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Encapsulation process of avobenzone in solid lipid microparticles by hot emulsification

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Abstract

Solid lipid microparticles (SLMs) containing significant amounts of the sunscreen ingredient butyl methoxydibenzoylmethane (avobenzone) were created in order to improve drug photostability. Numerous strategies, such as encapsulation, antioxidants, photostabilizers, and quenchers, have been employed to address the problems of photostability.A variety of methods have been used to find safe and efficient sunscreen ingredients in an effort to find the gold standard for photoprotection in medications that are photosensitive. Avobenzone was photostabilized via a solvent-free hot emulsification process using carnauba wax as the encapsulating medium.The encapsulation process produced a high efficiency since 96.41% of the avobenzone was successfully incorporated into the carrier system, resulting in a high encapsulation efficiency from the proposed procedure. The objective of study to provide drug delivery strategies applied for relatively high incorporation efficiency to reduce the sunscreen concentration needed, adequate microparticle size that precludes skin absorption and provides aesthetically pleasing qualities and controlled release of the sunscreen according to a biphasic pattern last over an in use relevant period of time which could be useful for photo unstable use of avobenzone.

Keywords: Avobenzone; Solid Lipid Microparticles; Lipospheres; Photodegradation; Carnauba Wax; Encapsulation.

1. Introduction

The quest for essential photo protection is a critical focus in dermatological research, encourage by growing knowledge of the damaging effects of ultraviolet (UV) radiation on skin health[1-2] UV radiation is known to cause various skin ailments, including sunburn, photoaging, and an elevated risk of skin cancer. Consequently, sunscreens have become an indispensable component of daily skincare regimens.[3-4]. There are two types of UV filters used for photoprotection. Dermatologists classified UV filters as inorganic and organic agents. Organic filters absorb a narrow band of ultraviolet radiation (UVR), whereas for inorganic filters, the interaction of absorption and scattering results in “wide spectrum” (UVA and UVB) protection [5,6,7]

Among the active ingredients in sunscreens, avobenzone (AVO) is widely recognized for its broad-spectrum UV protection, particularly against UVA rays. It is approved by the regulatory agencies of USA, Europe, Australia, and Japan.[8,9,10] Avobenzone has a high absorptivity in the UVA area, but when exposed to sunlight, it decomposes significantly, lowering the amount of UV protection that is expected after applying sunscreen.[11-12] Furthermore, free radicals produced by its photolysis have the potential to directly or indirectly harm skin. As a result, avobenzone's photostability have a limitation on suncare product formulation.[13,14,15] However, the stability and efficacy of avobenzone are often compromised by photodegradation and formulation challenges. Several strategies have been developed in order to reduce the instability of avobenzone under sunlight, such as inclusion complexation with cyclodextrins, incorporation in polymeric or lipid microparticles. [16-17] It has been demonstrated that carrier systems

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can improve the photostability of UVA filters; nevertheless, their low loading capacity (between 4 and 20% w/w) makes them less useful for final sunscreen preparations.[15 ,18.]

Microparticle technology presents a promising solution to improving the stability and performance of sunscreen formulations.[19-20]. The benefits of nanoengineering, nanotechnology is being included in conventional skin-care products. Carrier (polymeric NPs, SLNs, microparticles,reservoir systems, and liposomes) based sunscreens outperform conventional sunscreens in four ways. first, they are effective UV filters that can block and absorb UV radiation;second, they pack firmly on the skin for a uniform coating; third, because they are so small, they disappear into the skin, leaving no noticeable residue; and fourth, they can be combined in oil-free preparations for elegant cosmetic purposes.[21-22] By encapsulating active ingredients like avobenzone within microparticles, it is possible to protect them from direct UV exposure, reduce degradation, and potentially improve the overall photostability and efficacy of the sunscreen [15,23,24] The hot emulsification process is a well-established method for creating stable microparticle-loaded emulsions, offering advantages such as controlled particle size distribution and enhanced stability of the active compounds.[15,25]

This study aims to develop and characterize avobenzone microparticle-loaded sunscreen using the hot emulsification process. The primary objectives are to evaluate the encapsulation efficiency, photostability, relatively high incorporation efficiency to reduce the sunscreen concentration needed, adequate microparticle size that provides skin absorption and provides acceptable aesthetic property by controlled release mechanism and UV protection efficacy of the formulated sunscreen, Additionally, the study will investigate the physicochemical properties of the emulsions, including particle size, distribution, and morphology, to understand the effect of microparticle encapsulation on the overall performance of the sunscreen. By integrating avobenzone into a microparticulate system through hot emulsification, this research seeks to contribute to the advancement of more effective and stable sunscreen formulations. The findings have the potential to enhance the protective capabilities of sunscreens, providing improved skin health benefits and broadening the scope of photoprotection strategies in cosmetic and pharmaceutical applications.

2. Material and Methods

2.1. Chemicals and instruments

In this study, a sample of avobenzone (butyl methoxydibenzoylmethane) was procured from KVL Global Solution, Mumbai. Stearyl alcohol, polysorbate 80 (Tween 80), ethanol, and methanol were obtained from S.D. Fine Chemicals, Mumbai. Carnauba wax was sourced from Phospholipid GmbH Nattermann Lee, Germany. Deionized water was used throughout the experiments. All chemicals and reagents were of analytical grade and used as received without further purification.

For the preparation of microparticles, a homogenizer (IKA® ULTRA-TURRAX®) was employed to ensure uniform particle size distribution. The viscosity of the particle emulsion was measured using a Brookfield viscometer, Model DV-E (Brookfield Engineering Lab, Inc., USA), which provided precise viscosity readings crucial for process optimization. A hot plate (IKA®C-MAG HS,Merk) was used to maintain the required temperature during the formulation process. The morphology and size of the microparticles were examined using an optical microscope (Accu-scope,US), allowing for detailed visual inspection. Additionally, a double beam spectrophotometer was utilized for analytical assessments of the microparticle samples.

2.2. Liposphere preparation

Lipid particles (LPs) were prepared using the hot emulsification method.(15, 21, 26). The lipid phase comprised carnauba wax, stearyl alcohol, and the UV filter Avobenzone. Carnauba wax was melted in a silicon oil bath at 85°C before incorporating and dissolving the UV filter(Avobenzone). The aqueous phase consisted of 200 mL of water with polysorbate 80, heated to 90°C. The concentrations of stearyl alcohol, polysorbate 80, and Avobenzone were determined based on the experimental design (Table 1).

The lipid phase was introduced into the aqueous phase under constant stirring using a homogenizer (IKA® ULTRA-TURRAX®), with the temperature maintained at 85°C, resulting in an oil-in-water (O/W) emulsion. During emulsification, the oil bath temperature was held at 125°C for approximately 2 minutes to prevent solidification of the wax on the container surfaces and to enhance the sphericity of the microparticles (MPs). Rapid hardening of the wax and MP formation were achieved by adding an equal volume of ice-cold water (4°C) to the emulsion. Stirring continued

until the mixture cooled to room temperature (25°C). The MPs were washed three times with 100 mL of distilled water and then air-dried for 48 hours. Finally, the MPs were collected and stored in a desiccator at room temperature (25°C).

3. Result and Discussion

Table 1 Selection of external phase

Formulation batches	External phases	Comments
C-1	Polyvinyl alcohol(0.5%w/v)	Microparticle were not formed
C-2	Sodium lauryl sulphate (0.1%w/v)	Microparticle were not formed
C-3	Tween 80(1% v/v)	Irregular shaped particles
C-4	Tween 80(3%v/v)	Spherical and uniform in size
C-5	Tween 20	Irregular size particle

Among the various external phases studied, polyvinyl alcohol and sodium lauryl sulfate did not form microparticles. Microparticles prepared with Tween 80 (1%) and Tween 20 were irregular in shape. However, microparticles prepared with Tween 80 (3%) were spherical and uniform. Therefore, Tween 80 (3% v/v) was selected as the external phase for the formulation study.

Table 2 Different batches were prepared using carnauba wax, stearyl alcohol, Avobenzone, and Tween 80 in varying concentrations to achieve uniform particle size. The components were systematically varied according to the experimental design to optimize the formulation.

Formulation batches	Carnauba wax concentration	Stearyl alcohol concentration (%w/w)	Drug concentration (mg)	Tween 80 concentration (%w/w)	comments
A-1	5gm	3.0	1000	3.0	Microparticle not form
A-2	5gm	3.0	100	1.0	Powder form microparticle
A-3	5gm	1.0	100	3.0	Very fine microparticle
A-4	5gm	2.0	450	2.0	Rough microparticle
A-5	5gm	1.0	450	2.0	Irregular shape formed
A-6	5gm	1.0	100	1.0	uniform particles are form
A-7	5gm	1.0	1000	1.0	Un-uniform microparticle are form
A-8	5gm	1.0	1000	3.0	Not spherical microparticles
A-9	5gm	3.0	1000	1.0	Irregular shape formed

Batch no. A6 provides a uniform particle size with a concentration of 5g of carnauba wax, 1% w/w of stearyl alcohol, 100 mg of avobenzone, and 1% w/w of Tween 80.

3.1. Screening of polymer

The screening of polymers process to identify the most suitable candidates for achieving optimal particle size and stability in the formulation. Various polymers were evaluated based on their compatibility with the lipid matrix, ability to stabilize the emulsion, and impact on particle size distribution. Factors such as solubility, viscosity, and interaction with other formulation components were also considered. The selected polymers were incorporated into the formulations, and their effects on the characteristics of the lipid particles were analyzed as shown in Table 1

3.2. Effect of stirring rate on particle size of microparticles.

The effect of stirring rate on the particle size of microparticles was systematically investigated. Different stirring rates were applied during the emulsification process to determine their impact on particle size distribution. Higher stirring rates generally led to smaller particle sizes due to increased shear forces, promoting better dispersion and reducing coalescence of droplets. The relationship between stirring rate and particle size was analyzed to optimize the process conditions for uniform and stable microparticles. As shown in table 4

3.3. Spectrophotometric Method for Estimation of Avobenzone in Methanol

A spectrophotometric method was developed to estimate Avobenzone in methanol. A solution of 10 µg/mL was scanned, revealing maximum absorbance at 357 nm, which was determined as the λ max. as shown in Table 3

Table 3 Spectrophotometric Method for Estimation of Avobenzone in Methanol

Concentration (µg/ml)	Absorbance
1	0.098
2	0.217
3	0.31
4	0.41
5	0.52
6	0.62
7	0.72
8	0.82
9	0.92
10	1.022

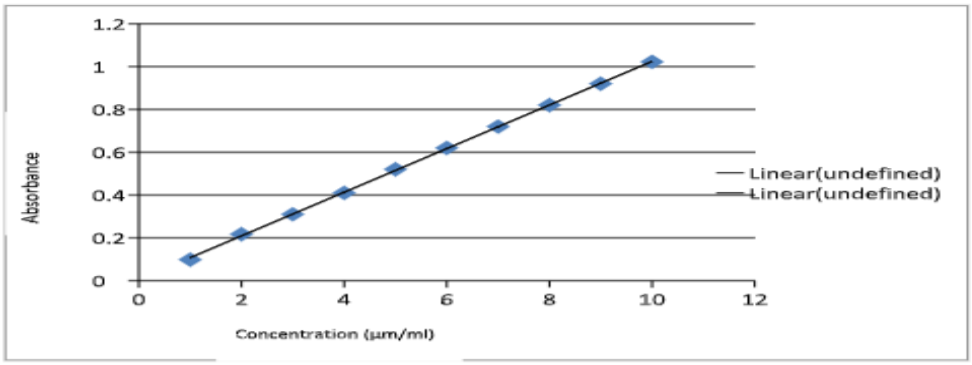

Figure 1 Standard Calibration Curve of avobenzone in Methanol

Table 4 Effect of stirring rate on particle size of microparticles**.**

Formulation of batches	Stirring rate (RPM)	Particle size (µm)	% Yield
B-1	500	-	
B-2	2500	23.12	89.73
B-3	3500	14.20	86.67
B-4	4500	9.46	81.34
B-5	5500	5.34	68.12

At 500 RPM, the polymer precipitated, preventing the formation of microparticles due to the insufficient speed to break the polymer solution into smaller emulsion droplets necessary for solid microparticle production. Increasing the stirring rate from 2500 to 5500 RPM resulted in decreased particle size but also reduced the percentage of practical yield. Therefore, 3500 RPM was selected as the optimum stirring rate for microparticle formulation. There is an inverse relationship between particle size and yield as stirring rate increases. As shown in Figure No.1

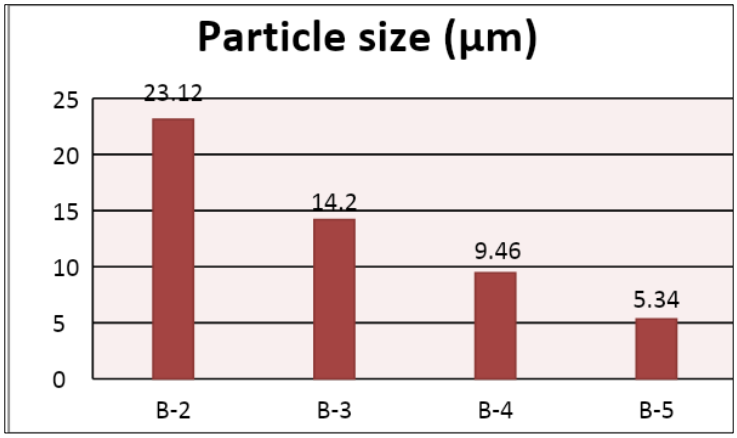

Figure 2 Comparison of average particle size of microparticles

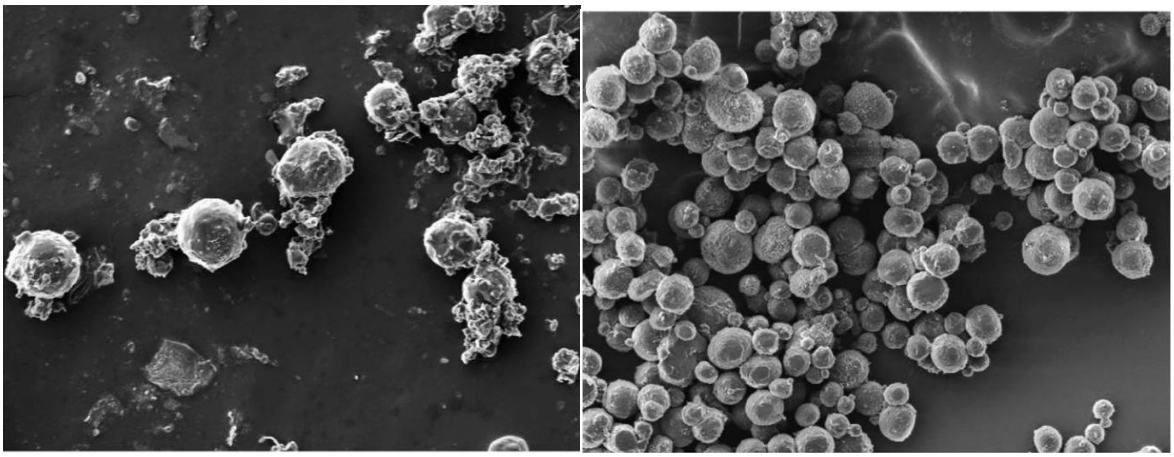

Figure 3 Avobenzone loaded Microparticle

3.4. Percentage Yield of LPs

Percentage yield of different formulation F-1 to F -9 were calculated and yield was found to be in range of 63.86%-95.11% respectively.

Table 5 Percentage yield of microparticle

Formulation batches	% Yield
F-1	63.86
F-2	69.76
F-3	76.65
F-4	81.23
F-5	85.93
F-6	88.47
F-7	91.01
F-8	93.32
F-9	95.11

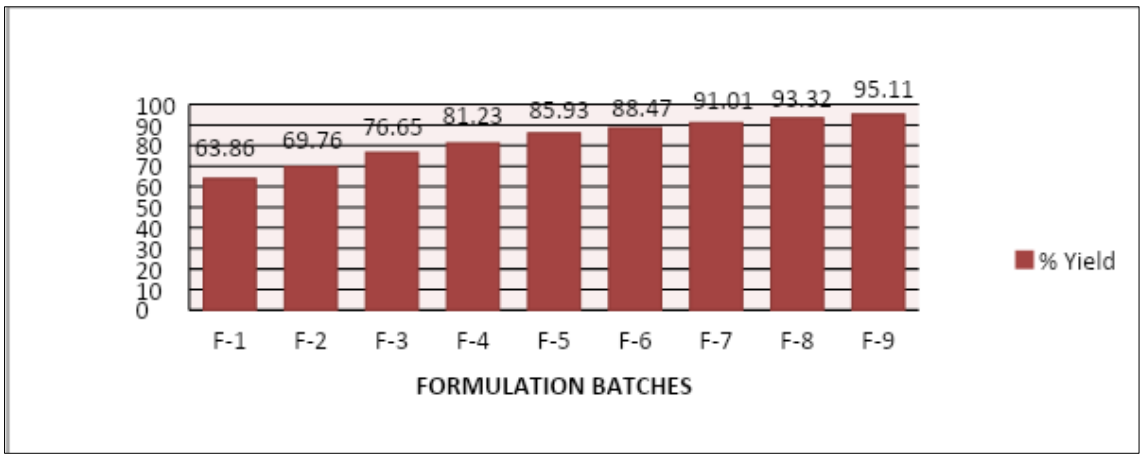

Figure 4 Comparison of % yield of Avobenzone microparticles

3.5. Drug entrapment Efficiency

The result of % drug entrapment efficiency is shown in table 6 .The formulation F-1 shows the least entrapment about 60.67% and higher drug entrapment was shown by F-5 formulation. Figure shows the comparison of % entrapment efficiency of formulation F-12

An accurately weighed quantity of microspheres were crushed into powder and added to 100 ml of ethanol. Mixture was kept for 92 h. Then the solution was filtered, and drug content was estimated by UV spectrophotometer at 357 nm. The drug entrapment efficiency was determined by using the formula, drug entrapment efficiency = (experimental drug content/theoretical drug content) ×100…. (1). The statistical difference in entrapment efficiency of prepared formulations was determined by student's t-test. The percentage yield of microsphere was also calculated based on the quantities of polymer, drug used in microspheres.

Table 6 Drug entrapment Efficiency.

Formulation of batches code	Percentage of drug entrapment
F-1	60.67
F-2	65.23
F-3	71.36

F-4	82.23
F-5	96.41
F-6	94.27
F-7	92.2
F-8	90
F-9	70.28

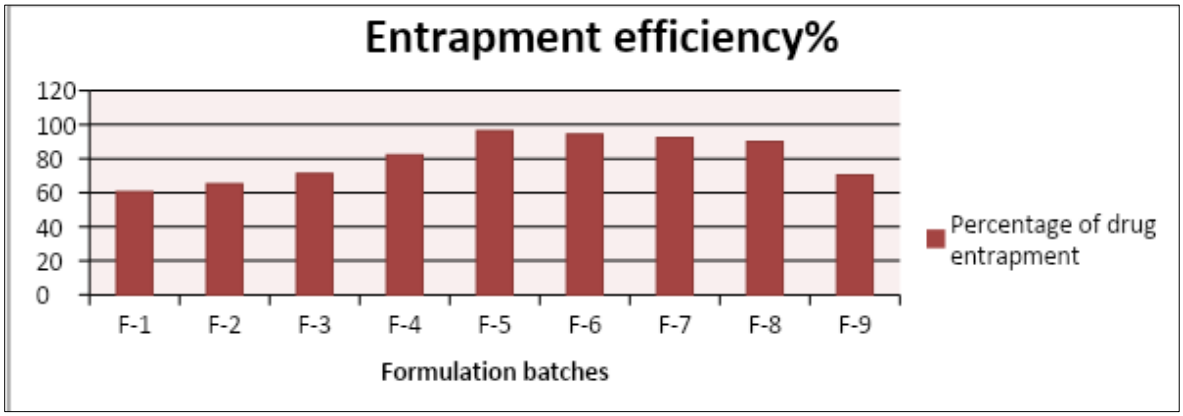

Figure 5 Comparison of drug entrapment efficiency of Avobenzone

Conclusion

To limit the photodegradation of UV filters induced by sunlight, the liposphere was formulated to provide effective encapsulation and photostability of UV filters utilizing a hot emulsification technique, provide uniform particle sizes with an impressive drug entrapment efficiency of 96.41%. Encapsulation and photostabilizer compound are used to make photostable formulation by adding filters like AVOB. Encapsulation process provide the stability toward UVA filter. The results demonstrate the potential of this formulation to enhance the durability and effectiveness of UV protection in sunscreen products.

Compliance with ethical standards

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Disclosure of conflict of interest

The author declares no conflict of interest.

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