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"REVOLUTIONIZING WOUND CARE: DEVELOPMENT AND ASSESSMENT OF A CURCUMIN-BASED GEL FOR ENHANCED HEALING"

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Abstract:

Curcumin, a compound from Curcuma longa, is renowned for its therapeutic properties, including antioxidant, anti-inflammatory, anticancer, antibacterial, wound healing, antiviral, hepatoprotective, and neuroprotective effects. Despite its high-dose safety, its poor water solubility hampers its efficacy. This study aimed to enhance curcumin's solubility using a gel formulation with Gelucire 44/14. Both curcumin and Gelucire 44/14 were confirmed via physicochemical and spectral analyses. Various proportions were tested, with a 1:3 ratio of curcumin to Gelucire 44/14 achieving the highest water solubility. Stability studies indicated that at 40°C, Gelucire 44/14 melted, impacting stability. FT-IR analysis suggested hydrogen bond interactions, while DSC and TGA confirmed thermal stability and interaction-driven solubilization. The 1:3 ratio significantly enhanced curcumin solubility, and gel formulations demonstrated faster and higher curcumin release, peaking at 60-90 minutes, compared to plain curcumin. In rat models, the gel improved wound healing efficacy over plain curcumin. However, stability issues arose at 40°C due to Gelucire melting, necessitating further formulation adjustments for better stability. These findings suggest that Gelucire 44/14 is promising excipients for enhancing curcumin solubility and therapeutic efficacy, though temperature stability remains a challenge.

Keywords: Curcumin, Gel, Wound Healing, DSC, FT-IR etc.

Introduction: Society is increasingly interested in traditional medicine, especially plant-based remedies. Researchers are studying natural product extensively to see how they can treat illnesses and prevent long-term diseases. Plants and herbal medicines are essential for healing various ailments. In fact, around 80% of people worldwide use herbal medicines. One popular example is the roots or rhizomes of the Curcuma longa plant, which contain a yellow pigment known as curcumin.[1]

Curcumin benefits and problems: Curcumin, found in the roots or rhizomes of certain plants, is renowned for its. Numerous medicinal benefits and is responsible for their vibrant yellow hue. Extensively researched for its chemical, pharmacological, and pharmaceutical properties, curcumin is a hydrophobic polyphenol known as bis-α, β-unsaturated β- diketone or diferuloylmethane. It exhibits keto-enol tautomerism, with a prevalent keto form in acidic and neutral conditions and a stable enol form in alkaline environments. However, its insolubility in water poses a challenge for formulations, limiting its bioavailability. To address this issue, researchers have explored various methods, including complexation with polymers, to enhance curcumin's solubility and

bioavailability. In this study, efforts were made to improve the solubility of curcumin in water, aiming to enhance its therapeutic potential for treating various diseases.[2]

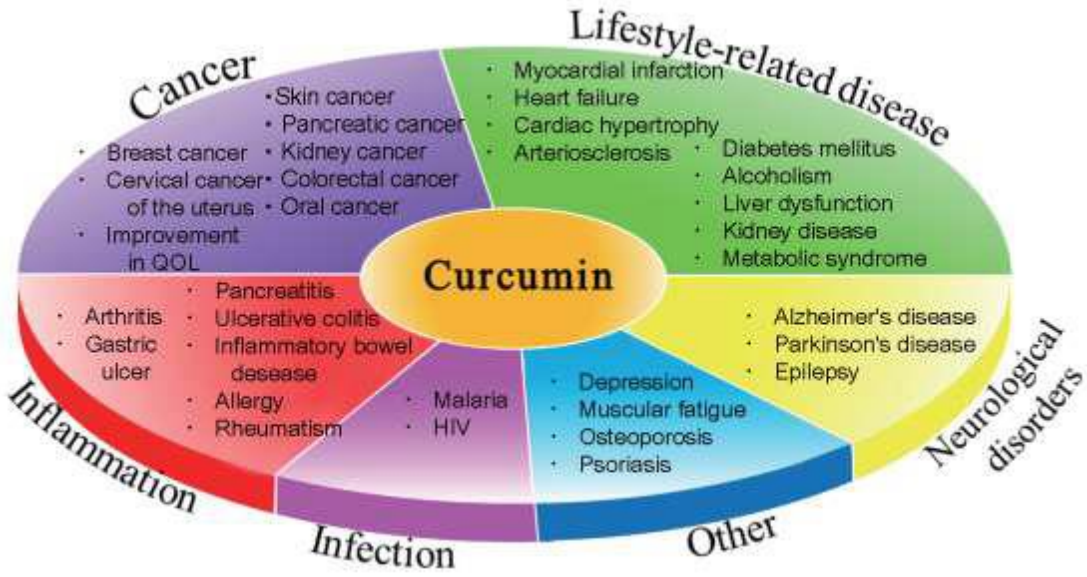


Figure 01: Curcumin has diverse therapeutic uses.

Experimental:

Chemical and reagent: Gift Sample of Curcumin was obtained from Dr. D. V. Agavekar "BAPS life sciences" dealer of Herbal plant extract in Thane, Mumbai. Gelucire 44/14 gift sample was procured from Gattefose Bombay College of Pharmacy, Kalina, Mumbai. The procured samples were tested to confirm their identity and this included UV visible wavelength scan, and recording of FT-IR spectra. FT-IR spectra were recorded. The sample was prepared as KBr palette for recording the spectra. The UV Visible spectra of curcumin were recorded using methanol as solvent while Gelucire 44/14 was recorded using water as solvent on Shimadzu 1900 series Instrument.[6-10]

Formulation Development: Various formulations of Curcumin-Based Gel (F8, F9, and F8) are prepared with different quantities of excipients to optimize the formulation of Gelucire 44/14 and curcumin Solid Dispersion.

Table no. 01: formulation and experimental design of Curcumin-Based Gel:

Sr. no.	Curcumin-Based Gel formulation	F8	F9	F10
1.	Carbopol 940	0.25gm	0.25gm	0.25gm
2.	Curcumin	500mg	500mg	500mg
3.	Gelucire 44/14	500mg	1500mg	1000mg
4.	Propylene glycol	100mg	500mg	500mg
5.	ORS Without Dextrose	700mg	700mg	700mg
6.	Distilled water	Q.S.	Q.S.	Q.S.

Preparation of Curcumin Topical Gel:

1. Soak Carbopol 940 in 10 ml water for 30 minutes to form a gel.
2. Dissolve curcumin and Gelucire 44/14 in propylene glycol at 40°C with thorough mixing.
3. Combine the gel from step 1 with the mixture from step 2, adding ORS without dextrose for thickness, and adjust with distilled water to 10 g.

Characterization and Evaluation: Formulations F8, F9, and F10 were evaluated for appearance, pH, viscosity, spreadability, drug content, and uniformity.

Compatibility Study: Formulations were stored at 40°C, 25°C/RH 60%, and 40°C/RH 75% for one month. Weekly, curcumin concentration was measured using UV-Visible spectrophotometry at 426 nm.

Drug-Excipients Interaction Study: Interactions were assessed over a month to identify any adverse effects.

Table no. 02: F8 composition of Curcumin-Based Gel formulation:

Sr. no.	Ingredient	Quantity (% w/w)
1	Standard Curcumin	0.5gm w/w
2	Carbopol 940	0.1gm w/w
3	Gelucire 44/14	0.02 gm w/w
4	Propylene glycol	0.0001ml w/w
5	Water quantity sufficient	Up to 10gm w/w

Table no. 03: F9 composition of standard Curcumin-Based Gel with gelucire 44/14 formulation:

Sr. no.	Ingredient	Quantity (% w/w)
1	Carbopol 940	0.1gm w/w
2	ORS without dextrose	0.7 gm w/w
3	Gelucire 44/14	1.6 gm w/w
4	Propylene glycol	0.0001ml w/w
5	Water quantity sufficient	Up to 10gm w/w

Table no. 04: F10 composition of standard Curcumin-Based Gel without gelucire 44/14 formulation:

Sr. no.	Ingredient	Quantity (% w/w)
1	Standard Curcumin	0.5gm w/w
2	Carbopol 940	0.1gm w/w
3	ORS without dextrose	0.7 gm w/w
4	Gelucire 44/14	1.6 gm w/w
5	Propylene glycol	0.0001ml w/w
6	Water quantity sufficient	Up to 10gm w/w

Wound Healing Study: Curcumin gel (0.2% w/w curcumin) was evaluated on Albino rats. Wound healing efficacy was monitored by measuring wound contraction and healing time over 15 days, comparing plain curcumin gel and Gelucire 44/14-enhanced gel.

Stability Study: Stability was assessed at 40°C, 25°C/RH 60%, and 40°C/RH 75% for one month. Curcumin content was determined weekly using UV-Visible spectrophotometry at 426 nm.

Results and discussion:

Procurement of Gelucire 44/14 and Curcumin:

Curcumin was acquired from Dr. D. V. Agavekar at BAPS Life Sciences, Thane, Mumbai, and Gelucire 44/14 from Gattefose, Bombay College of Pharmacy, Kalina, Mumbai. Preliminary physicochemical characterization, including appearance, solubility, and melting point, was performed, with results compared to reported data (Table 7.1).

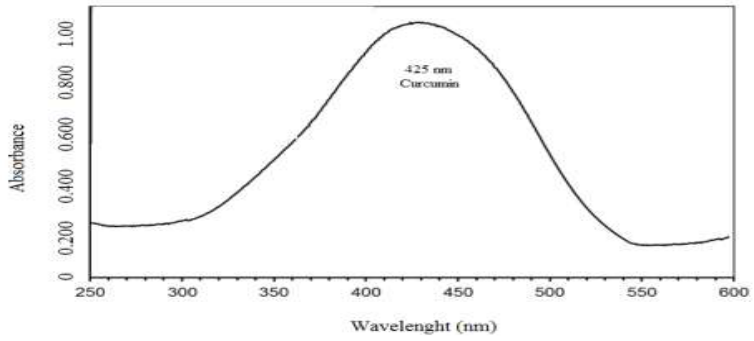


Figure no. 02: UV- Visible scan of Curcumin sample in methanol.

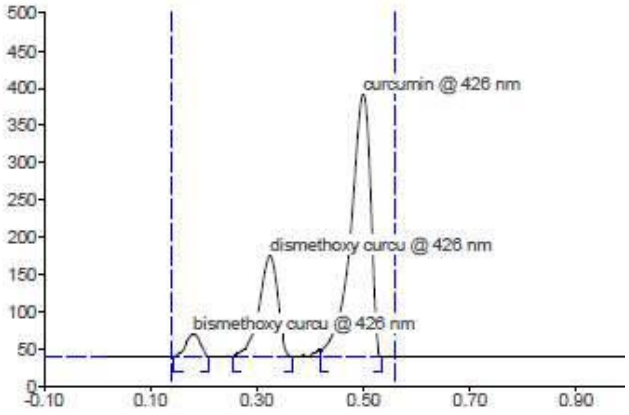


Figure no.03: Chromatogram of HPTLC analysis of Curcumin sample.

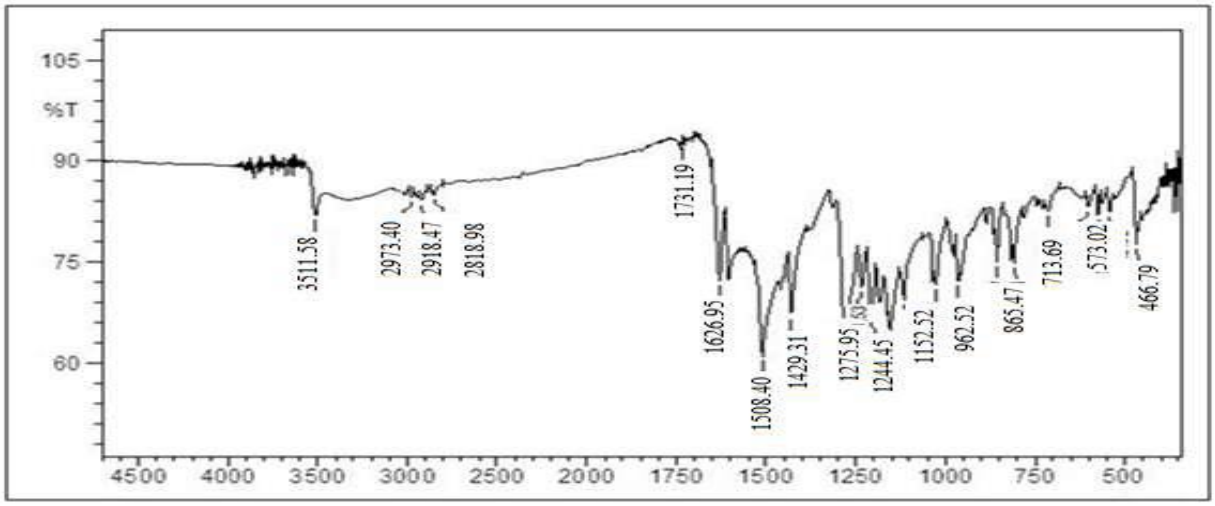


Figure no. 04: - FT-IR spectrum of curcumin sample.

Characterization:

Curcumin was analyzed using UV spectroscopy and HPTLC. The λ max in methanol was 425 nm, matching the reported 426 nm (Fig. 02). HPTLC profiles showed three major peaks with Rf values of 0.21, 0.36, and 0.53, corresponding to bisdemethoxycurcumin, desmethoxycurcumin, and curcumin respectively. FT-IR spectra matched reported data, confirming curcumin identity (Fig. 03 & 04, Table 05).

Table no. 05: FT-IR data of standard Curcumin and sample curcumin:

Frequency cm^{-1} Standard curcumin	**Frequency cm^{-1} Sample of curcumin**	**Possible groups assignment**
3341	3340	Free hydroxyl-group of phenol (Ar-OH). (broad)
719, 815 and 962 cm-1	713,807 & 962	-C-H bending of alkene
1745	1731	- vibration of the carbonyl bond (C=O))
shoulder at 1712	-	- Keto-enol tautomerism of curcumin
1463 and 1378	1430,1350	vibration mode of C−O elongation of the alcohol and phenol
-	1601,1508,1429	Vibration stretching of double bonds (C=C) aromatic

It was analyzed using UV spectroscopy and HPTLC. The λ max value for the Curcumin in methanol is found to be 425 nm, which is matching with the reported value 426 nm. (Fig.03) The HPTLC profile (Fig. 03) indicates 3 major spots /peaks related to

bismethoxycurcumin, desmethoxycurcumin and Curcumin, with Rf values 0.21, 0.36 and 0.53 respectively. The Rf and λ max values of Curcumin were found to be comparable to the reported data. FT-IR was also recorded for the Curcumin sample and it was compared with the reported spectrum (Fig. 04) the results presented in Table 05; indicate that the peaks coincide with the reported data. Hence, the identity of the Curcumin sample is confirmed. [01-08]

Formulation Development: Various formulations of Curcumin-Based Gel (F8, F9, and F10) are prepared with different quantities of excipients to optimize the formulation. Curcumin and Gelucire44/14 were mixed in different proportions and the SD was dissolved in water. The λmax value for the complex was determined against water blank and it was found to be 426 nm. The optimization of the proportions of Gelucire 44/14 and curcumin was done through recording the absorbance at 426 nm. The results presented in Table 06 and Fig. 05 indicates that the proportion of Curcumin and Gelucire44/14 (1:3) was found to completely soluble and yielded maximum concentration of solubilized curcumin, hence it was considered to be the optimum proportion. The complex thus prepared was evaluated by recording FT-IR spectrum of the Curcumin-Based Gel compared with the individual spectrum of Gelucire 44/14 and Curcumin.

Table no. 06: Optimization of ratio of curcumin and Gelucire 44/14 (Mean± SD,µg/ ml)

Formulation	Cur: Gelucire 44/14 gm: gm	Concentration of Curcumin in water
F1	0.5: 0.2	9.28 ± 0.09
F2	0.5: 0.4	11.34 ± 0.21
F3	0.5: 0.6	15.99 ± 0.28
F4	0.5: 0.8	31.14± 0.73
F5	0.5: 0.1	37.70 ± 0.48
F6	0.5: 1.2	42.0 ± 0.64
F7	0.5: 1.4	44.32 ± 0.20
F8	0.5: 1.6	63.08 ± 0.09
F9	0.5: 1.8	62.17 ± 0.04
F10	0.5: 02	63.37 ± 0.40
F11	0.5: 0.0	0.000 ± 0.0
F12	0.0: 1.6	0.000 ± 0.0

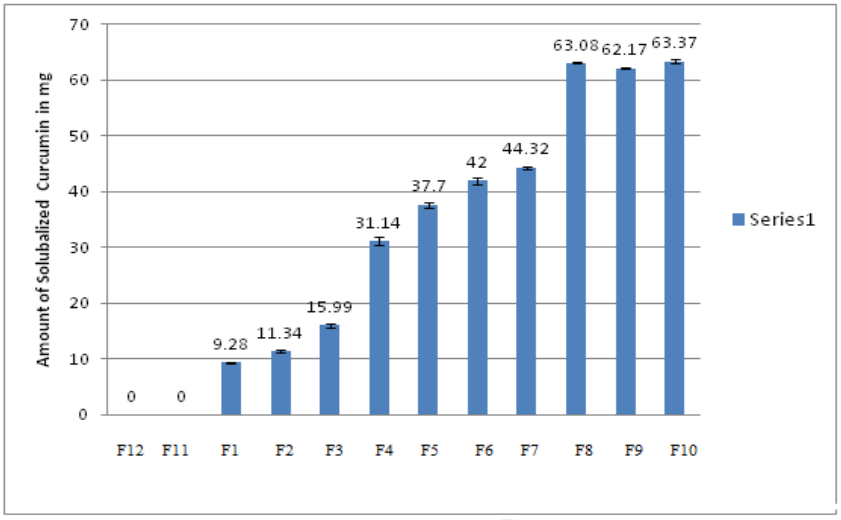


Figure no.05: Effect of increasing the amount of Gelucire 44/14 on solubility of Curcumin in water.

Characterization and Evaluation:

The prepared formulations (F8, F9, and F10) are characterized and evaluated for their physical and chemical properties, including:

Table no. 07: Evaluation parameter of Curcumin-Based Gel:

Sr. No.	Parameter	Ranges
1.	Appearance	Clear transparent yellow gel
2.	pH	6-7
3.	Viscosity	15-17 poise
4.	Spreadability	5-7 cm

Curcumin and Gelucire were mixed in different proportions and the complex was solubilized in water. The λmax value for the complex was determined against water blank and it was found to be 426 nm. The optimization of the proportions of Gelucire 44/14 and curcumin was done through recording the absorbance at 426 nm. The results presented in Table 10 and Fig. 26 indicates that the proportion of Curcumin and Gelucire (1:3) was found to completely soluble and yielded maximum concentration of solubilized curcumin, hence it was considered to be the optimum proportion. The complex thus prepared was evaluated by recording FT-IR spectrum and compared with the individual spectrum of Gelucire 44/14 and Curcumin.

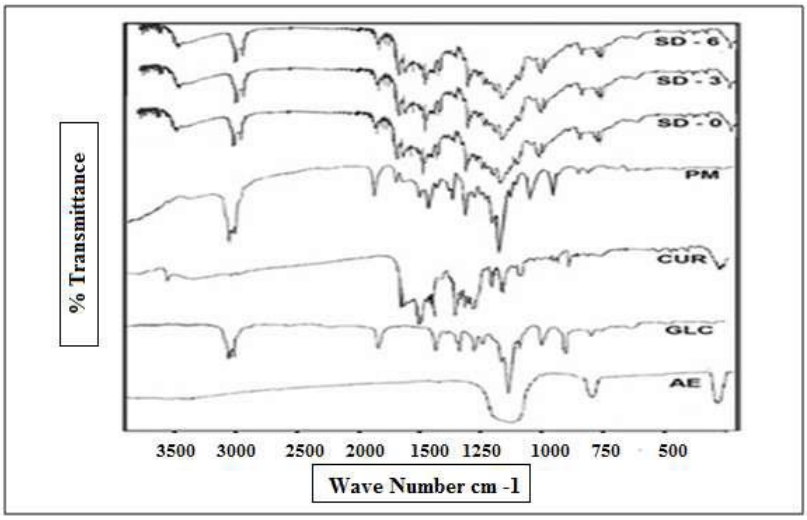


Figure no. 06: Fourier transform infrared spectra for curcumin (CUR), Aerosil® (AE), Gelucire®44/14 (GLC), physical mixture (PM) and solid dispersions SD-0 (just prepared), SD-3 (after 3 months) and SD-6 (after 6 months).

Dissolution Testing:

Dissolution testing of the different formulations is conducted three times on three different days to assess their release profiles and dissolution rates. In vitro release profile of Curcumin from three formulations viz. F8 (0.250gm = 85mg drug), F9(0.250gm = 85mg drug) and F10 (0.250gm = 85mg drug) were carried out by carrying out dissolution studies using the Dissolution Apparatus Type II basket type, with speed of 100 prm, temp of 37 ^{0}C ± 0.5 ^{0}C and dissolution medium of 0.1 N HCl (900 ml). The results were compared with the dissolution testing of equivalent amount of plain curcumin and Curcumin-Based Gel.

The results of the dissolution testing are presented in Table 08 and Fig. 07 The image presented in Fig. 08 and Fig. 09 reveals that the basket containing the plain curcumin (D) does not show yellow color in the medium, while the baskets containing the formulations F8, F9 and F10 indicate the yellow color of the medium after 30 mins revealing the release of curcumin from the formulations.

The results presented in Table 08 and Fig 09 indicates the mean % release of curcumin from various formulations. The highest amount of curcumin that is 61.69 mg from total loading of 85 mg of curcumin constituting to 72.06% was obtained from formulation F10 (gelucire 44/14, sodium carbonates and calcium carbonates).

It is observed that the % release of curcumin from formulation F10 is significantly (P<) higher than the Formulations F8 and F9, although there is no significant difference in the entrapment efficiency of curcumin in the formulations. The F10 has higher drug loading as compared to the F8 and F9.

Release of curcumin from formulations containing plain curcumin and the Curcumin-Based Gel containing plain curcumin was found to be significantly (P<) lower than the formulations containing the SD of Curcumin and Gelucire 44/14.

Figure no. 07: Dissolution study of Curcumin-Based Gel formulations containing complex of Curcumin and Gelucire 44/14 compared with gel containing plain Curcumin. [(A= F8, B= F9, C= F10, D= Plain Curcumin and E= standard Curcumin beads without Gelucire 44/14).

Dissolution Type: Type II Basket Type RPM =100 rpm, TEMP =37 ^{0}C ± 0.5 ^{0}C, Dissolution Medium = 0.1 N HCL (900 ml), PH =1.2, Aliquot = 5 ml

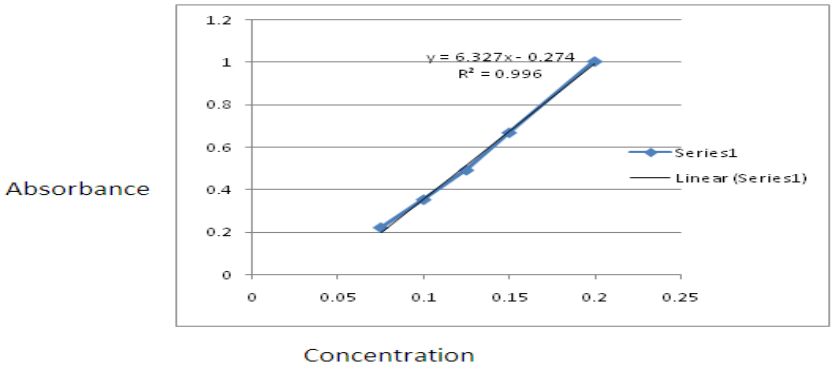


Figure no. 08: Standard Curve of Curcumin.

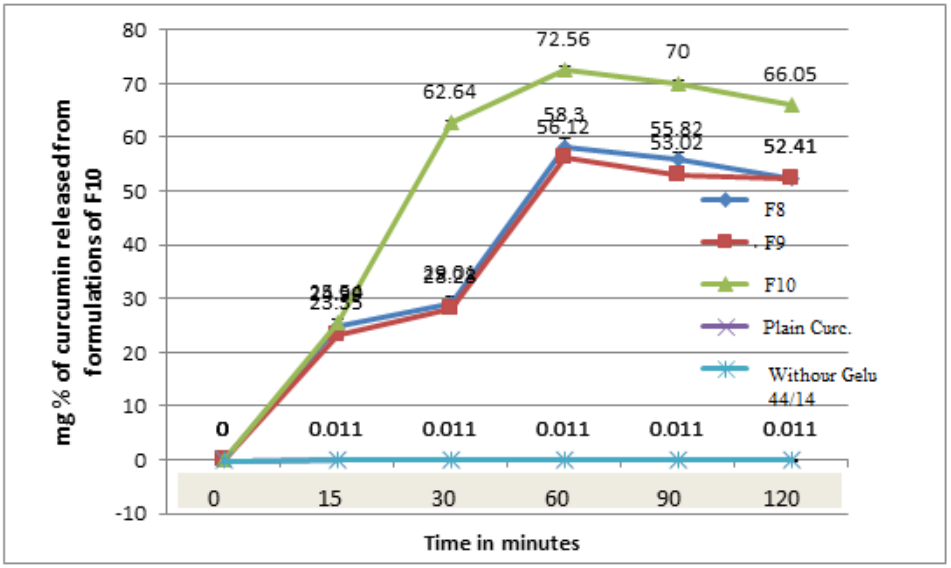


Figure no. 09: In-vitro release Profile of Curcumin from various formulations of F10 Containing curcumin -Gelucire 44/14 SD and plain Curcumin.

Table no. 08: In-vitro Release Profile of Various Curcumin-Based Gel Formulations in Dissolution Testing.

Formulations → TIME ↓	F8 (%) Mean ± S.D.	F9 (%) Mean ± S.D.	F10 (%) Mean ±S.D.	Plain Curcumin (%) Mean ± S.D.	S1 DRUG (%) Mean ±S.D.
0 Min	0.000	0.000	0.000	0.000	0.000
15 Min	24.99 ±1.40	23.35 ±0.96	25.54±0.72	0.011 ± 0.0	0.011 ± 0.0
30 Min	29.01± 1.16	28.28 ±0.74	62.64±0.77	0.011 ± 0.0	0.011 ± 0.0
60 Min	58.30± 1.41	56.12 ±0.78	72.56±0.39	0.011 ± 0.0	0.011 ± 0.0
90min	55.82± 1.40	53.02 ±0.79	70.0 ±0.56	0.011 ± 0.0	0.011± 0.0
120 Min	52.41±1.37	52.41 ±0.28	66.05±0.73	0.011 ± 0.0	0.011± 0.0

Amount of the drug in the Curcumin-Based Gel = 85 mg, N=3

Compatibility Study: Stability and compatibility studies are conducted on the different formulations of Curcumin-Based Gel to assess their shelf-life and ensure compatibility with packaging materials. Compatibility Study of curcumin and the excipients used in Curcumin-Based Gel formulation was carried out by storing the mixture of drug and the excipients for one month, at different environmental conditions viz. 40,250 (RH= 65 %), and 400 (RH=75 %). The physical characteristics like appearance or any visible changes in the appearance of the mixture were noted down. These results underscore the sensitivity of Curcumin to specific environmental factors, particularly elevated temperature and humidity levels. The stable concentrations observed at lower temperatures suggest potential preservation benefits for Curcumin-based products under mild storage conditions. Conversely, the pronounced change observed at higher temperature and humidity highlights the necessity for controlled storage environments to maintain Curcumin efficacy. These findings provide valuable insights into optimizing storage conditions and preserving the potency of Curcumin-based formulations, thereby enhancing their utility and effectiveness in various applications.

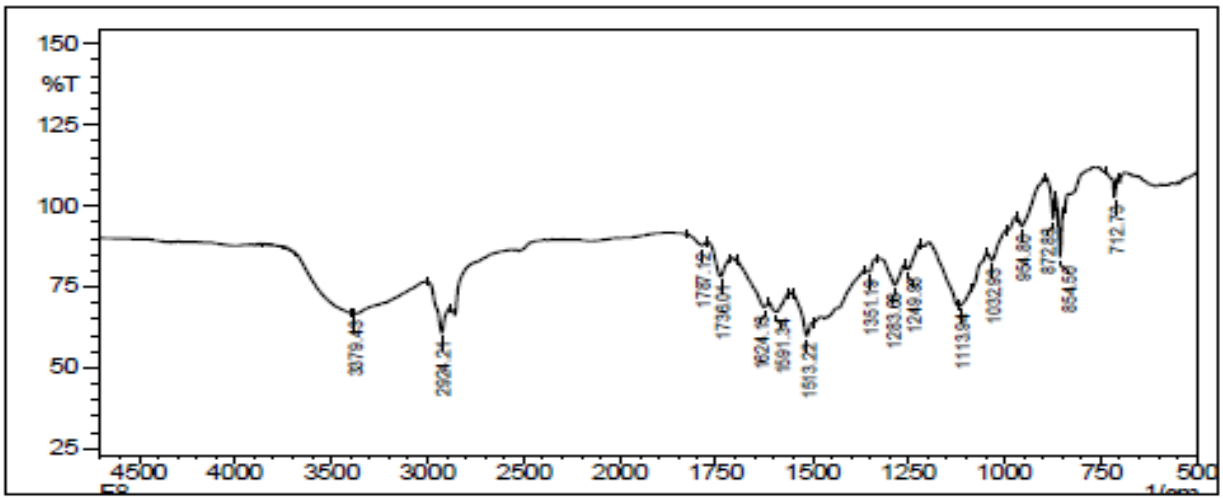


Figure no. 10: FT-IR spectrum to Curcumin-Based Gel: F10.

The Curcumin-Based Gel formulation F10 was utilized for characterization, as the formulation yielded maximum entrapment of the curcumin. The formulation was characterized by comparing the changes in the FT-IR spectra of curcumin and Gelucire 44/14. The FT-IR spectra of the formulation F10 is presented in Fig. 31 and 32. The data was compared with the FT-IR spectrum of the Solid Dispersion of Gelucire 44/14 and curcumin reported by 190^{0}C. It was found that the In the F10 spectra, the bands related to the stretching of (C=C) of the benzene ring not only appear expanded but they also seem to have moved to 1513, 1510 cm−1. These bands correspond to the peak at 1508 cm−1 in the curcumin spectrum that has shifted to a higher frequency. Benzene rings with electron donor character usually show a broad band at 1510 cm−1.Curcumin-Based Gel formulation F10 was also characterized through thermal analysis viz. Differential Scanning Calorimetric (DSC) and Thermo gravimetric analysis (TG) at UICT (University Institute of Chemical Technology), Matunga,

Mumbai. The results are presented in Fig 11. The results indicate that the Gelucire 44/14 and Curcumin have melting points at 45-46° C and 170-172° C while the formulation F10 containing the SD indicated two peaks at 150 and 190° C.

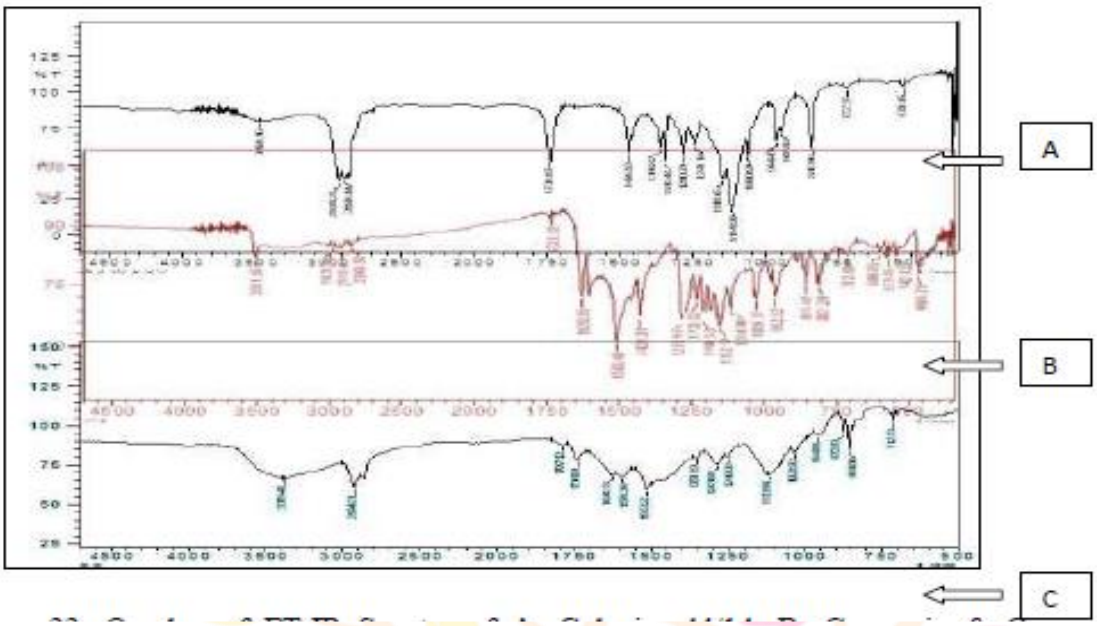


Figure no. 11: Overlap of FT-IR Spectra of A: Gelucire 44/14, B: Curcumin & C: Curcumin-Based Gel: F10 with SD of Curcumin and Gelucire 44/14.

Wound Healing Study: The efficacy of Curcumin-Based Gel in wound healing is assessed using different animal models. Parameters such as wound closure rate, tissue regeneration, and inflammatory response are evaluated to determine the gel's effectiveness in promoting wound healing.

The Curcumin-Based Gel SD of Curcumin and Gelucire 44/14 in the proportion of 1: 3 was utilized for the preparation of gel for topical application. The Carbopol 940 was utilized for preparation of the gel base. The formulation of the same is given in fig. 12. The gel base of Carbopol was also utilized to suspend plain Curcumin in equivalent quantity. Curcumin being utilized for treatment of wounds; the gel was evaluated in-vivo by comparing the wound healing potential of the plain Curcumin-Based Gel and the gel containing the complex of Curcumin and Gelucire 44/14. Excision wounds were inflicted on the back of Westar albino rats and the gels were applied to determine the time required for complete healing of wounds. The results of the wound healing study on the gels are presented in the Table 15, 16, and Figure no. 13.

Figure no. 12: A) carpool 940 gel without Curcumin, B) standard Curcumin gel without Gelucire 44/14 polymer, and C) standard Curcumin-Based Gel with Gelucire 44/14 polymer.

Evaluation of wound healing activity of Curcumin-Based Gel: The result of wound healing activities by excision wound model presented in table number 15 & 16 Fig. 14, 15,16 indicate the mean % wound contraction due to treatment of various formulations on days 3, 5, 7, 9, 11, 13 and 15 days. The group of animals treated with the gel base could not heal the wound as the mean % contraction of the wound was found to be the lowest. Groups treated with the gel containing the plain curcumin and the curcumin –Gelucire 44/14 SD

indicated significantly (P<) higher contraction of wound area. There is no significant difference in the epithelization period of the groups treated with curcumin plain and the curcumin –Gelucire 44/14 SD.

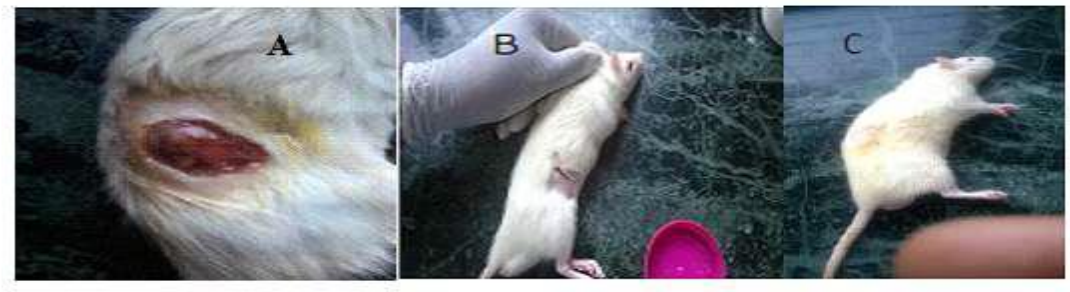


Figure no. 13: Effect of topical application of different curcumin gel formulations to the excision wounds on fifteenth day. Group A = plain Carbopol 940 gel without curcumin, Group B = Plain Curcumin, Group C = Curcumin-Based Gel.

Table no. 09: Effect of topical application of different formulation of Curcumin on mean contraction of wound area of excised wound in rats:

Groups	% Wound concentration Mean ±SEM				
	Day 3	Day 5	Day 7	Day 11	Day 15
Group A	0.00 ± 0.0	7.80± 0.80	15.4±0.84	25.06±1.36	35.0±1.78
Group B	22.59±0.56	42.22±0.50	49.6± 0.67	87.0 ± 0.83	98.7± 0.75
Group C	29.48±1.10	51.83±0.77	70.5± 1.12	92.1 ± 0.44	100± 0.44

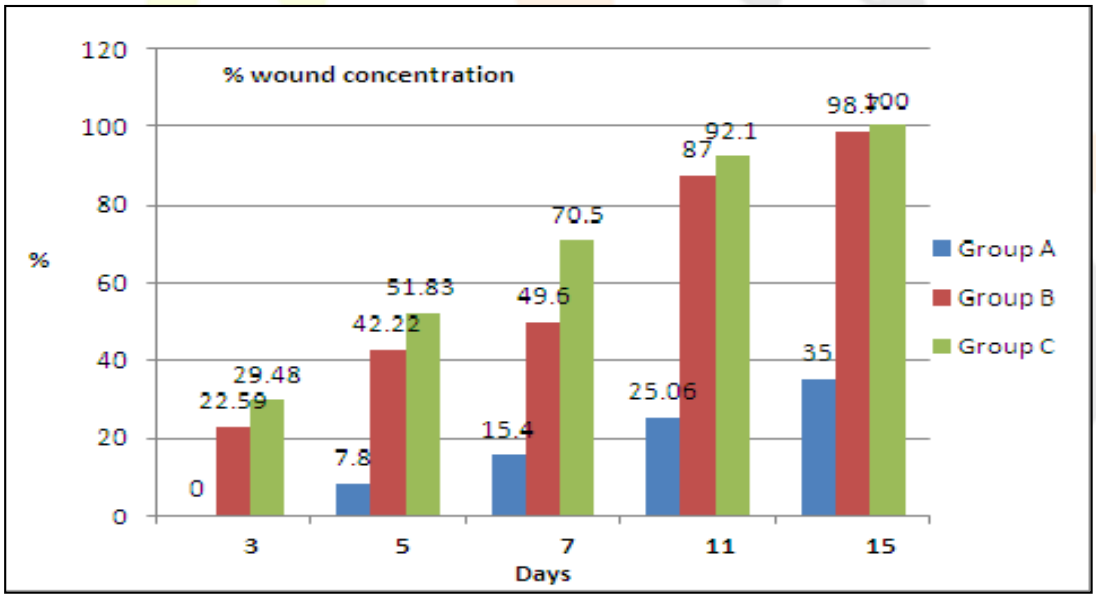


Figure no.14: Effect of topical application of different formulation of Curcumin on mean contractions of wound area of excised wound in rats. Group A: plain Carbopol 940 gel without curcumin, Group B = Plain Curcumin, Group C = Curcumin-Based

Gel.

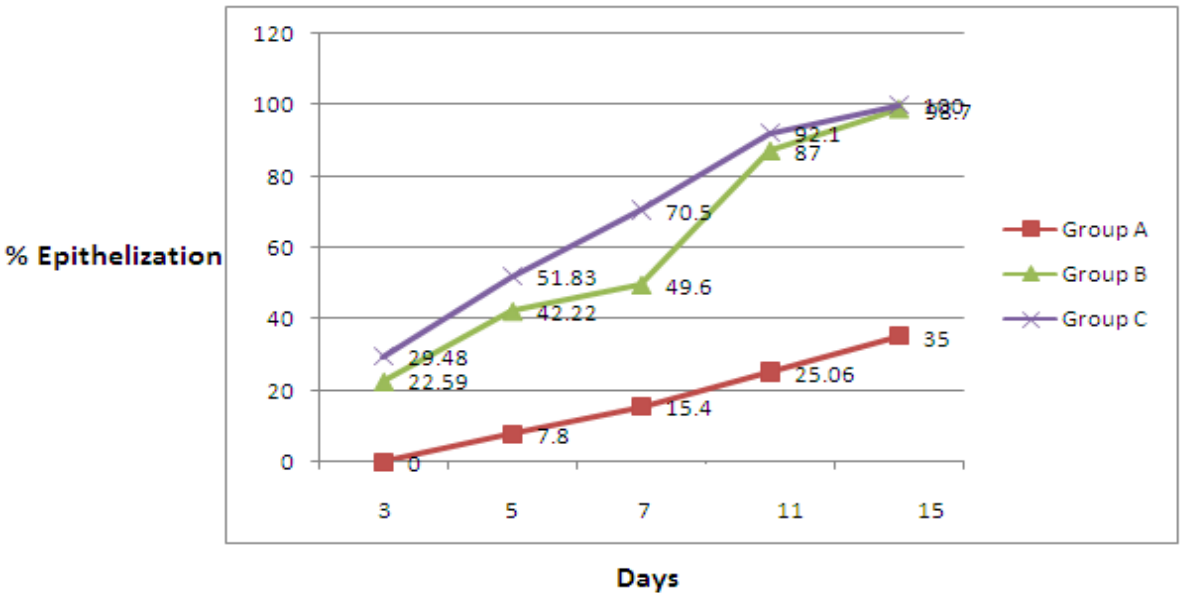


Figure no. 15: Effect of topical application of different formulation of Curcumin on mean contraction of wound area of excised wound in rats. Group A: plain Carbopol 940 gel without curcumin, Group B = Plain Curcumin, Group C = Curcumin-Based Gel.

Table no 10: Effect of topical application of different formulation of Curcumin on Epithelization: Period of excised wound in rats:

Groups	Animals						Period of Epithelization (in days)
	1	2	3	4	5	6	
Group A	21	24	30	25	25	28	25.5 ± 1.11
Group B	16	16	17	17	16	16	16.33 ± 0.32
Group C	15	15	15	14	15	15	14.83 ± 0.13

Group A: plain Carbopol 940 gel without curcumin, Group B = Plain Curcumin, Group C = Curcumin-Based Gel, N=6

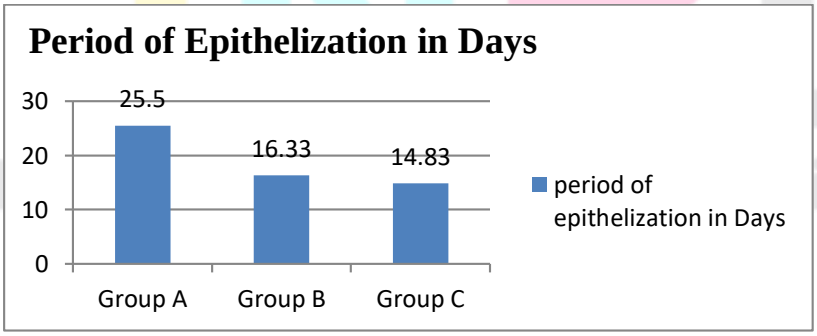


Figure no. 16: Effect of topical application of different formulations of Curcumin on period of epithelization of excised wound in rats. Group A: plain Carbopol 940 gel without curcumin, Group B = Plain Curcumin, Group C = Curcumin-Based Gel. N = 6 Wister albino rats.

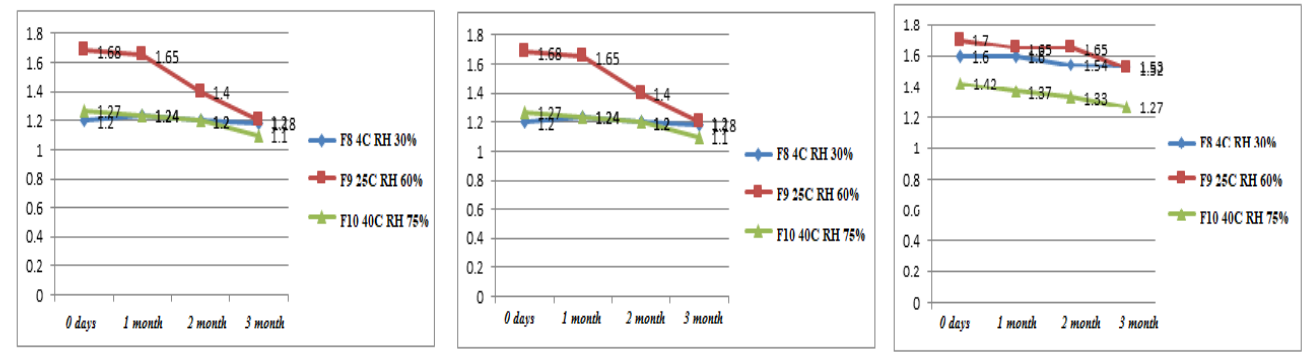
Stability Study: Stability studies are conducted on the different formulations of Curcumin-Based Gel to assess their shelf-life and ensure compatibility with packaging materials.

Three different formulations viz. F8, F9 and F10 were prepared by incorporating SD of curcumin and Gelucire 44/14 prepared in various proportions and these were stored at 4o C RH 30%, 25o C /RH60% and 40o C/ RH 75 %. The samples were withdrawn at weekly intervals and the content of curcumin was determined. The results are presented in Table no. 11, and Fig. 14.

Table no. 11: Stability study of Curcumin-Based Gel: 3 Month Results:

Formulation	Temp ^{O}C/ % RH	Concentration (mg) Mean±S. D	Temp ^{O}C/ % RH	Concentration (mg) Mean±S. D	Temp ^{O}C/ % RH	Concentration (mg) Mean±S. D
F8	4/30	1.18 ± 0.81	25/60	1.2 ± 0.31	40/75	1.1 ± 2.11
F9	4/30	1.53 ± 0.89	25/60	1.52 ± 0.67	40/75	1.27 ± 0.29
F10	4/30	1.46 ± 0.41	25/60	1.06 ± 0.34	40/75	1.03 ± 0.92

Mean ± S.D, N=3



Stability study of F8 formulation containing SD OF Gelucire 44/14: Curcumin (1:1)

Stability study of F9 formulation containing SD OF Gelucire 44/14: Curcumin (1:3)

Stability study of F10 formulation containing SD of Gelucire: Curcumin (1:2)

Figure no. 14: Stability study of F8, F9 and F10 formulation.

The results of the stability studies presented in Table 11 and Fig 14 reporting the concentration of curcumin in gel indicate that the formulation F10 is stable at conditions of 4o C/ RH 30% and 25o C / RH 60%, as there is no significant change in the concentration of curcumin at the end of 3 month.

Discussion:

Enhancing Curcumin Solubility with Curcumin-Gelucire 44/14 Gel: Curcumin, derived from Curcuma longa, possesses numerous therapeutic benefits such as antioxidant, anti-inflammatory, anticancer, antibacterial, wound healing, antiviral, hepatoprotective, and neuroprotective properties. Despite its safety at high doses, curcumin's poor water solubility limits its effectiveness. This study explores enhancing curcumin's solubility using a gel formulation with Gelucire 44/14.

Material Confirmation: Curcumin and Gelucire 44/14 were verified through physicochemical and spectral analysis. Gel Optimization: Various proportions of curcumin and Gelucire 44/14 were tested, with a 1:3 ratio yielding the highest curcumin concentration in water. Stability Study: Mixtures of curcumin and excipients were stored under different conditions. At 40°C, Gelucire 44/14 melted, affecting stability. Characterization: FT-IR Analysis: Indicated hydrogen bond interactions. DSC and TGA: Confirmed thermal stability and interactions facilitating curcumin solubilization.

Results Solubility Enhancement: The 1:3 curcumin: Gelucire 44/14 ratio significantly improved curcumin's solubility. Dissolution Rate: The gel formulations released curcumin faster and in higher quantities compared to plain curcumin, peaking at 60-90 minutes. Wound Healing: In rat models, the gel enhanced wound healing compared to plain curcumin. Stability Issues: Formulations were unstable at 40°C due to Gelucire melting.

Conclusion:

This study demonstrates that the solubility and therapeutic efficacy of curcumin can be significantly enhanced by using a gel formulation with Gelucire 44/14. Despite curcumin's known therapeutic benefits—such as antioxidant, anti-inflammatory, anticancer, antibacterial, wound healing, antiviral, hepatoprotective, and neuroprotective properties—its poor water solubility limits its effectiveness. Through physicochemical and spectral analysis, the materials were confirmed, and the optimal ratio of curcumin to Gelucire 44/14 was determined to be 1:3, which yielded the highest concentration of curcumin in water. Characterization techniques, including FT-IR, DSC, and TGA, indicated hydrogen bond interactions and confirmed thermal stability and solubilization interactions. The gel formulation showed significant improvement in solubility and dissolution rate, releasing curcumin faster and in higher quantities compared to plain curcumin, with peak release at 60-90 minutes. In wound healing studies using rat models, the curcumin-Gelucire 44/14 gel demonstrated enhanced healing properties compared to plain curcumin. However, stability issues were observed at 40°C due to the melting of Gelucire 44/14, indicating a need for further optimization to maintain stability under varying conditions.

Conflict of interest:

Authors don't have any conflict of interest

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References:

1. Bachar, Zebib.; zephrin, Mouloungui.; Virginie, Noirot.; Stabilization of Curcumin by Complexation with Divalent Cations in Glycerol/Water System, *Bioinorganic Chemistry and Applications*, **volume 2010**, 8, 10.1155.
2. Anand, P.; Thomas, S.G.; Kunnumakkara, A.B.; Sundaram, C.; Harikumar, K.B.; Sung, B.; Tharakan, S.T.; Misra, K.; Priyadarsini, I.K.; Rajasekharan, K.N.; Aggarwal, B.B.; Biological Activities of Curcumin and Its Analogues (Congeners) Made by Man and Mother Nature. *Biochem Pharmacol.***2008**, *76*, 1590-1611
3. National Tropical Botanical Garden e- Mail: Administration@Ntbg.Org
4. Online Gernot Katzer's Spice Pages, List of All Spices, Turmeric (Curcuma Longa)
5. Aggrawal, B.B.; Sundaram, C.; Malani, N.; Ichikawa, H.; Curcumin The Indian Solid Gold, Advance S in Experimental Medicine and Biology, **2007**, 595, 1-75.
6. Strimpakos, A.S.; Sharma, R.A.; Comprehensive Invited Review of Curcumin Preventive and Therapeutic Properties in Laboratory Studies and Clinical Trials, *Antioxidant and Redox Signaling* **2008**, 10, 511-546.
7. Goel, A.; Kunnumakkara, A.B.; Aggrawal, B.B.; Curcumin as Curcumin from Kitchen to Clinic, *Biochemical Pharmacology*,**2008**, 75, 787-809.
8. Dobelis, In. Ed.; Magic and Medicine of Plant, Pleasantville, *NY ReadermDigest Association*,**1986**
9. Leung, A.; Encyclopedia of Common Natural Ingredient Used in Food, Drug and Cosmetics, New York NY: John Wiley, 1980, 313-314.
10. Litwinienko, G.; Ingold, K. U.; Abnormal Solvent Effect on Hydrogen Atom Abtraction.2. Resolution of The Curcumin Antioxidant Controversy the Role of Sequential Proton Loss Electron Transfer, *Journal of Organic Chemistry*,**2004**, 69, 5888-5896.
11. Wahlstrom, B.; Blennow, G.; A Study on The Fate of Curcumin in the Rat, *Acta Pharmacology Toxicol*, **1978**, 43, 86-92.
12. Ravindranath, V.; Chandrasekhar, N.; Absorption and Tissue Distribution of Curcumin in Rats *Toxicol***1980**, 16, 259-265
13. Parusitum, Basnet.; Natasha, Skalko, Basnet.; Curcumin an Anti-Inflammatory Molecules from A Curry Spice on The Path to Cancer Treatment, *Molecules* **2011,** 16, 4567-4598.

14. Brouet, I.; Ohshim, A.; CuHr; cumin.; an Anti-Tumour Promoter and Anti-Inflammatory Agent, Inhibits Oxide Synthetase In Activated Macrophages. *Biochem Biophys Res Commun* **1995;** 206, 533-540
15. Park, E.J.; Jeon, C.H.; KO, G. et al.; Protective Effect of Curcumin in Rat Liver Injury Induced by Carbon Tetrachloride. *J Pharm Pharmacol* ***2000,*** 52, 437-440.
16. Kiso, Y.; Suzuki, Y.; Watanabe, N. et al.; Antihepatotoxic Principles of *Curcuma Longa* Rhizomes. *Planta Med* **1983,** 49, 185-187.
17. Chandra, D.; Gupta, A.; Anti-inflammatory and Anti-Arthritic Activity of Volatile Oil of Curcuma Longa(Haldi). *Ind J Med Res* **1972**, 60, 138-142.
18. Mukhopadhyay, A.; Basu, N.; Ghatak, N et al.; Anti-Inflammatory and Irritant Activities of Curcumin Analogues in Rats. *Agents Actions* **1982**, 12, 508-515.
19. Limtrakul, P.; Lipigorngoson, S.; Namwong, O et al.; Inhibitory Effect of Dietary Curcumin on Skin Carcinogenesis in Mice. *Cancer Lett* **1997**, 116, 197-203.
20. Apisariyakul, A.; Vanittanakom, N.; Buddhasukh, D.; Antifungal Activity of Turmeric Oil Extracted from *CurcumaLonga* (Zingiberaceae). *J Ethnopharmacol***1995,** 49, 163-169.
21. Ramirez. Tortosa, M.C.; Mesa, M.D.; Aguilera, M.C et al.; Oral Administration of a Turmeric Extract Inhibits Oxidation and Has Hypocholesterolemic Effects in Rabbits with Experimental Atherosclerosis. *Atherosclerosis***1999,** 147, 371-378.
22. Rafatulla, S.; Tariq M.; Alyahya, M.A. et al.; Evaluations of *Turmeric (CurcuminLonga*) For Gastric and Duodenal Antiulcer Activity in Rats. *J Ethnopharmacol***1990**, 29, 25-34.
23. Aggarwal, B.B.; Kumar, A.; Bharti, A.C.; Anticancer Potential of Curcumin: Preclinical and Clinical Studies. *Anticancer Res***2003**, *23*, 363-398.
24. Cheng, A.L.; Hsu, C.H.; Lin. J.K.; Hsu, M.M.; Ho, Y.F.; Shen, T.S.; Ko, J.Y.; Lin, J.T.; Lin, B.R.; Ming-Shiang, W.; Yu, H.S.; Jee, S.H.; Chen, G.S.; Chen, T.M.; Chen, C.A.; Lai, M.K.; Pu, Y.S.; Pan, M.H.; Wang, Y.J.; Tsai, C.C.; Hsieh, C.Y.; Phase I Clinical Trial Of Curcumin, A Chemo preventive Agent, In Patients With High-Risk Or Premalignant Lesions. *Anticancer Res***2001**, 21, 2895-2900.
25. Zhongfa, L.; Chiu, M.; Wang, J.; Chen, W.; Yen, W.; Fan-Havard, P.; Yee, L.D.; Enhancement of Curcumin Oral Absorption and Pharmacokinetics of Curcuminoids And Curcumin Metabolites in Mice. *Cancer Chemother Pharmacol***2012**, 69, 679-689.