Introduction:

Inflammation is the body's protective immune reaction to either acute or chronic injury. The painful sensory and effective experience that result from actual tissue damage or the possibility of such damage is generally referred to as pain. It can also be defined in connection with the injury. It is indicated by swelling and fluid accumulation in the wounded area, as well as accumulation of white blood cells and antibodies at the site of injury [1]. Pain and inflammation are closely related biological processes that involve some mechanisms like denaturation of proteins and increased vascular permeability. By minimizing drug breakdown from metabolism and enzymatic activity and enabling the drug permeates deeper epidermal layers; topical drug administration offers localized therapeutic action that improves treatment efficacy [2].

Around the world, inflammatory illnesses are common, particularly among the elderly population. One of the most typical inflammatory arthritic disorders affecting the elderly is gout. It arises as an indication of metabolic imbalance, specifically hyperuricemia, or increased blood uric acid

levels. Monosodium urate crystals are created in the joints when uric acid builds up, causing discomfort, swelling and inflammation [3]. There are mainly two types of inflammation that is acute and chronic. Acute inflammation it is a short-term inflammation like a redness, swelling, heat, pain, etc. and chronic inflammation it is a long-term response of body with causing tissue damage, fibrosis, macrophages and lymphocytes [4]. Inflammation is an effect of wide range of undesirable triggers that destroy tissue homeostasis. Physical, chemical, biochemical, immunological, ischemic and foreign body related factors are among the main reasons [5].

Currently, a range of topical dosage forms are used to treat inflammatory disorders; hydrogels are especially favored because of their ease of use, improved patient compliance and capacity to produce long-lasting and targeted therapeutic effects. Because of these benefits, hydrogels are a very effective and appropriate method for topical medication delivery. Natural and synthetic polymers are incorporated to create hydrogels, which are semisolid preparations that act as three- dimensional gelling networks. Hydrogels have drawn a lot of interest in applications linked to food, cosmetics and pharmaceuticals because of their high-water affinity, superior biocompatibility and ability to release drug release over an extended period of time [2].

Many synthetic medications are used as traditional therapies for inflammation; however, these medications have adverse reactions that can make effective therapy more difficult, which makes the usage of herbal plants more likely. Medicinal plants have long been used to treat inflammation, which is a major pathological process implicated in many acute and chronic illnesses.

Carissa Carandas, a flowering shrub in the Apocynaceae family, has considerable medicinal benefits. The leaves are one of the plants many sections that have been shown to have anti-inflammatory and wound healing properties. In addition to their well-known antipyretic and antioxidant qualities, Carissa Carandas (Karonda) leaves have been widely used in traditional medical systems like Ayurveda and homeopathy because of these advantageous qualities [4]. Carbohydrates, saponins, alkaloids (carissamine), phenolic compounds (like gallic acid), steroids (stigmasterol), glycosides, protiens, cardiac glycosides (carandiol) and triterpenoids (oleanolic acid, betulinic acid, ursolic acid, carissic acid methyl ester and carissic acid monoacetate) are among the many phytoconstiyuents and active compounds found in Carissa Carandas leaves [6].

A major spice crop, mango ginger (Curcuma Amada) is a member of the zingiberaceae family. Mangifera indica is a perennial herb that looks a lot like ginger (Zingiber officinale) but has a distinct flavor similar to raw mango. Because of its many pharmalogical qualities, mango ginger rhizomes are used extensively in Ayurvedic and Unani medical systems. The rhizome is traditionally used to treat bronchitis, asthma and a variety of skin conditions. It is significant for its strong anti-inflammatory properties as well as its appetizer, laxative, expectorant and wound healing properties [7]. Numerous phytoconstituents can be found in the rhiozmes of Curcuma amada rhisiome. Flavonoids, volatile oils (terpenoids, of which camphor, myrcene, ocimene, amadannulen and amadaldehyde are major components), tannins, steroids, alkaloids and glycosides as well as phenolic compounds (curcuminoids and phenolic acid) and rhizomes are said to contain compounds like cis-hydro-ocimene, trans-hydro-ocimene, α-longipinene, linalool, β-curcumene, turmerone, curcumin, amadaldehyde, β-asarone caffeic acid, gentisic acid, ferulic acid, gallic acid and cinnamic acid [8].

Materials and Methods:

Collection, authentication and extraction: The Leaves of Carissa Carandas were collected from the college campus located in the Konkan region. Fresh rhizomes of Curcuma Amada were collected from the college campus located in the Konkan region during December to January. Both the collected plant samples were authenticated at Shri Pancham Khemraj Mahavidyalaya, Sawantwadi, and Maharashtra. Both the collected plant materials were shade dried at room temperature.

Figure 1: *Fresh Leaves were collected*

Figure 2: *Dried Leaves were collected*

Figure 3: *Fresh Rhizomes were collected*

Figure 4: *Dried Rhizomes were collected*

Extraction Procedure: Ethanolic cold maceration is a simple and effective method to extract of phytoconstituents from Carissa Carandas leaves and Curcuma Amada rhizomes. This shade-dried, finely powdered leaves and rhizomes soaked in ethanol at a 1:10 (w/v) ratio and kept at room temperature usually in dark place with occasionally stirring for 48-72 hours. Both extract are filtered, and residue was remacerated. All filtrates was cooled and evaporate under reduce pressure at temperature below 40°C to obtained a concentrated extract. Those both extracts are stored in amber-colored containers in refrigerator [9,10].

Maceration process of plant material in solvent for extraction:

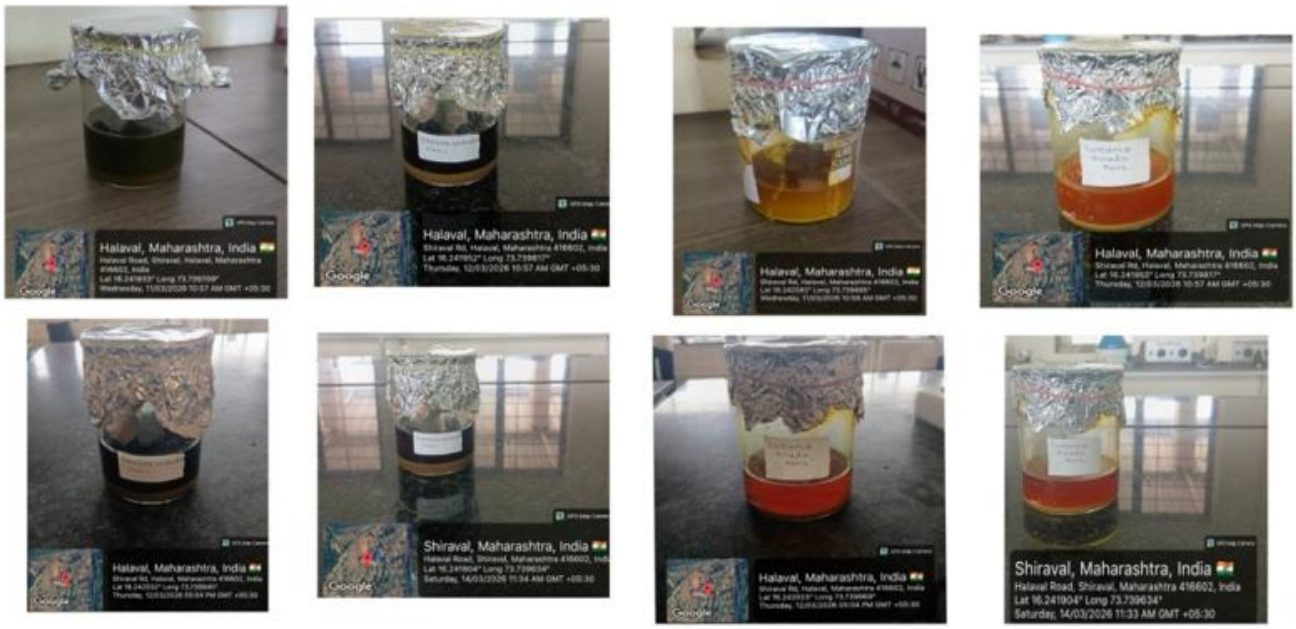


Figure 5. Carissa carandas leaves

Figure 6. Curcuma Amada Rhizomes

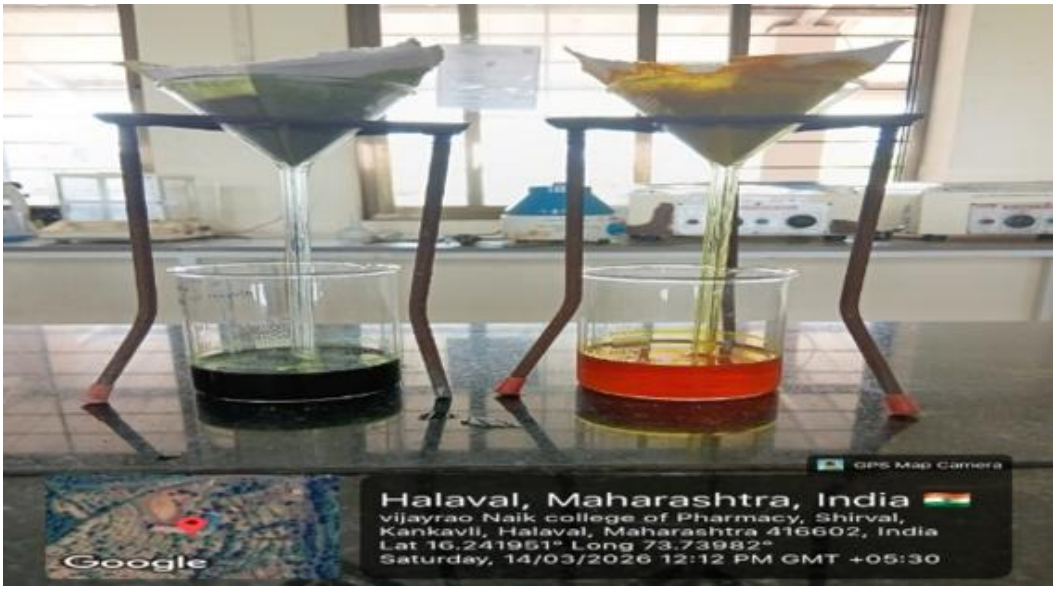


Figure 7: ***Extracts of both plants***

Materials and instrumentation:

Carbopol 940 was purchased from BFC Laboratory, Bangalore, India. Tasmanian blue gum oil was purchased from AVA International Pvt. Ltd., India.) HPMC (Hydroxypropyl methylcellulose), glycerine, methyl paraben, propyl paraben, and triethanolamine (TEA) were obtained from the college laboratory.

Weighing balance, pH meter, magnetic stirrer, transmission electron microscope, refrigerator, humidity chamber, ultra sonicator, hot air oven, thermometer, Brookfield viscometer, and UV–Visible spectroscopy. These instruments were utilized for formulation development, characterization, and evaluation of the prepared samples.

Preformulation Study:

Preformulation is defined as the investigation of the chemical and physical properties of a drug's active ingredient, both alone and when combined with excipients. To develop an effective and optimal drug delivery system, the physicochemical characteristics of the drug substance are established using biopharmaceutical concepts during the preformulation stage. In this process, thorough research is carried out before the development of other dosage forms. As the saying goes, "A step taken in advance prevents many steps backward." Similarly, conducting proper preformulation studies for a new product helps prevent potential failures and complications at later stages of development [11].

Sr No.	Phytoconstituents	Test	Procedure	Observation
1	Alkaloids	Mayer's test	Few mL extract + 1-2 drops of Mayer's reagent (Along the sides of test tube)	Creamy white/yellow precipitate
		Dragendroff's test	Few mL extract + 1-2 mL	Reddish-brown precipitate
2	Flavonoids	Alkaline Reagent Test (NaOH Test)	Add a few drops of sodium hydroxide solution to the plant extract.	yellow color that becomes colorless after adding dilute acid
4	Terpinoides	Salkowski's test	2ml chloroform + 5mL plant extract, (evaporated on water bath) + 3mL conc. H2SO4 (boiled on water bath)	Reddish brown Color
5	Cardiac glycosides	Keller-Killani test	1mL filtrate + 1.5mL glacial acetic acid + 1 drop of 5% ferric chloride + conc. H2SO4 (along the side of test tube)	Brown ring at interference with bluish green upper layer
6	Phenolic compounds	Ferric Chloride Test	Extract aqueous solution + few drops 5% ferric chloride sol.	Blue black / green colour

7	Saponin	Foam Test	Shake extract with 10 ml distilled water for and let stand 15–30 sec 10 min.	Formation of persistent foam (1 cm or more)

Table 1: *Carissa Carandas Leaves Extract Phytochemicals Test*

Sr No.	Phytoconstituents	Test	Procedure	Observation
	Alkaloids	Mayer's test	Few mL extract + 1-2 drops of Mayer's reagent (Along the sides of test tube)	Creamy white/yellow precipitate
		Dragendroff's test	Few mL extract + 1-2 mL	Reddish-brown precipitate
1	Phenolic compounds	Ferric chloride test	Extract aqueous solution + few drops 5% ferric chloride sol.	Dark green/bluish black colour
		Lead acetate test	Plant extract is dissolved in 5mL distilled water + 3mL of 10% lead acetate sol.	A white bulky precipitate
	Curcuminoids	Alkaline reagent test (NaOH test)	Add a few drops of sodium hydroxide (NaOH) solution to 2–3 mL of the extract.	yellow to reddish-brown color appears
	Flavonoids	Shinoda Test	To 2–3 mL of the plant extract, add a small piece of magnesium ribbon followed by a few drops of concentrated hydrochloric acid.	pink, crimson red, or orange color
	Volatile oil	Filter Paper Test	A drop of oil on filter paper evaporates completely	Fixed oils leave a permanent greasy stain.
	Terpinoids	Salkowski's Test	2ml chloroform + 5mL plant extract, (evaporated on water bath) + 3mL conc. H2SO4 (boiled on water bath)	Reddish-brown color

Table 2: *Curcuma Amada Rhizomes Extract Phytochemicals Test [12]*

Solubility Studies:

Solubility is defined as the ability of a substance to dissolve in a specified quantity of solvent at a given temperature and pressure, as per the Indian Pharmacopoeia (IP). The solubility study of dried powdered leaves of Carissa Carandas and rhizomes of Curcuma Amada was carried out using 1 mg of each sample suspended in various solvents. The mixtures were shaken for 2 hours at room temperature. Crude solubility was assessed by visual inspection for clarity and presence of undissolved particles. The observed solubility profile of the drug was recorded and presented in tabulated form.

Method of preparation of Hydrogel:

INGREDIENTS	Formulation Batches (gm)				
	B1	B2	B3	B4	B5
Carissa Carandas leaves extract	0.67(ml)	0.67(ml)	0.67(ml)	0.67(ml)	0.67(ml)
Curcuma Amada rhizomes extract	0.33(ml)	0.33(ml)	0.33(ml)	0.33(ml)	0.33(ml)
Carbopol 940	0.18	0.22	0.24	0.26	0.28
Hydroxypropyl methylcellulose (HPMC)	0.16	0.20	0.22	0.26	0.26
Glycerine	1.24(ml)	1.24(ml)	1.24(ml)	1.24(ml)	1.24(ml)
Propylene glycol	1.6(ml)	1.6(ml)	1.6(ml)	1.6(ml)	1.6(ml)
Methyl paraben	0.03	0.04	0.04	0.04	0.04
Propyl paraben	0.04	0.04	0.04	0.04	0.04
Triethanolamine (TEA)	0.14(ml)	0.14(ml)	0.14(ml)	0.14(ml)	0.14(ml)
Tasmanian blue gum oil	q. s	q.s	q. s	q. s	q. s
Distilled Water	q.s	q.s	q.s	q.s	q.s

Table 3: *Formulation Table [13]*

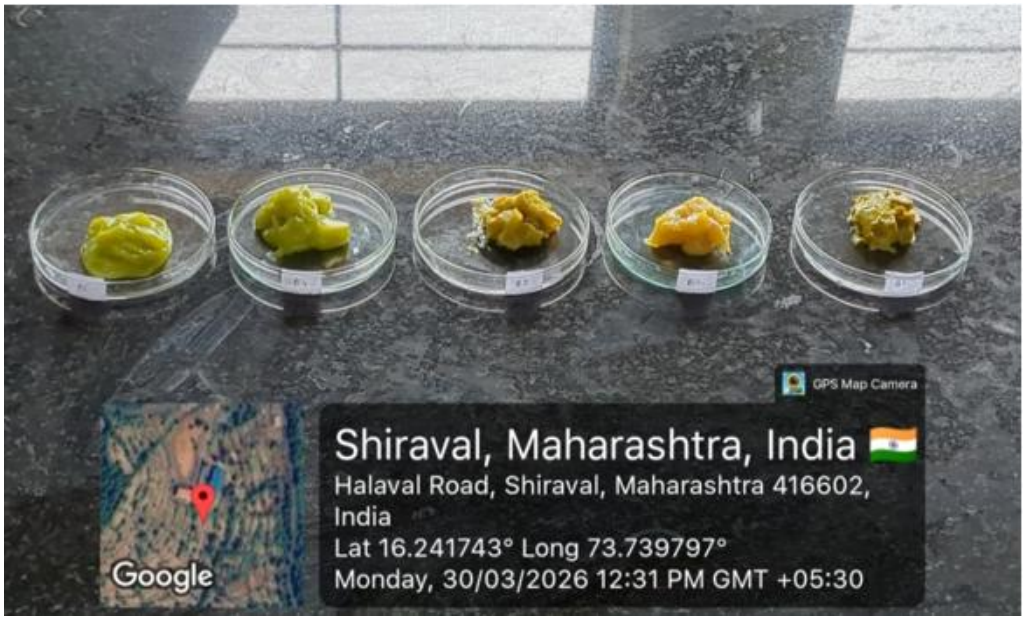


Figure 8: *Formulation Batches*

Procedure:

The hydrogel base was prepared by using polymer dispersion and neutralization method. Carbopol 940 and HPMC were dispersed in small amount of distilled water. The dispersion was allowed to hydrate and swell for 24 hours at room temperature (Solution A). Methyl paraben and propyl paraben were dissolved in warm water (solution B). Then addition of glycerin and Tasmanian blue gum oil and mixture was blended uniformly (Solution C). Herbal extract of Carissa Carandas leaves and Curcuma Amada rhizomes were dissolved in propylene glycol (solution D). After solution B cooled, the solution C was mixed with solution B with continuous stirring. Then this combined solution B+C and solution D mixture was gradually added to gel base (Solution A) and triethanolamine was added drop wise to neutralize the polymer dispersion to neutralize the polymer dispersion and adjust the pH to 4.5-5.5. Final the remaining distilled water was added to achieve the final weight and the hydrogel was mixed thoroughly to obtain a uniform polymeric gel. The prepared hydrogel was filled into clean and air tight container. And stored in cool dry and light protected environment for further use [14].

Evaluation Parameters of hydrogel:

1. **Organoleptic Evaluation:** The color and texture of the formulation were evaluated visually.

2. **Measurement of pH:** The pH meter was switched on and calibrated by using standard buffer solutions. And the sample was taken in the clean beaker and the electrode place into this sample beaker. Once the readings stabilized, pH of gel was noted.

3. **Viscosity Determination:** The hydrogel sample was transferred into a clean beaker and allowed to stand at room temperature and air bubbles were removed. A suitable spindle was immersed properly without touching the sides. The viscometer was set at 10-20 rpm. After stabilization, the viscosity was recorded in centipoise. Three readings were taken and the average value was recorded for accuracy.

4. **Determination of Spredability:** About 1 g of sample was placed on a glass slide, and another slide was gently placed on top. A 500 g weight was kept over it for one minute to ensure uniform spreading. After removing the weight, a known weight was attached to the upper slide and the time taken to move a fixed distance was recorded in seconds.

Formula:

$$S = \frac{M \times L}{T} \quad \text{----------(1)}$$

Where:

S = Spread ability

M = Weight tied to upper slide (g)

L = Length moved by slide (cm)

T = Time taken (sec)

5. **Extrudability Study:** The extrudability test is to performed to check how easily the gel can be squeezed out from a tube. In this method 10 gm of gel was filled into an aluminum collapsible tube. The tube was placed manually using finger pressure and the amount of gel can came out was measured. The greater quantity of gel extruded indicates better extrudability of the formulation.

6. Grittiness: A light microscope was used to look at each formulation to see if any visible particles were present. The observations showed that the gel preparation met the necessary requirements for topical applications because it was absence of foreign particles and had no rough texture. All formulations were examined under a light microscope to check for the presence of any visible particulate matter. The observations revealed that the gel preparation was free from foreign particles and did not exhibit any gritty texture, thereby meeting the required criteria for topical formulations.

7. Skin irritation test: Three human volunteers participated in a skin irritancy test to determine whether the gel irritates their skin. A small region close to the wrist was covered with around 1 gram of gel. The site was then observed for any redness, irritation or any skin reaction and the observed data were recorded.

8. Stability studies: The prepared gel formulation was packed, labeled and stored in different conditions as per International Council for Harmonization of Technical Requirement for Pharmaceuticals for Human Use (ICH) guidelines for stability testing's. Samples were examined for changes in viscosity, drug content, pH and appearance at regular intervals. To assess the formulation overall stability observation were documented.

9. Determination of swelling index: After accurately measuring a specified amount of the sample (W0), it was immersed in distilled water for a certain period of time to allow for swelling. The sample was taken out after the allotted time any extra water was carefully rinsed off, and it was then weighed once more (W1). The gel's swelling index was then determined using the conventional formula and the recorded weights.

Formula:

$$\text{Swelling Index} = \frac{W1 - W0}{W0} \times 100 \quad \text{----------(2)}$$

Where:

W_0 = Initial weight

W_1 = Final swollen weight

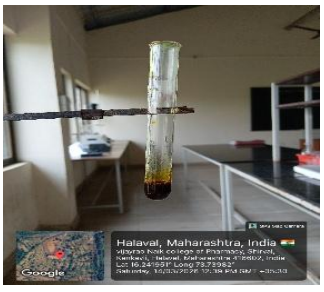
10. Wash ability: The wash ability test is carried out to check how easily the gel could be removed. A small amount of gel was applied on a glass slide and on a volunteer's skin, and then left for a few minutes. After that, a measured volume of water was used to wash the area, and it was noted if the gel was entirely removed or if any residue remained. Good wash ability was indicated by easy removal; whereas poor wash ability was indicated by any residue that remained.

11. Homogeneity study: The homogeneity of the hydrogel was evaluated to ensure that the drug was uniformly distributed throughout the gel. A small amount of the hydrogel was carefully taken on a clean glass slide and, separately, on the fingertip. Firstly, gel was examined with necked eye for any obvious defects like lumps or phase separation. The texture of the gel was lightly rubbing it between the fingertips. During this process, the gel was checked for smoothness, uniformity, and absence of any gritty particles or undissolved lumps. This examination was repeated 2–3 times at different spots of the gel to confirm consistent homogeneity throughout the formulation. All observations regarding texture, consistency, and uniformity were recorded systematically.

12. Drug Content: For the determination of drug content, a specified quantity of the prepared formulation was accurately weighed using a digital weighing balance and transferred into a volumetric flask. A suitable solvent (ethanol) was added, and the solution was subjected to sonication for a specific period to ensure complete dissolution of the drug. After complete dissolution, the volume was made up to the mark with the same solvent and mixed thoroughly. The resulting solution was filtered through Whatman filter paper to remove any undissolved particles. The absorbance of the filtered solution was measured at the predetermined λmax using a UV–Visible spectrophotometer. The drug content present in the formulation was calculated using the standard calibration curve and expressed as a percentage of the labeled claim (%) [11].

Result:

Preformulation Study:

Sr No.	Phytoconstituents	Test	Observation	Result
1	Alkaloids	Mayer's test	 **Figure 9. Mayer's Test Result**	+
		Dragendroff's test	 **Figure 10. Dragendroffs Test Result**	+
2	Flavonoids	Alkaline Reagent Test (NaOH Test)	 **Figure 11. Alkaline Reagent Test**	+

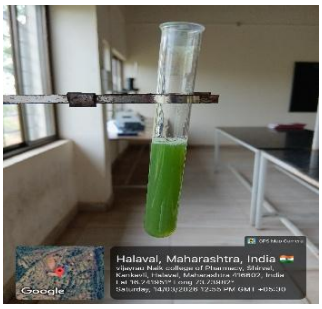
4	Terpinoides	Salkowski's test	 **Figure 12. Alkaline Reagent Test**	+
5	Cardiac glycosides	Keller-Killani test	 **Figure 13. Keller- Killani Test Result**	+
6	Phenolic compounds	Ferric Chloride Test	 **Figure 14. Ferric Chloride Test Result**	+
7	Saponin	Foam Test	 **Figure 15. Foam Test Result**	+

Table 4: *Carissa Carandas Leaves Extract Phytochemicals Test*

Digital Microscopic Evaluation:

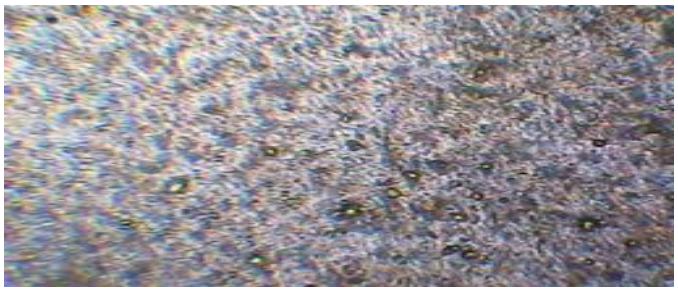


Figure 24: *Hydrogel*

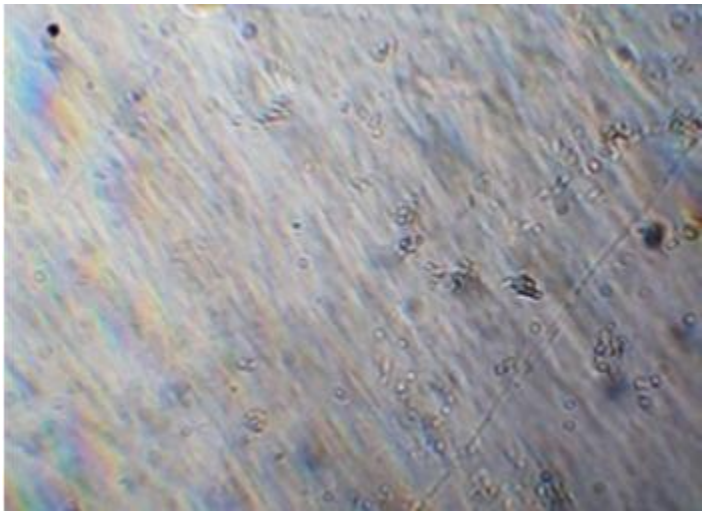


Figure 25: *Carissa carandas extract*

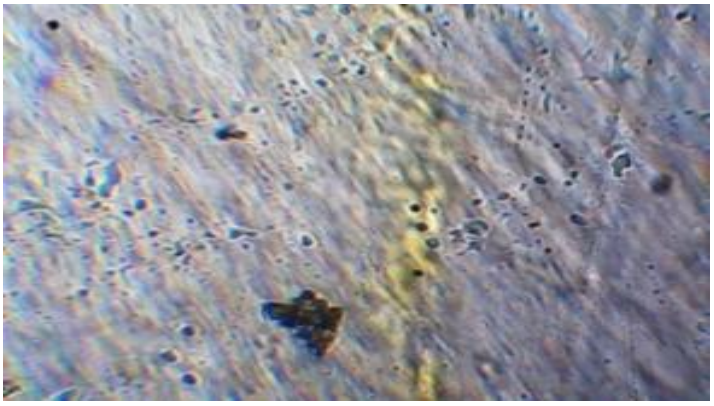


Figure 26: *Curcuma amada extract*

Evaluation Test:

1.Organoleptic Evaluation:

After visual identification of the hydrogel following are the results:

Parameters	Observation	Standard requirements	Results
Color	Yellowish green	Should be uniform	Passed
Odor	Astringent	Should be acceptable	Passed
Appearance	Smooth	No lumps or phase separation	Passed
Texture	Non-gritty	Should be free from grittiness	Passed

Table 5: *Organoleptic Evaluation Results*

Figure 27: *Batch 5*

•Batch B complied with all organoleptic evaluation parameters and was found suitable for topical application. This was an optimum batch.

Figure 28: *pH Determination*

Sr. No.	*Formulation*	*pH*
1	B1	6.5
2	B2	6.3
3	B3	6.0
4	B4	6.1
5	B5	6.1

Table 6: *pH Determination Test Results*

The optimum batch B5 was obtained and its pH was found to be 6.1.

- The pH of hydrogel was found to be 6.1.
- Standard Range of pH: 4.5 – 6.5

3.**Viscosity Determination:** Among all formulations, B5 exhibited optimum viscosity at 100 rpm. Which provided ideal consistency and enhanced retention at the site of application.

Figure 29: *Viscosity of Hydrogel*

Sr. No.	Formulation	Viscosity (cP)
1	B1	4276
2	B2	4509
3	B3	4896
4	B4	5064
5	B5	5856

Table 7: Viscosity Determination Results [15]

4.**Determination of Spreadability:** The hydrogel spreadability was found to be 5.4 cm. An ideal range for the topical hydrogel is 5-10 g.cm/sec.

Figure 30: *Spredability Result*

Sr.No.	Formulation	Spreadability (Cm)
1	B1	3.9
2	B2	4.1
3	B3	4.3
4	B4	5.1
5	B5	5.4

Table 8: *Spredability test result*

5.**Extrudability Study:** The extrudability of hydrogel was found to be 2.7 cm. That is large amount of hydrogel was represents better extrudability. In following tabular observation batch B5 was found to be optimum batch.

Figure 31: *Extrudability test*

Sr. No.	Formulation	Extrudability (cm)
1	B1	1.5
2	B2	2.1
3	B3	1.8
4	B4	2.4
5	B5	2.7

Table 9: *Extrudability test result*

6.**Grittiness:** The prepared hydrogel formulation was found to be free from grittiness, indicating uniform dispersion of ingredients and smooth texture, which is suitable for topical application.

7.**Skin irritation test:** No irritation was found when applied on the skin.

8.**Drug Content:** The drug content of the prepared hydrogel formulations was found to be within acceptable limits, indicating uniform distribution of the drug throughout the formulation. Among all batches, formulation B5 showed drug content of 100.8%, confirming good content uniformity and accuracy of the formulation method.

9.**Wash ability:** A small amount of prepared hydrogel was applied to the skin and placed under running water after observation. The hydrogel was easily washed using tap water. Optimum batch was found to be B5 batch.

Figure 32: *Before wash*

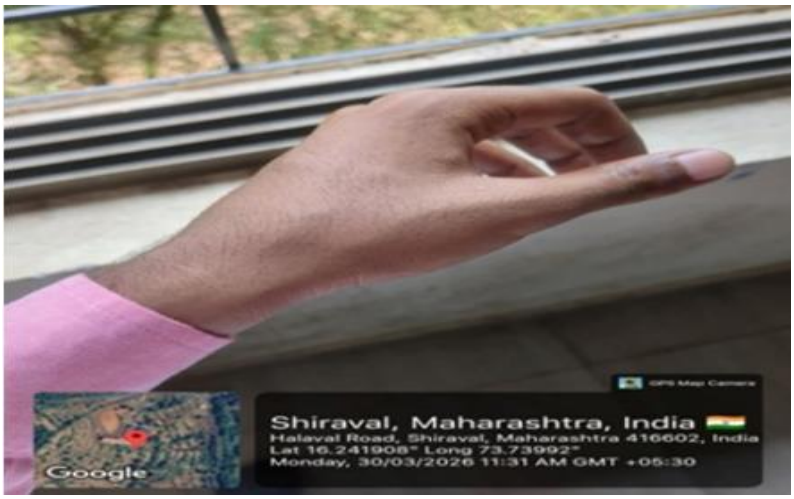


Figure 33: *After wash*

10.Homogeneity study: The formulation was tested for the homogeneity by visual appearance and by touch. No any lumps formation observed. Batch B5 exhibited superior homogeneity compare to other batches [16]

Figure 34: Homogeneity study

11.**Determination of swelling index:** The hydrogel exhibited a swelling index of 84.61%, indicating good water absorption and polymer hydration. This indicates adequate swelling behavior, supporting effective moisture retention and suitability or topical application. Batch B5 was observed a higher swelling index as compare to other formulations.

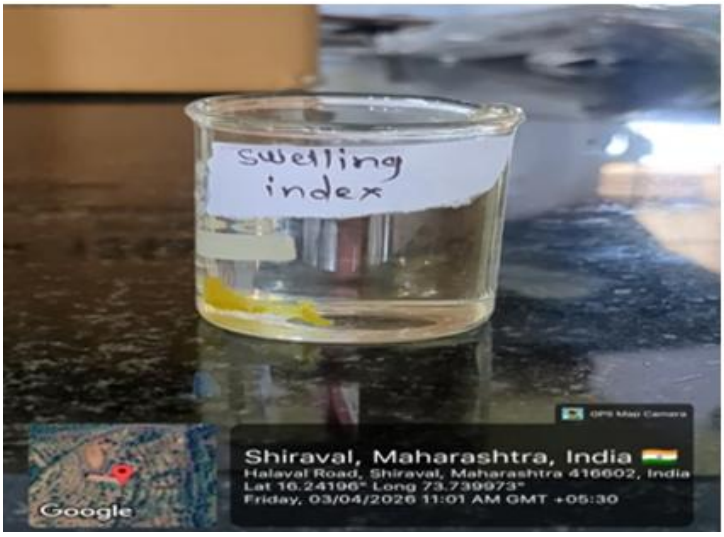


Figure 35: *Swelling Index*

12.Stability Study:

Sample code	Time Duration (hr)	Temperature (^{0}C)	Colour	Odour	Texture	pH	Washability	Skin Irritaion
B5A	24	4^{0}C	NC	NC	NC	6.14	Easily Washable	No arrhythema and edema
B5B	24	25^{0}C	NC	NC	NC	6.11	Easily Washable	No arrhythema and edema
B5C	24	47^{0}C	NC	NC	NC	6.13	Easily Washable	No arrhythema and edema
B5D	48	4^{0}C	NC	NC	NC	6.14	Easily Washable	No arrhythema and edema
B5E	48	25^{0}C	NC	NC	NC	6.12	Easily Washable	No arrhythema and edema
B5F	48	47^{0}C	Slightly change	NC	NC	6.13	Easily Washable	No arrhythema and edema
B5G	72	4^{0}C	NC	NC	NC	6.14	Easily Washable	No arrhythema and edema
B5H	72	25^{0}C	NC	NC	NC	6.11	Easily Washable	No arrhythema and edema
B5I	72	47^{0}C	Slightly change	NC	NC	6.13	Easily Washable	No arrhythema and edema

Table 10: *Stability study results*

Figure 36: *Formulation Batches for stability study*

Results and Discussion:

The current study successfully produced and evaluated a herbal anti-inflammatory hydrogel using ethanolic extracts from the rhizomes of Curcuma Amada and the leaves of Carissa Carandas. These plants were selected due to their well-established anti-inflammatory and antioxidant properties, which were further confirmd by preliminary phytochemical screening. Flavonoids, phenolic chemicals, alkaloids, terpenoids, and curcuminoids play significant role in formulation and enhanced their therapeutic efficacy. Several physicochemical characteristics were evaluated in order to determine whether the generated hydrogel compositions were appropriate for topical application. The pH values of all the formulations were determined to be within the acceptable range for skin compatibility, ranging from 4.5 to 6.5. The pH of batch B5 was 6.1, indicating a strong compatibility with the physiological skin environment and a low risk of skin irritation. The spreadability and retention of topical formulations are significantly influenced by viscosity. The viscosity of the formulations increased steadily from B1 to B5, with B5 exhibiting the maximum viscosity (5856 cp at 100 rpm). This implies the ideal balance between simplicity and consistency of application, ensuring that the formulation remains at the application site for an extended period of time without becoming overly rigid. Results showed that spreadability and viscosity, a characteristic of semisolid formulations, had an inverse relationship. The spreadability of Batch B5 was 5.4 cm, indicating regulated spreading behavior and falling within the permitted range for topical hydrogels. This ensures adequate coverage of the affected area while maintaining enough residence time for better therapeutic activity. Extrudability is important for application convenience and patient compliance.

The results showed that B5 had the highest extrudability (2.7 cm), suggesting that the formulation may be easily dispensed from the container with minimal force, improving patient convenience. The hydrogels homogenous, smooth texture and absence of grit indicate that the active components are dispersed uniformly throughout the polymer matrix. This ensures consistent drug administration and raises the overall quality of the formulation. The mixture was found to be easily washable and non-irritating to the skin, which further confirmed its viability for topical administration. The drug content investigation showed that al formulations were within acceptable boundaries, with B5 showing 100.8% drug content indicating consistent distribution and formulation accuracy. B5's swelling index of 84.61% show that excellent water absorption and polymer hydration capacity are essential for maintaining a moist environment and permitting regulated drug release. Stability testing showed that the optimized formulation (B5) exhibited no appreciable changes in pH, texture or other physical characteristics under a range of temperature settings. The slightly changes seen at high temperatures that were within acceptable boundaries demonstrated the formulations good stability. All things considered batch B5 exhibited the best physicochemical properties of all the formulations, including exceptional extrudability, optimum viscosity, controlled spreadability and superb stability.

Conclusion:

The present investigation demonstrates the successful formulation and comprehensive evaluation of a novel herbal hydrogel, highlighting its promising role as a safe, effective and patient compliant system for topical anti-inflammatory drug delivery. The study confirmed that the ethanolic extract of Carissa Carandas leaves and Curcuma Amada rhizomes are rich in bioactive constituents such as flavonoids,

phenolic compounds, alkaloids, terpenoids, and curcuminoids, which are known for their ant inflammatory, antioxidant and wound healing activities. Carissa Carandas leaves also exhibit notable emollient properties and do not cause any significant irritation, indicating their suitability for safe topical application. The anti-inflammatory effect of Carissa Carandas is mainly attributed to ursolic acid, which modulates key inflammatory mediators by inhibiting pathways such as NF-κB and enzymes like COX-2 and 5-LOX, along with regulating cytokines including TNF-α and IL-6. Similarly, Curcuma Amada rhizomes contribute through curcumin, which suppresses inflammatory responses by targeting NF-κB signlling, downregulating COX-2 expression and influencing receptors such as Toll-like receptor 4 (TLR4) while also reducing oxidative stress. The combining presence of ursolic acid and curcumin produces synergistic anti-inflammatory effect, enhancing the overall therapeutic performance of the formulation.

Additionally, the presence of volatile oils aids improving skin permeability thereby increasing the bioavailability of active compounds at the target site. Among all prepared formulations batch B5 performed superior physicochemical properties, including an optimal skin compatible pH, good spreadability and excellent extrudability. The hydrogel was found to be smooth, homogenous, non-gritty, easily washable and non-irritant, indicating good patient acceptability and safety. Stability studies further confirmed the reliability of the formulation. In conclusion, the developed herbal hydrogel offers safe, effective and natural alternatives to conventional synthetic ant inflammatory agents, with improved therapeutic efficacy and reduced risk of adverse effects. This study emphasizes the potential of integrating traditional herbal knowledge with modern formulation strategies for advanced topical drug delivery systems.

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