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Research Article

DESIGN AND CHARACTERIZATION OF FLUCONAZOLE MICROEMULSION FORMULATED WITH LEMONGRASS OIL

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ABSTRACT

The goal of the current investigation is to formulate Fluconazole loaded microemulsion (ME) with Lemongrass oil for deeper skin penetration and to obtain the dual benefit of drug and oil combination to improve antifungal efficacy of a drug with a reduced dose. We developed a Pseudo ternary phase diagram to identify the microemulsion zone by using the oil (clove oil), surfactant (Tween 20 and Tween 80), and co-surfactant (Propylene glycol) by water titration method. We formulated six different formulations (LM1 – LM6) by changing the oil/surfactant and cosurfactant ratio. The developed microemulsion formulation was characterized for various parameters % Transmittance, viscosity, pH, drug content, surface morphology, zeta potential, and in-vitro drug release study. The optimized microemulsion emulsion formulation is further converted into Microemulgel by dispersing the ME into 2% w/v Carbapol gel (LM-G) and further evaluated for various parameters. The antifungal efficacy was carried out for ME and Microemulgel by diffusion method against *Candida albicans* (MTCC no: 227) and compared with marketed gel which showed LM and LM-G have a better antifungal effect than marketed product, proved that the synergistic effect could be achieved by both clove oil and fluconazole drug by microemulsion formulation with deeper skin penetration effect.

KEYWORDS: Fluconazole, Lemongrass oil, Microemulsion (ME), Microemulgel, Pseudo ternary phase diagram, antifungal effect.

INTRODUCTION

Topical products are one of the most common forms of drug delivery systems, and their use in therapy is growing.[1] While topical formulations for treating ailments have been around since the beginning of time, using the skin as an alternate route for systemic and regional therapy is a relatively new entity[2]. Topical dosage forms aim to administer drugs to a specific area of the skin in a convenient manner. Hoar and Schulman first proposed the idea of microemulsion in the 1940s. It is characterized as a liquid micro-dispersion system made up of water, oil, and amphiphile that is optically isotropic and thermodynamically stable.[3-6]. While microemulsions can be used to deliver drugs through a variety of routes, they have been extensively studied as topical administration vehicles. Because of their ease of formulation, thermodynamic stability, and solubilization properties, microemulsions are appealing vehicles for drug delivery.[7-9]. Fluconazole, an engineered fluorinated bis-triazole subsidiary, is perhaps the most important antimycotic specialist with an expansive range and beneficial physical-synthetic properties, which guarantee a decent bioavailability and permit both oral and parenteral (i.v.) admiration. It is broadly utilized not just in serious fundamental mycoses of the peritoneum, lungs, urinary lot, and cryptococcal meningitis yet also in shallow, cutaneous, and mucous (buccal, oropharyngeal, esophageal, and vaginal) candidiasis. Fluconazole is accessible monetarily as cases for oral organization and as an answer for i.v. mixture. Contrasted and other azole subordinates (for example ketoconazole, itraconazole, miconazole), Fluconazole is less lipophilic (log P=0.5) and has expanded antifungal movement, watery solvency, and higher bioavailability, because of the presence of a halogenated phenyl ring and two triazole rings. The Fluconazole viability in the treatment of cutaneous mycosis by the oral organization has been credited to its quick and broad collection in the layer corneum, in this way the accomplished convergence of Fluconazole in the skin is higher than its fixation in the serum and as the base hindrance focus for most dermatophytes. The oral organization of Fluconazole is frequently connected with unfriendly impacts, particularly gastric problems including sickness, gastric disturbance, regurgitating, and stomach distress, which lessens the patient's consistency with long treatment. To beat this both, skin treatment of dermatomycosis utilizing a medication conveyance framework, which limits the Fluconazole at the level of the skin has been suggested. In the course of the most recent years, diverse dose structures including lip gels, amphiphilogels, hydrogels, emulsions, microemulsions, emulgels, microemulsion gels, and liposomal gels have been used.[10]

Lemongrass oil has been used for a variety of purposes in the past, including as an antifungal to assist in the killing of fungi. Lemongrass essential oil is said to send signals to the limbic system of the brain, which controls the nervous system when inhaled or absorbed through the skin. Essential oils, according to advocates of aromatherapy, can influence a variety of biological factors such as heart rate, stress levels, blood pressure, breathing, and immune function. Acne, anxiety, athlete's foot, excessive sweating, headaches, indigestion, and muscle aches are all common uses for lemongrass essential oil. Lemongrass essential oil is also said to be a natural insect repellent and air freshener, as well as a stress reliever and pain reliever.[11]

In this study, we tried to develop a new formulation of Fluconazole in microemulsion formulated with lemongrass oil for topical application which may lead to improvement in patient compliance. Microemulsions containing Fluconazole were formulated and examined for and in-vitro drug release of Fluconazole from the formulation.

MATERIALS AND METHOD

Fluconazole was acquired as a blessing gift from Karnataka antibiotic pharma. Ltd. Bangalore. Tween 20, Tween 80 and Propylene glycol (SD-Fine substance ltd, Mumbai), lemongrass oil (Swastik essential oil co., Ooty).

Development of pseudo ternary stage outline

The pseudo ternary stage graph was utilized to discover the present scope of microemulsions, and stage outlines were built utilizing the water titration strategy at encompassing temperature (25 ºC). Given the accessible dissolvability profile of the medication. The Lemongrass oil was chosen as an oil stage; Tween 20, Tween 80 were utilized as a surfactant, and Propylene glycol was utilized as a co-surfactant. The Smix (surfactant + Co-surfactant) proportions were chosen to be 1:1, 2:1, and 3:1 w/w and utilized. For each stage chart at explicit Smix focus and clove oil was added from a scope of 1:9, 2:8, 3:7, 4:6, 5:5, 6:4, 7:3, 8:2, 9:1 (%w/w) and the blend was weakened with refined water by the consecutive option of 0.1ml of water. The water was added drop by drop while blending on an attractive stirrer at room temperature, and the examples were set apart as being optically clear or turbid. The microemulsion areas were recognized as straightforward and isotropic combinations. The level of three unique stages oil, water, and a combination of surfactant and co-surfactant were determined (Table 1). From the endpoint synthesis of titrated tests, the mass percent piece of the segments like oil, Smix, and water was determined and afterward plotted on a three-sided organize to build the pseudo ternary stage diagram.[12]

The Solubility of Fluconazole

The Solubility was performed for the oil, surfactants, and co-surfactant for forming microemulsion. The solvency of the Fluconazole in oil is a fundamental advance for the microemulsion plan. So before building the stage outline one should need to choose the oil, surfactant, and co-surfactant in which the medication shows the most extreme solvency, to be in the ideal dissolvability range, which is fundamental for the detailing of a microemulsion drug conveyance framework. The powder medication of Fluconazole has included overabundance to every one of the oils, surfactants (S), cosurfactant (CoS), and afterward vortexed for blending. After vertexing, the examples were saved for 72 hours at the surrounding temperature for achieving harmony. The equilibrated tests were then centrifuged at 5000 rpm for 30 minutes to eliminate the undissolved medication. The supernatant was taken and weakened with methanol and saw by UV spectrophotometric strategy at 260 nm.[13]

Formulation Fluconazole microemulsion

Fluconazole stacked o/w microemulsion was set up by water titration technique. Surfactant and co-surfactant were blended in a fixed proportion and added into the water dropwise shown in Table 1. The medication was broken up in the oil stage and added dropwise in the above arrangement with nonstop blending. Permitted the answer for structure a reasonable and straightforward fluid, which was microemulsion. Then the prepared microemulsion formulation incorporated to 2% w/w carbopol 934. And evaluated the parameters like pH, viscosity, % drug content particle size and zeta potential, Surface morphology, compatibility studies, centrifugation). [14]

EVALUATION OF FLUCONAZOLE MICROEMULSION [15-19]

The prepared microemulsion formulation was characterized for parameters like Drug content, Particle size analysis, melting point, viscosity, Surface morphology, FT-IR analysis, Zeta potential. In-vitro drug release and In-vitro antifungal activity. The optimized formula was incorporated into 2% carbapol gel and evaluated for spreadability, rheological property, pH and In-vitro drug release, and In-vitro antifungal activity.

In-vitro release studies

An in-vitro drug release study was performed using diffusion cells. Egg membrane was placed between receptor and donor compartments. Microemulsion gel equivalent to 1 gm was placed in the donor compartment and the receptor compartment was filled with phosphate buffer pH 7.4. The diffusion cells were maintained at 37 ± 0.5 ℃ with stirring at 100 rpm throughout the experiment. At a fixed time, interval, 5 ml of aliquots were withdrawn for every 1, 2, 3, 4, 5, and 6 hrs from the receiver compartment through the side tube and analyzed by UV spectrophotometer at λ max 260 nm.

Antifungal activity against *Candida albicans*

Sample preparation: The samples were prepared using 100% DFM. The fungal strain used in this study was *Candida albicans* MTCC no: 227 The strain was used to determine the Antibacterial activity by well diffusion method.

Preparation of inoculums

The fungal strain was transferred from the stock solution to PDA agar and incubated for 48 hRS *at* 37°C. A single colony from the plate was transferred to the PD broth and incubated at 37˚C, for 48 h, and used as inoculums. The turbidity of the suspension was adjusted spectrophotometrically (range of 0.5–1.0) to the McFarland 0.5 turbidity standard (1.5×10^8 CFU/mL).

Antifungal activity by well diffusion method

The antifungal activity of given samples was investigated using the well-diffusion method. Test plates (diameter 10 cm) were prepared with 20 mL of PD agar (PDA). After the media get solidified, 100 µl of 48 h fungal culture (1.5×10^8 CFU/mL) was added and uniformly spread over plates using L shaped loop. Then make well (about 6mm diameter) and add 20 µL of Lemongrass oil, different concentrations of the given samples 5ug/ml drug, 80ug/ml gel, and 80 ul of formulations. The wells loaded with sterile media considered Blank. 30ug/40ul of marketed gel was used as a standard. After loading plates were kept in a sterile condition until complete absorption of the test compounds. Plates were incubated at 37°C in an appropriate gaseous condition for 48 hrs. Zones of inhibition of microbial growth around the well were measured and recorded after the incubation time. The inhibitory zone was considered the shortest distance (cm) from the outside margin of the samples to the initial point of the microbial growth.[20-21]

RESULT AND DISCUSSION

The pseudo ternary stage charts of different proportions of surfactants (Tween 20, Tween 80)/Co-surfactant (Propylene glycol) were utilized to develop. The Smix weight proportions [1:1, 2:1, 3:1] are addressed in Fig.1 to Fig.2 and Table 1, in pseudo-ternary stage graph where microemulsion regions are noticed by using Ternary plot.com software.

Table 1: Formulation development of Lemongrass oil -based Fluconazole microemulsion with selected percentages of oil, Smix, and water from the Pseudoternary phase

Formulation code	Smix ratio	Surfactants	Oils	Percent w/w component in formulation			
				Oil %	Smix %	Water%	Drug %
LM1	1:1	**Tween 80**	**Lemongrass oil**	20	45	35	0.5
LM2	2:1			30	45	25	0.5
LM3	3:1			30	41	29	0.5
LM4	1:1	**Tween 20**	**Lemongrass oil**	20	50	30	0.5
LM5	2:1			15	45	40	0.5
LM6	3:1			13	45	42	0.5

Table 2: Solubility of Fluconazole in different excipient solvents

Phase type	Excipient	Solubility mg/ml
Aqueous	Water	4.36±785
Oil	Lemongrass Oil	90 ± 0.073
	Clove Oil	50 ± 0.273
Surfactant	Tween 20	60 ± 0.370
	Tween 60	46 ± 0.435
	Tween 80	94 ± 0.279
Co-Surfactant	Propylene glycol	90.23 ± 0.083
	PEG 400	71.53 ± 0.16
Phosphate Buffer	pH1.2	00.63 ± 0.517
	pH 4.4	56.00 ± 0.141
	pH 6.8	40.93 ± 0.191
	pH 7.4	50.98 ± 0.029

Table 3: Determination of % transmittance, viscosity and pH, and % drug content of the microemulsion formulation

Formulation code	Transmittance	Viscosity cps	pH	% drug content
L111	94.62±0.71	15.67±0.35	5.86±0.05	95.69±0.15
L121	90.63±0.55	15.42±0.41	6.16±0.11	93.04±0.11
LM3	98.98±0.63	11.58±0.29	6.33±0.05	98.82±0.01
L311	97.90±0.73	17.67±0.81	6.70±0.20	85.32±0.01
L321	93.46±0.86	18.01±0.67	6.46±0.25	92.56±0.55
L331	95.75±0.31	20.10±0.25	6.03±0.20	80.94±0.05

Table 4: FTIR comparison of the characteristic peak of pure drug and formulation

Functional group	Wavenumber (cm^{-1}) of pure drug	Wave number (cm^{-1}) of LM3 formulation
-OH (Stretch)	3676.45	3470.06
C-F	1417.73	1458.23
C=C	1620.26	1637.67
C=N(Stretch)	1676.20	1672.34
C-H (Stretch)	2800.73	2866.32
C-H (Aromatic Stretch)	3018.03	3022.55

Table 5: *In-vitro* diffusion study of Lemongrass oil microemulsion

Time in hrs	% Cumulative drug release					
	L111	L121	LM3	L311	L321	L331
0	0	0	0	0	0	0
1	20.000	17.835	16.907	13.814	14.845	12.783
2	30.509	24.508	39.962	39.931	39.942	39.921
3	51.224	30.421	62.628	52.288	62.608	60.525
4	60.282	74.817	70.738	60.263	67.604	70.635
5	70.236	81.311	80.827	77.405	79.683	84.765
6	79.630	89.375	90.505	82.701	89.268	87.701

Table 6: Viscosity, pH and % drug content of microemulsion gel

Formulation code	Spreadability	Viscosity	pH	% drug content
LM3-G1	7.3 ± 0.03	6898.72 ± 64.13	6.4 ± 0.23	91.68 ± 0.16

Table 7: Antifungal effect of microemulsion formulation and oils against *C. albicans*

Components	Quantity	Zone of inhibition in cm
Drug (Fluconazole)	5µg/ml	2.8
Standard (marketed product)	40 µl	1.5
Lemongrass oil	20 µl	2.6
Microemulsion LM3	80 µl/ml	3.5
Microemulsion gel LM3-G	80 µg/ml	2.5

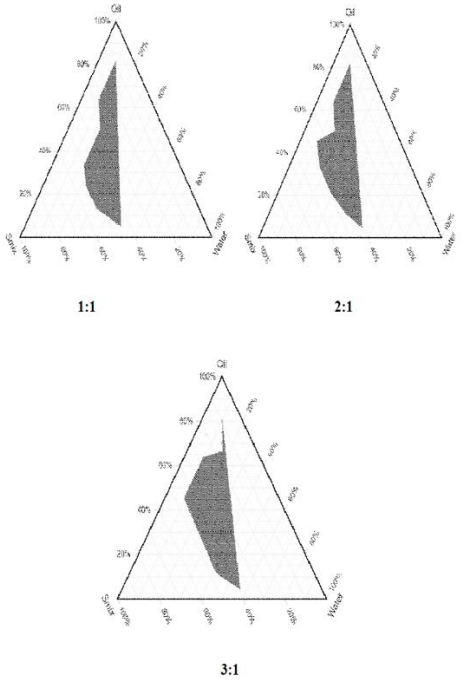

Figure 1: Pseudo ternary phase diagram using Lemongrass oil as oil, Tween 20 as a surfactant, propylene glycol as co-surfactant, and water (Tween 20: Propylene glycol = 1:1, 2:1 and 3:1).

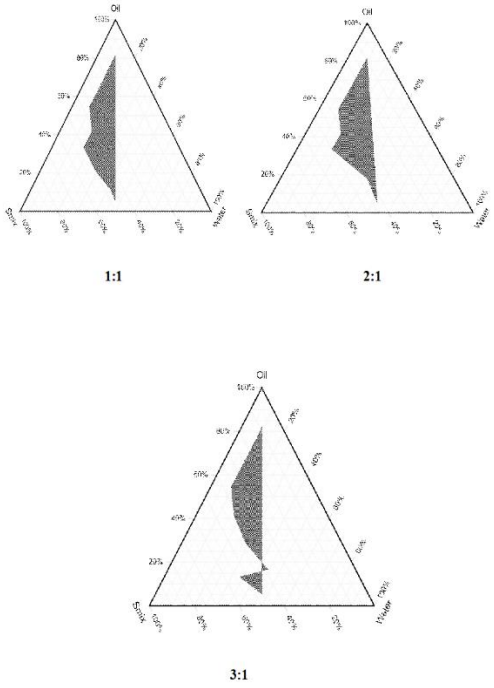

Figure 2: Pseudo ternary phase diagram using Lemongrass oil as oil, Tween 80 as a surfactant, propylene glycol as co-surfactant, and water (Tween 80: Propylene glycol = 1:1, 2:1 and 3:1).

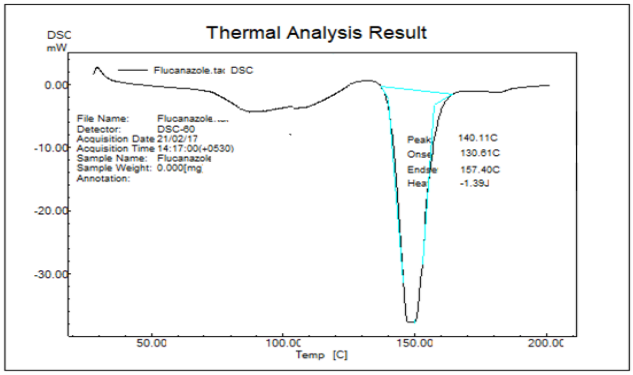

Figure 3: DSC Thermograph of Fluconazole

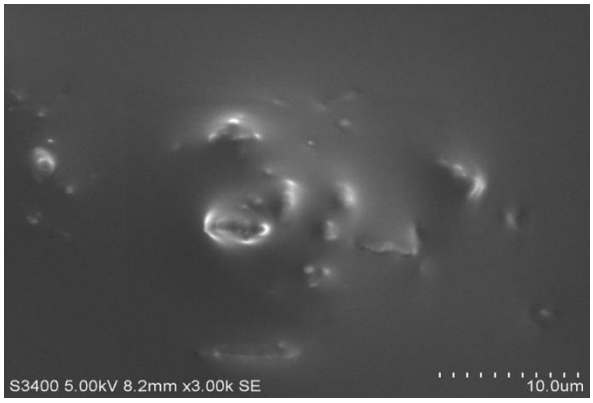

Figure 4: SEM image of LM3

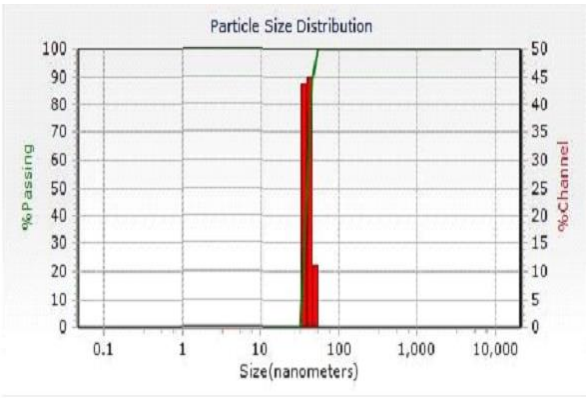

Figure 5: Result of particle size of the formulation LM3.

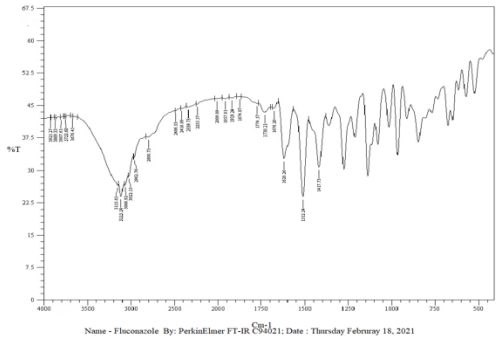

Figure 6.1: FTIR spectra of Fluconazole

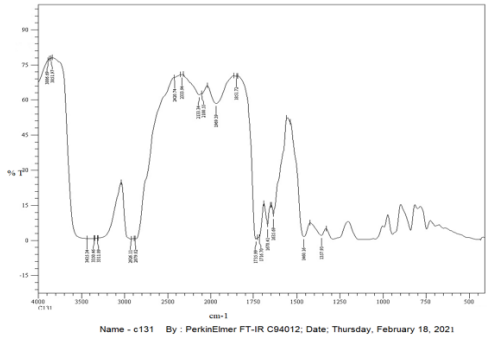

Figure 6.2: FTIR spectra of LM3 formulation

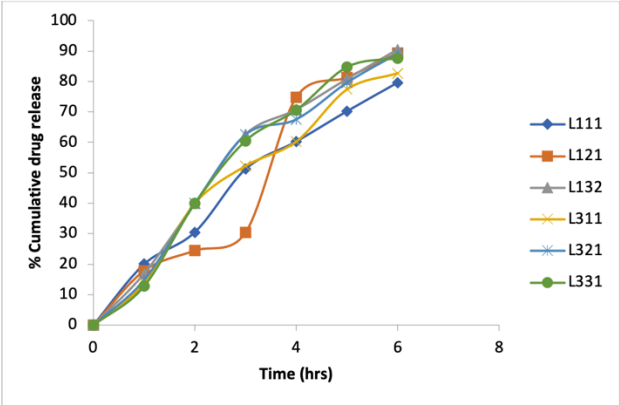

Figure 7: Comparison of % cumulative drug release of LM1-LM6

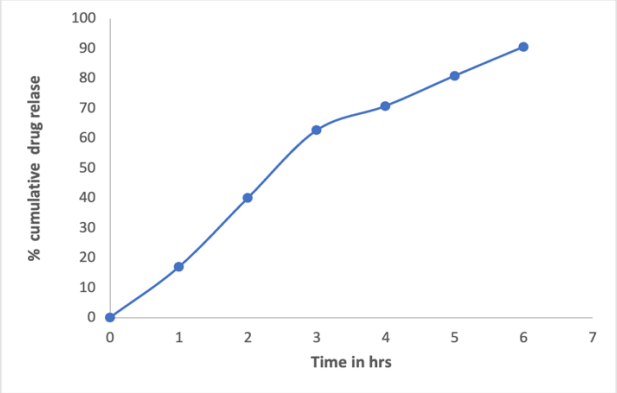

Figure 8: % cumulative drug release of LM3-G1

Figure 9: The Antifungal activity of (A) Lemongrass oil with drug (B) Microemulsion LM3 and gel LM3-G against ***Candida albicans*** **using well-diffusion method.**

The optimized microemulsion LM3 was formulated into a gel by the use of Carbopol 934 gels containing 2% w/w gel was found to be suitable for gelling the microemulsion because of desirable consistency. And the optimized formulation was further evaluated for spreadability, viscosity, pH, and percentage assay as shown in Table 6.

The Fluconazole melting point was found to be 138 ℃ by Thiel's method and 140.11 ℃ by DSC (Fig.2) method which complied with IP standards, thus indicating the purity of the drug.

The greatest solvency of fluconazole in surfactants was found in Lemongrass oil (90 ± 0.073) Tween 80 (94 ± 0.279mg/ml), Tween 20 (60 ± 0.370mg/ml) and co-surfactant propylene glycol (90.23 ± 0.083mg/ml) and furthermore dissolvable in pH 7.4 phosphate buffer (50.98 ± 0.029mg/ml). Shown in Table 3.

The drug content of all the formulations of fluconazole microemulsion is shown in Table 3. LM3 was exhibited 98.82±0.01 higher drug content than other formulations. The microemulsion drug content of all formulations was found to be within the range of 85-99% which was within the limits of USP specifications. The prepared Fluconazole microemulsion gel LM3-G was subjected to drug content uniformity. The microemulsion gel was in the permissible range of 93.45 ± 0.73% it indicated the drug was uniformly dispersed throughout the formulation. (Table 6).

All the prepared formulations were checked for their pH. All the formulations were showing pH in the range of 5.86 to 6.70 as shown in Table 3. This is well in the range for topical administered formulation and formulation. The pH value of optimized microemulsion formulation LM3 was 6.33±0.05 (Table 3) and is suitable for topical as well as a transdermal application because of the pH of the skin in the range of 5.5 to 7.0. The pH of microemulsion gel LM3-G gel was found to be 6.3 ± 0.36. (Table 6) and is suitable for topical as well as transdermal application.

The clarity of the microemulsion formulation was checked by % transmittance. All formulations of transmittance values are above 90% as shown in Table 3, which indicates that the microemulsions were transparent which is considered as the primary property of a microemulsion. The LM3 formulation showed 98.98 ± 0.63% compare to other formulations.

The viscosity of microemulsion formulation was determined as shown in Table 3, all samples exhibited Newtonian flow behavior and formulation LM3 showed 11.58 ±0.29 cps shows less viscous compared to other microemulsion formulations. And the optimized gel LM3-G viscosity was found to be 6898.72 ± 64.13cps. (Table 6).

The surface morphology was studied by SEM for the optimized formulations which were confirmed that the particles are globular with globule size in the nanometre scale with a smooth surface as shown in Fig. 4, for LM3. This can have the ability to form a microemulsion.

The particle size and zeta potential were measured by a Marwin zeta analyzer and it was Found that 48.80 nm for LM3. Confirmed that microemulsions are within the required size ranges confirmed. The Zeta potential of microemulsion LM3 was found to be 32.70 Mv (Fig.5) which shows that they are adequate to be stable.

FTIR Spectrum of Fluconazole was obtained by scanning the drug in the range of 4000 to 400. Major peaks observed were as 3676.45, & 3470.06 cm-1 (-OH Stretch), 1417.73, & 1458.23 (C-F),1620.26 & 1637.67 cm-1 (C=C), 1676.20, & 1672.34 cm-1 (C=N Stretch) and 2800.73, & 2866.32 cm-1 (C-H Stretch), and, 3018.03 & 3022.55 cm-1 (C-H Aromatic Stretch) whose presence resembled the structure of Fluconazole. Observed FTIR spectra and standard values were as depicted in Fig. 6.1, 6.2, and Table 4. The observed value was within the range or very close to the characteristic peaks of standard value confirming the drug as Fluconazole. And there is no interaction between drugs and other components.

The cumulative drug content permeated from the membrane for all microemulsion formulations was calculated. In-vitro release profiles of Fluconazole across the membrane from the microemulsion system were carried out by diffusion method for 6 hrs and results are depicted in Table 5, for Lemongrass oil-based Fluconazole microemulsion. From the results, we observed that 0 - 16% of the drug was released in 1 hr and more than 50% drug release in 3 hrs, and more than 80% of drug released in 6 hrs for all the formulations. It was observed that higher drug release of 90.50% for LM3 formulation and a very lower release of 79.63 % for LM1 formulation (Fig.7). The result of the in-vitro release of fluconazole from the gel formulation. However, the results clearly show that the gels can retain the drug for prolonged periods. The % CDR of microemulsion gel formulation LM3-G was found to be 90.50 %, respectively as shown in Fig. 8.

The spreadability is an important property of topical formulation from a patient compliance point of view. The increase in the diameter due to spreading of the formulation g LM3-G1 was 7.1 ± 002. Which is good for topical application.

In-vitro antifungal effect to evaluate the efficacy of optimized formulations, oils, and drugs against antifungal evaluation was carried out using fungal strain *Candida albicans MTCC no: 227.* The antifungal activity by the well-diffusion method was performed at a concentration of 80 µg/ml gels and sterile media as blank, marketed product as standard placed in well and measured zone of inhibition. *Candida albicans* was used as a standard fungus that has shown in Fig. 8. The antifungal activity by the well-diffusion method was performed, that shown in Fig. 8. The zone of inhibition was to be for drug 2.8 cm (5µg/ml), standard 1.5 cm (40 µl) Lemongrass oil 2.6 Cm (20 µl), Microemulsion LM3 3.5cm (80 µl), Microemulsion gel LM3 2.5cm (80 µl) shown in Table 7 & (Fig 9). The LM3 and LM3-G show a greater antifungal effect compare to marketed product.

CONCLUSION

In this investigation, the optimized formulation of LM3 microemulsion and Microemulgel LM3-G showed a good antifungal effect of Fluconazole along with essential oil like Lemongrass oil to be formulated as microemulsions, compared with other microemulsion formulation and marketed gel, LM3 and LM3-G have a better antifungal effect than marketed product, this proved that the synergistic effect could be achieved by both clove oil and fluconazole drug by microemulsion formulation with deeper skin penetration effect.

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REFERENCES

1. Shah VP, Behl CR, Flynn GL, Higuchi WI, Schaefer H. Principles and criteria in the development and optimization of topical therapeutic products. J pharm sci. 1992 ;81(10):1051-4.
2. Jadhav KR, Shetye SL, Kadam VJ. Design and evaluation of microemulsion based drug delivery system. Int. j Adv pharm Sci. 201;1(2).
3. Lindman B, Danielson I. The definition of microemulsion. Colloid Surf. 1981;3(391392.3).
4. Tenjarla S. Microemulsions: an overview and pharmaceutical applications. Crit. Rev. Ther. Drug Carrier Syst. (1999) 16: 461-521.
5. Lawrence J and Rees G. Microemulsion-based media as novel drug delivery systems. Adv. Drug Deliv. Rev. (2000) 45: 89-121.
6. Shah RR, Magdum CS, Patil SS, Niakwade NS. Preparation and evaluation of aceclofenac topical microemulsion. Iranian j pharm res: IJPR. 2010;9(1):5.
7. Santos P, Watkinson AC, Hadgraft J, Lane ME. Application of microemulsions in dermal and transdermal drug delivery. Skin Pharmacol Physiol 2008;21: 246–59. DOI: 10.1159/000140228.
8. Hadgraft J, Guy RH. Transdermal drug delivery: Developmental issues and research initiatives. J drug pharm sci. 1989;35.
9. Singh K.M., Chandel V., Gupta Vandana and SumanRamteke.: Formulation Development and Characterization of Microemulsion for Topical Delivery of Glipizide. Der Pharma letter, (2010) 33-42.
10. Oliveira MB, Calixto G, Graminha M, Cerecetto H, González M, Chorilli M. Development, characterization, and in-vitro biological performance of Fluconazole-loaded microemulsions for the topical treatment of cutaneous leishmaniasis. BioMed. Res Int. 2015; 2015:1-12.
11. Wuthi-Udomlert M, Chotipatoomwan P, Panyadee S, Gritsanapan W. Inhibitory effect of formulated lemongrass shampoo on Malassezia furfur: a yeast associated with dandruff. Southeast Asian J Trop Med Public Health. 2011(2):363-9. PMID: 21710859

12. Madikattu K, Naidu SV, Srisailam K. Microemulsion based transdermal gels of Isradipine to enhance bioavailability: In-vitro and in vivo evaluation. Asian J Pharm., 2016; 9(5): 23-30.
13. Samrudhi P and Padmini R. Honey based Clotrimazole microemulsion for topical delivery. Indo American J Pharm Res., 2016; 6(11): 6908-25.
14. Shah RR, Magdum CS, Patil SS, Niakwade NS. Preparation and evaluation of aceclofenac topical microemulsion. Iranian j pharm res: IJPR. 2010;9(1):5.
15. Muzaffar FA, Singh UK, Chauhan L. Review on microemulsion as futuristic drug delivery. Int J Pharm Pharm Sci. 2013;5(3):39-53.
16. Peira E, Carlotti ME, Trotta C, Cavalli R, Trotta M. Positively charged microemulsions for topical application. Int j pharm. 200;346(1-2):119-23.
17. Okur NU, Yavasoglu A, Karasulu HY. Preparation and evaluation of microemulsion formulations of Naproxen for dermal delivery. Chem Pharm Bull., 2014; 62(2): 135-43.
18. Hu L, Wu H, Niu F, Yan C, Yang X, Jia Y. Design of fenofibrate microemulsion for improved bioavailability. Int j pharm. 2011;420(2):251-5
19. Dev A, Dwivedi J, Momin M. Formulation and characterization of acyclovir based topical microemulsions by QBD approach. J. drug deliv. ther. 2019;9(1):237-43.
20. Tandel H, Patel P, Jani P. Preparation and study of Efavirenz microemulsion drug delivery system for enhancement of bioavailability. European J Pharm Med Res., 2015; 2(5): 1156-74.
21. PATEL TB, Patel TR, Suhagia BN. Preparation, characterization, and optimization of microemulsion for topical delivery of itraconazole. J. drug deliv. ther. 2018;8(2):136-45.

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