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Formulation and evaluation of nanoemulsion for topical drug delivery system

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ABSTRACT
This study centers on the thorough assessment of optimal curcumin-loaded nanoemulsion formulations designed for improved topical administration. We extensively looked at important physicochemical factors such globule size, polydispersity index (PDI), pH, refractive index (RI), viscosity, and zeta potential. B3 had the smallest globule size (78.03 nm) and the lowest PDI (0.13) of all the formulations evaluated. This means that the dispersion was steady and uniform. Transmission electron microscopy corroborated spherical shape in alignment with particle size measurements. In vitro drug release experiments showed a sustained release profile, with formulation B3 having the maximum curcumin release (98.12% over 24 hours). Tests of stability at varied temperatures and humidity levels indicated that the droplet size, PDI, and other metrics changed very little over 90 days, which shows that the formulation is strong. These results indicate that formulation B3 is a good choice for stable and effective topical administration of curcumin.

Keywords: Nanoemulsion, Topical, FTIR, Transmission electron microscopy

I. INTRODUCTION

The skin is one of the most amazing and important parts of the body. It is very important for staying healthy and alive. The skin is the body's biggest organ. It covers the whole body and protects it from many outside hazards, such as dangerous germs, UV radiation, pollution, and physical traumas. The skin does a lot more than only protect us. It helps the body adjust to different weather conditions by producing perspiration and moving blood around. It is also a sensory organ with many nerve endings that let us feel touch, pressure, pain, and temperature [1]. This lets us safely and efficiently engage with the environment around us.The skin is also an important part of the immune system since it protects the body from viruses by being the first line of defense. When you get sunshine on your skin, it helps your body make vitamin D, which is good for your bones and immune system. It also helps the body get rid of waste through perspiration and keeps you hydrated by stopping you from losing too much water. The skin has several layers, each with its own cells and jobs that work together to keep it healthy [2-4]. Taking care of your skin is important because it is complicated and important. You need to do things like wash your hands, eat well, drink enough water, and protect your skin from hazardous things in the environment. Skin health is not just a sign of good physical health, but it is also intimately related to a person's emotional and social confidence, which makes it an important aspect of their entire quality of life [5].

Nanoemulsions are small droplets of oil in water or water in oil that are usually between 20 and 200 nanometers in size. Because their droplets are so minute, they seem clear or somewhat cloudy. They also offer special qualities including excellent stability, a larger surface area, and better bioavailability of active substances [6]. Nanoemulsions are often employed in the pharmaceutical, cosmetic, and food sectors to facilitate the delivery of poorly soluble medicines, enhance skin absorption in topical formulations, and improve the efficacy of nutrients. They are particularly useful in targeted medicine delivery and controlled release systems because they may encapsulate and preserve sensitive molecules [7].

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II. MATERIAL AND METHOD

2.1 FTIR Analysis

Using the KBr pellet method and an IR Prestige-21 spectrophotometer (Shimadzu, Japan), the FTIR spectra of curcumin was recorded. A 1:1 combination of curcumin and KBr was carefully mixed and pressed into a clear pellet. We looked at the spectra between 4000 and 400 cm^{-1} to find the distinctive absorption peaks of functional groups. We examined the spectra we got with reference data to make sure that curcumin was the right one and that its structure was still intact [8].

2.2 Analytical method

2.3 Calibration curve of curcumin in phosphate buffer at 7.4 pH

A standard calibration curve for curcumin was prepared using a solvent mixture of isopropyl alcohol and phosphate buffer (pH 7.4). From a 10 ml curcumin solution, 1 ml was diluted to 10 ml to make a 10 µg/ml stock solution. Serial dilutions were then performed to obtain concentrations from 1 to 18 µg/ml. The absorbance of each dilution was measured at 426 nm using a UV-Visible spectrophotometer. A calibration curve was plotted by graphing average absorbance values against the corresponding curcumin concentrations to determine its content accurately [9].

2.4 Formulation of nanoemulsion

The aqueous titration approach was used to make a drug-loaded nanoemulsion (NE). Oleic acid was the oil phase, Tween 80 was the surfactant, and PEG 400 was the co-surfactant. These three were chosen because they worked well together to make an emulsion. Since curcumin doesn't dissolve well in water (0.68 µg/ml), an oil-in-water (O/W) NE was made using a spontaneous emulsification method [10]. Using a vortex mixer (Nirmal International, Delhi, India), curcumin was combined with the oil phase. Then, Smix was added. The mixture was vortexed for 15 minutes and then gently heated to 40°C for 5 minutes to help it spread out. Adding distilled water slowly while swirling constantly made a transparent, isotropic, and stable nanoemulsion [11].

2.5 Tharmal stability examination

We performed thermodynamic stability experiments on the produced nanoemulsions (NEs) to see how well they could handle physical and chemical stress. We employed modified and verified procedures to check things like phase separation, clarity, droplet size, and medication content. We put the NEs through centrifugation, heat cycling, and freeze-thaw cycles to look for symptoms of instability, such as creaming, cracking, or precipitation. We tested the clarity and phase separation by looking at them, and we assessed the droplet size with dynamic light scattering. Analyzing the drug content showed that the active component was present and stable in the system. The results demonstrated that the nanoemulsions that were made were stable and could be stored for a long time [12].

2.6 Evaluation parameters of formulated nanoemulsion

2.6.1 Globule size and Polydispersity Index

A Zetasizer Nano-ZS90 (Malvern Instruments, UK) was used to assess the size of the globules and the polydispersity index (PDI) of the nanoemulsion. Before the analysis, around 50 µl of the formulation was mixed with 2 ml of distilled water [13]. To make sure it was correct and could be repeated, the droplet size distribution was tested three times. The mean droplet size and the PDI gave us information about how stable and even the nanoemulsion was. A lower PDI meant that the distribution of droplet sizes was more even, which meant that the formulation was more stable and homogeneous[14].

2.6.2 Transmission Electron microscopy (TEM)

We employed Transmission Electron Microscopy (TEM) to look at the shape and structure of the oil globules in the nanoemulsion (NE) formulations (CM 200, Philips, USA). We made a sample by mixing the NE with water at a 1:1000 ratio. For one minute, a drop of this diluted solution was put on a carbon-coated copper grid and stained with 2% w/v phosphotungstic acid to make the contrast better. The grid was looked at under a TEM after it had dried to find out the size, shape, and structural characteristics of the oil globules. This gave us a clear picture of the nanoemulsion's microstructure [15].

2.6.3 Refractive Index and Viscosity

Using an Abbe's refractometer (Precision Standard Testing Equipment Corp., Germany), we assessed the refractive index of the nanoemulsion (NE). This gave us reliable information on the formulation's optical characteristics. We also used a Brookfield viscometer (MCR101, Rheoplus, Anton Paar India Pvt. Ltd.) to measure the NE's viscosity. This helped us figure out how it flowed and how consistent it was. These measures are critical for

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figuring out how stable and easy to use the nanoemulsion [16].

2.6.4 pH and Transmittance

At 25°C, a calibrated pH meter (Mettler Toledo, Switzerland) was used to test the pH of the formed nanoemulsion (NE). This gave important information about how acidic or basic the formulation is, which impacts its stability and how well it works with skin. We also checked the NE's transmittance by putting 1 ml of the sample into a cuvette and measured it three times at 630 nm with a UV-Vis spectrophotometer (Shimadzu, Japan). This test helped figure out how clear and transparent the formulation was, which showed that it was homogeneous and didn't have any particles or aggregates that weren't dissolved [17].

2.6.15Zeta Potential

A Zetasizer Nano-ZS (Malvern Instruments, UK) was used to test the microemulsion's zeta potential at 25°C. This was done to look at the charge interactions between particles and check for stability. A greater absolute zeta potential value means that the electrostatic repulsion is stronger. This helps keep particles from sticking together and makes sure that the microemulsion is stable and uniform [18].

2.6.16Invitro drug release study

A Franz diffusion cell with an open glass cylinder was used to study the in vitro release of curcumin from nanoemulsions (NEs). A cellophane membrane, pre-soaked in phosphate-buffered saline (PBS, pH 7.4) for 24 hours, was coated evenly with 2 mg of the NE formulation. The donor compartment contained PBS (pH 7.4), and the setup was maintained at 37 ± 2 °C with stirring at 100 rpm to mimic physiological conditions. Samples of 1 ml were withdrawn at set intervals over 24 hours, and curcumin release was measured by UV spectrophotometry at 421 nm [19].

2.6.17Stability study

Three batches of optimal nanoemulsion (NE) formulations were created and kept in glass vials for stability testing according to International Conference on Harmonisation (ICH) standards. The samples were stored for three months under varying conditions: 25°C ± 2°C/60% ± 5% RH and 40°C ± 2°C/75% ± 5% RH. To keep an eye on stability over time, we looked at key metrics such droplet size, polydispersity index (PDI), viscosity, refractive index, pH, and transmittance at 0, 1, 2, and 3 months [20].

III. RESULTS AND DISCUSSION

3.1 FTIR Examination

FTIR spectra shows characteristic peaks of drug sample curcumin and almost matched when compared with standard reference asshowntheFigure 4.1

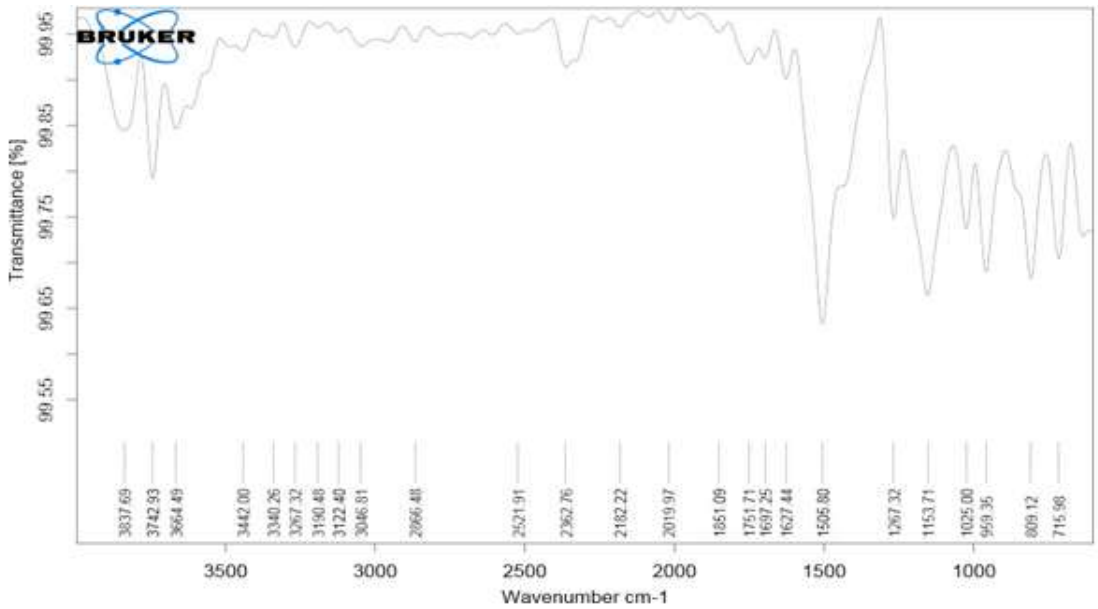

Figure 1: FTIR spectra of curcumin

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3.2 Preparation of standard calibration curve of curcumin

The calibration curve of curcumin in methanol and phosphate buffer was prepared according to the described procedure, and the outcomes are presented in Figure 2. The reversion coefficient (R^2) values obtained for curcumin in both solvents demonstrated excellent linearity within the selected concentration range. This confirms that the absorbance values were directly proportional to the concentration, indicating that UV spectrophotometric analysis is a reliable method for the quantitative estimation of curcumin. the linear equations and corresponding R^2 values for curcumin in methanol and phosphate buffer are summarized in Table 1, supporting the validity of the method. These findings establish that UV spectrophotometry can beeffectively utilized for routine analysis of curcumin in various formulations and research applications.

Table 1: Observation table for calibration curve

S. No.	Concentration (µg/ml)	Absorbance (at 426 nm)
1	**1**	0.092
2	**3**	0.280
3	**5**	0.465
4	**7**	0.650
5	**9**	0.840
6	**12**	1.120

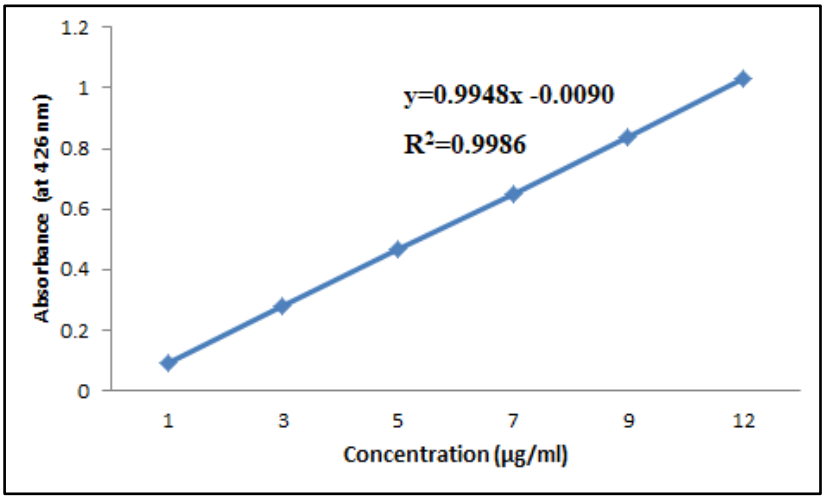

Figure 2: Calibration curve of curcumin in Phosphate buffer

3.3 Formulation of nanoemulsion

The aqueous titration approach was used to make nanoemulsion formulations that would improve medication penetration and skin deposition for efficient topical distribution. It is important to have the right amount of surfactant and co-surfactant since too much surfactant might irritate the skin. Tween 20 was chosen because it is a non-ionic surfactant that is less harmful and stable when the ionic strength and pH alter. Heuschkel et al. (2008) say that PEG-200 was employed as the co-surfactant because it decreases interfacial tension, which makes the interface more flexible and helps drugs diffuse. This thermodynamically favorable condition improves medication partitioning and diffusion while enabling lower doses of surfactant (Anarjan and Tan, 2013). The Smix ratios of 3:1 and 4:1 were left out because they might cause skin irritation due to excessive surfactant concentrations in the nanoemulsion area of the pseudo-ternary phase diagram. So, three Smix ratios were chosen for further study: 1:1 (A), 1:2 (B), and 2:1 (C). The findings are shown in Table 2.

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Table 2: composition nanoemulsion formulation

Smix ratio	Formulation code	Oil	Smix	Water
Batch A (Smix ratio 1:1)	A1	3.5	23.5	76
	A2	3	18	82
	A3	4.5	22	74
	A4	5	32	67
Batch B (Smix ratio 1:2)	B1	4	23	80
	B2	3	27	78
	B3	5	17	82
	B4	4	22	76
Batch C (Smix ratio 2:1)	C1	3	16	84
	C2	3.5	18	80.5
	C3	4	23	77
	C4	5	32	68

3.4 Thermodynamic stability

Nanoemulsions are kinetically stable systems that remain clear and uniform without phase separation when oil, surfactant/co-surfactant (Smix), and water are mixed in proper ratios. They resist instability signs like creaming under normal conditions. Stability tests such as heating–cooling cycles, centrifugation, and freeze-thawing help identify unstable formulations affected by Ostwald ripening. Only stable nanoemulsions were selected for drug loading. Curcumin was dissolved in the oil phase at 3 mg/ml, then water was added until a clear nanoemulsion formed. Among tested formulations, B3 showed the best stability and properties, making it the optimal choice for further studies.

3.5 Evaluation parameter of optimized nanoemulsion formulation

3.5.1 Globule size and Polydispersity Index Examination

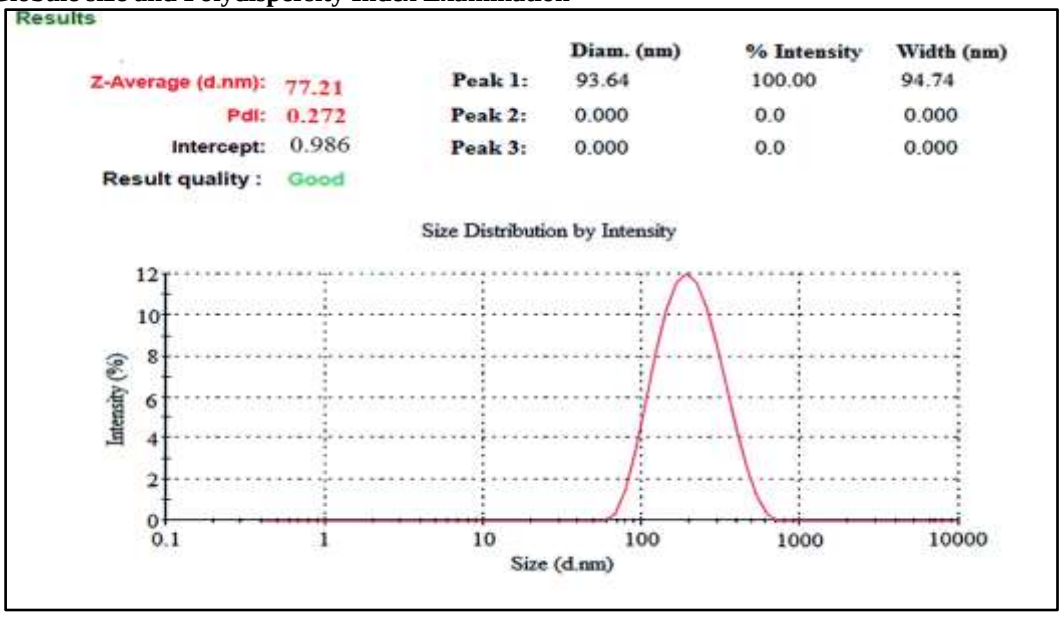

Figure 3: Globule size of optimized nanoemulsion formulation

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3.5.2 Transmission electron microscopy (TEM)

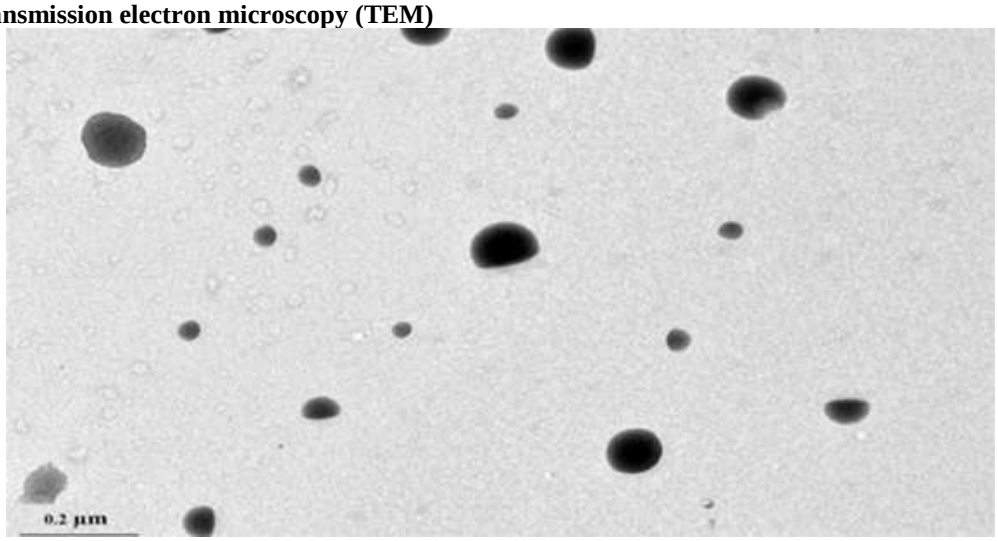

Figure 4: picture of TEM of optimized nanoemulsion formulation

Table 3: Results of evaluation parameter

Formulation code	Evaluation parameter				
	Particle size (mm)	PDI	pH	RI	Viscosity (mP)
A1	332.2±1.56	0.27±0.2	6.2±0.56	1.405±0.006	44.87±2.64
A2	158.8±1.89	0.22±0.7	6.5±0.36	1.407±0.008	52.82±2.87
B1	98.23±1.45	0.33±0.5	6.4±0.27	1.403±0.002	145.8±4.67
B3	78.03±1.75	0.13±0.4	6.6±0.34	1.401±.0.001	160.4±6.90
C1	133.2±1.45	0.21±0.8	6.7±0.64	1.408±0.004	154.9±2.87
C2	102.5±1.39	0.16±0.6	6.9±0.27	1.405±0.0024	140.5±5.87

3.5.3Zeta potential

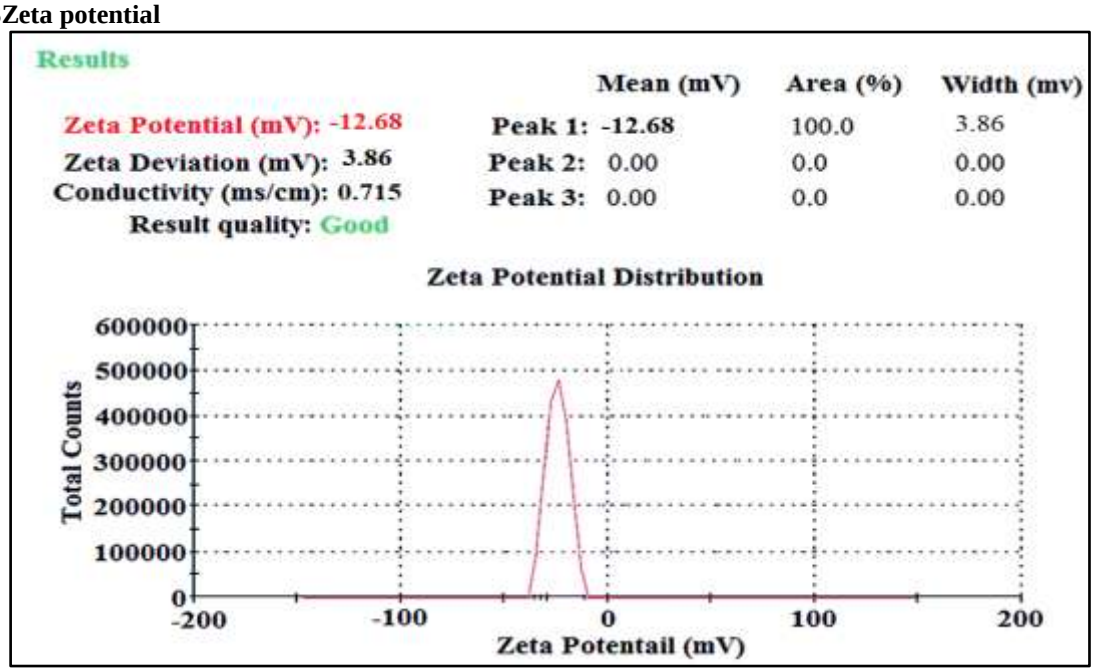

Figure 5: Zeta potential of optimized formulation

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3.5.4Invitro drug release

Table 4: Invitro drug release examination of optimized formulation

Time (hr)	Formulation code					
	A1	A2	B1	B3	C1	C2
0	0	0	0	0	0	0
4	24.09±0.76	23.92±0.72	25.76±0.74	28.90±0.45	22.87±0.76	21.67±0.67
8	48.04±1.76	47.87±1.53	49.87±1.26	52.76±1.83	43.86±1.26	43.87±1.23
12	62.65±0.14	64.62±0.25	65.76±0.81	68.09±0.16	61.98±0.24	60.76±0.25
16	72.76±0.87	75.90±0.76	74.76±0.62	78.12±0.76	76.89±0.34	74.98±0.62
20	83.71±0.85	82.92±0.76	84.77±0.61	88.22±0.36	84.80±0.31	81.98±0.64
24	90.73±0.23	91.22±0.36	94.57±0.11	98.12±0.36	94.88±0.33	92.93±0.61

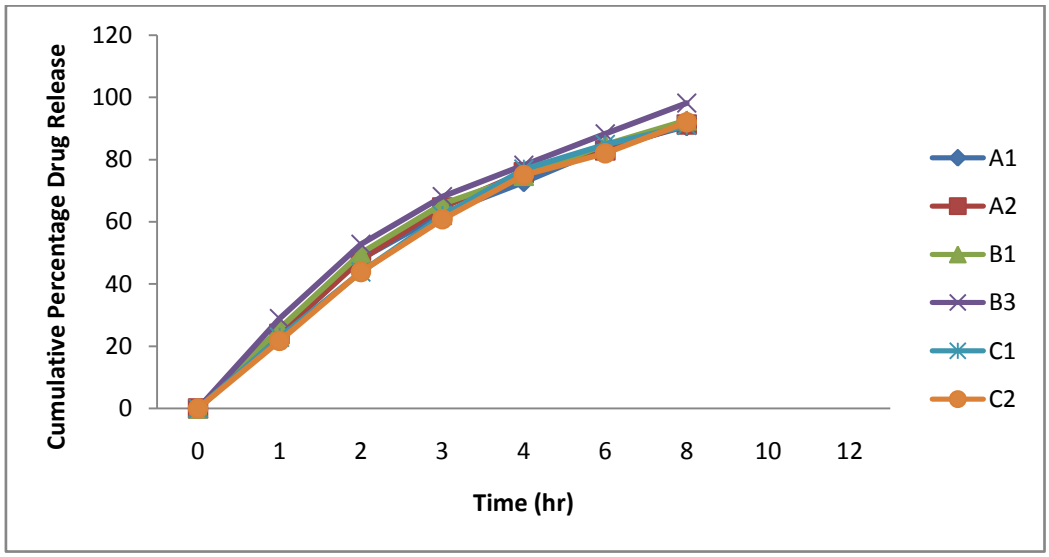

Figure 6: Invitro drug release examination of optimized formulation

3.5.5Stability study

Table 5: stability study of nanoemulsion formulations

T (°C)/RH (%)	Time (days)	Meandroplet size (nm)±SD	PDI±SD	pH±SD	RI±SD	V(cP)±SD	Transmittance (%)±SD
25°C±2°C /60%±5%	30	78.03±1.75	0.13±0.4	6.6±0.34	1.401±.0.001	160.4±6.90	98.45 ± 0.05
	60	83.2±3.1	0.88±0.049	6.2±0.18	1.427±0.018	155.9±4.54	97.38±0.33
	90	89.4±5.6	0.120±0.0.88	6.5±0.20	1.444±0.016	151.4±1.24	97.56±0.42
40°C±2°C /75%±5%	30	78.03±1.75	0.13±0.4	6.6±0.34	1.401±.0.001	160.4±6.90	98.45 ± 0.05
	60	102.0±4.3	0.90±0.085	6.4±0.18	1.449±0.017	135.20±1.53	98.13±0.23
	90	120.1±1.5	0.120±0.050	6.5±0.26	1.452±0.019	88.33±1.03	97.21±0.35

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3.6 Discussion

We used a number of physicochemical characteristics to characterize the improved nanoemulsion formulations. These factors are particularly important for determining their quality, stability, and applicability for topical drug administration. Globule Size and Polydispersity Index (PDI): The formulations' particle sizes ranged from around 78 nm (B3) to 332 nm (A1). Formulation B3 had the smallest droplet size and the lowest PDI value (0.13). A low PDI means that the sizes are more consistent and less spread out, which is good for better stability and controlled drug release. Formulations like B3 with smaller globule sizes help curcumin get into the skin better and become more available to the body. TEM examination (Figure 4.6) validated the spherical and homogeneous shape of the nanoemulsion droplets, supporting the size data acquired from the Zetasizer. The clarity and uniform shape shown reflect the formulation's stability and consistency. The refractive index (RI) readings were between 1.401 and 1.408, which means that the formulas were mostly the same and had good optical clarity. The viscosity tests showed that the formulations were different, with B3 having the maximum viscosity (around 160 mP). This can help the formulation stick to the skin better and keep the medicine in the body longer. But there needs to be a balance since too high viscosity might make it hard to disperse. The pH of all the formulations was between 6.2 and 6.9, which is safe for use on the skin and lowers the chance of irritation. High transmittance values (>97%) across formulations showed that the formulations were clear and didn't have any phase separation or turbidity, which showed that they were all the same. The zeta potential data (Figure 4.7) showed that the surface charge was strong enough to cause electrostatic repulsion between droplets, which keeps them from coming together and helps them stay stable over time. The in vitro release patterns (Table 4.8, Figure 4.8) demonstrated that curcumin was released steadily over 24 hours, with formulation B3 releasing the most overall (~98%). This means that B3 not only has the best physicochemical qualities, but it also has better drug release properties, perhaps because its droplets are smaller and the Smix ratio is better. Table 4.9 shows that formulation B3 kept its physicochemical parameters, such as droplet size, PDI, pH, RI, viscosity, and transmittance, for more than 90 days when tested under both accelerated and normal circumstances. There are little changes in droplet size and PDI when the temperature and humidity rise, which suggests that the formulation is becoming somewhat less stable, but not enough to alter its effectiveness. This shows that B3 is strong and can be stored for a long time.

IV. CONCLUSION

The improved nanoemulsion formulations exhibited advantageous physicochemical properties, such as reduced globule size, low polydispersity index, appropriate pH, and consistent refractive index, signifying homogeneity and stability. B3 had the smallest droplet size (78.03 nm), the lowest PDI (0.13), and the maximum viscosity (160.4 mP) of all the formulations tested. These factors made it more stable and consistent. TEM examination verified that the droplets were round, which backs up the size distribution data. The zeta potential values showed that the electrostatic stability was good enough to lower the probability of aggregation. In vitro drug release experiments showed that curcumin was released steadily, with formulation B3 having the greatest cumulative release (98.12% over 24 hours). Stability experiments confirmed the durability of B3 across various temperature and humidity settings, with negligible changes in physicochemical characteristics over a 90-day period. Overall, our results show that formulation B3 is a good choice for delivering curcumin via the skin with great stability and performance.

REFERENCES

[1]. Akhtar, M., Imam, S.S., Afroz Ahmad, M., Najmi, A.K., Mujeeb, M., Aqil, M., 2014. Neuroprotective study of Nigella sativa-loaded oral provesicular lipid formulation: in vitro and ex vivo study. Drug delivery 21, 487–494. Akhter, S., Jain, G.K., Ahmad, F.J., Khar, R.K., Jain, N., Khan, Z.I., Talegaonkar, S., 2008.

[2]. Investigation of nanoemulsion system for transdermal delivery of domperidone: ex-vivo and in vivo studies. Current Nanoscience 4, 381–390. Alexander A, Dwivedi S, Giri TK, Saraf S, Saraf S, Tripathi DK. Approaches for breaking the barriers of drug permeation through transdermal drug delivery.

[3]. Journal of Controlled Release. 2012; 164(1):26–40. Al-Harchan NA-AH (2010) Treatment of Acne Vulgaris with Nigella sativa oil lotion. Iraqi Academic Scientific Journal 9:140–144 Ali, A., Ali, S., Aqil,

International Journal of Pharmaceutical Research and Applications
Volume 10, Issue 3 May-June 2025, pp: 1750-1758 www.ijprajournal.com ISSN: 2456-4494

[4]. M., Imam, S.S., Ahad, A., Khan, A.Q., 2019. Thymoquinone loaded dermal lipid nano particles: Box Behnken design optimization to preclinical psoriasis assessment. Journal of Drug Delivery Science and Technology. Alvarez-Román, R., Naik, A., Kalia, Y., Guy, R.H., Fessi, H., 2004.

[5]. Skin penetration and distribution of polymeric nanoparticles. Journal of Controlled Release 99, 53–62. Anarjan, N., Tan, C., 2013.

[6]. Effects of selected polysorbate and sucrose ester emulsifiers on the physicochemical properties of astaxanthin nanodispersions. Molecules 18, 768 777. Aqil M, Kamran M, Ahad A, Imam SS. Development of clove oil based nanoemulsion of olmesartan for transdermal delivery: Box–Behnken design optimization and pharmacokinetic evaluation. Journal of Molecular Liquids. 2016 Feb 1; 214:238-48.

[7]. Ardigo M, Cota C, Berardesca E, González S. Concordance between in vivo reflectance confocal microscopy and histology in the evaluation of plaque psoriasis. Journal of the European Academy of Dermatology and Venereology. 2009; 23(6):660–7.

[8]. Barygina, V., Becatti, M., Soldi, G., Prignano, F., Lotti, T., Nassi, P., Wright, D., Taddei, N., Fiorillo, C., 2013. Altered redox status in the blood of psoriatic patients: involvement of NADPH oxidase and role of anti-TNF-α therapy. Redox Report 18, 100–106.

[9]. Bassett IB, Barnetson RSC, Pannowitz DL (1990) A comparative study of tea-tree oil versus benzoylperoxide in the treatment of acne. Medical Journal of Australia 153:455 458

[10]. Baur JA, Sinclair DA (2006) Therapeutic potential of resveratrol: the in vivo evidence. Nature reviews Drug discovery 5:493

[11]. Belhaj, N., Dupuis, F., Arab-Tehrany, E., Denis, F.M., Paris, C., Lartaud, I., Linder, M., 2012.

[12]. Formulation, characterization and pharmacokinetic studies of coenzyme Q10 PUFA's nanoemulsions. European Journal of Pharmaceutical Sciences 47, 305–312. Chainani-Wu N (2003) Safety and anti-inflammatory activity of curcumin: a component of tumeric (Curcuma longa).

[13]. The Journal of Alternative & Complementary Medicine 9:161–168 Chomnawang MT, Surassmo S, Wongsariya K, Bunyapraphatsara N. Antibacterial activity of Thai medicinal plants against methicillin-resistant Staphylococcus aureus.

[14]. Fitoterapia. 2009, 80:102–104 Collier CN, Harper JC, Cantrell WC, Wang W, Foster KW, Elewski BE. The prevalence of acne in adults 20 years and older. Journal of the American Academy of Dermatology. 2008 Jan 1;58(1):56-9.

[15]. Dange V, Dinde S, Doiphode A, Dhavane S, Dudhal B, Shid S, Yadav A. Formulation and Evaluation of Herbal gel Containing Lantana Camara for Management of Acne Vulgaris. Journal of University of Shanghai for Science and Technology. 2020; 22 (11): 799; 809.

[16]. de Vargas, B.A., Bidone, J., Oliveira, L.K., Koester, L.S., Bassani, V.L., Teixeira, H.F., 2012. Development of topical hydrogels containing genistein-loaded nanoemulsions. Journal of biomedical nanotechnology 8, 330–336

[17]. Arens EA, Zhang H. The skin's role in human thermoregulation and comfort. 2006; Armstrong AW, Read C. Pathophysiology, Clinical Presentation, and Treatment of Psoriasis: A Review. Jama. 2020; 323(19):1945–60.

[18]. Avasatthi V, Pawar H, Dora CP, Bansod P, Gill MS, Suresh S. A novel nanogel formulation of methotrexate for topical treatment of psoriasis: optimization, in vitro and in vivo evaluation. Pharmaceutical development and technology. 2016 Jul 3;21(5):554

[19]. Azeem, A., Rizwan, M., Ahmad, F.J., Iqbal, Z., Khar, R.K., Aqil, M., Talegaonkar, S., 2009. Nanoemulsion components screening and selection: a technical note. Aaps Pharmscitech 10, 69–76.

[20]. Babazadeh, B., Sadeghnia, H.R., Kapurchal, E.S., Parsaee, H., Nasri, S., Tayarani Najaran, Z., 2012. Protective effect of Nigella sativa and thymoquinone on serum/glucose deprivation-induced DNA damage in PC12 cells. Avicenna journal of phytomedicine 2, 125.