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Use of bitter melon seed oil (*Momordica charantia*) to improve the photoprotective effect of sunscreen formulations

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ABSTRACT

Bitter melon seed oil (BMSO) was identified as having the potential as an anti-UV radiation agent due to alpha-oleo stearic acid, flavonoids, tannins, polyphenols, and phytosterols, which have the potential as antioxidants. Antioxidants are the main protection for the skin from the dangers of solar radiation, making BMSO a good quality if developed in sunscreen cream. This research aims to determine the effect of adding variations in the concentration of BMSO on the physical characteristics and in vitro photoprotective effectiveness of oxybenzone and octyl methoxycinnamate cream. Sunscreen creams are made with each BMSO concentration of 0%, 6%, 8%, 10%, and 12%. The result shows that the greater the concentration of BMSO added, the lower the viscosity and pH values, the %TP (percentage of transmission pigmentation) and %TE (percentage of transmission erythema), while the spreadability and SPF (sun protection factor) values of the cream increase. The best formula contains the highest concentration of BMSO (12%). The characteristics of the best formula are a slightly yellowish, soft cream and a slight smell typical of bitter melon. The spreadability value of the best formula cream is 6.6 ± 0.1 cm, pH is 6.57 ± 0.01, and viscosity is 88.3 ± 4.1 dPa.s, SPF value is 24.27 ± 0.28, %TE is 0.931 ±0.084, and %TP is 0.981±0.0001. These results show that BMSO has the potential to be an active ingredient in sunscreen to reduce the negative effects of using synthetic sunscreen, such as allergenic and irritant.

Keywords: BMSO, oxybenzone, octyl metoxycinamates, sunscreen

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INTRODUCTION

The skin possesses a natural defense system that guards against radiation from sunlight. It thickens the stratum corneum and generates the hormone melanin as a protective response to radiation exposure (Brenner & Hearing, 2008). Sunlight, at appropriate exposure levels, contributes to vitamin D synthesis by converting 7-dehydrocholesterol into cholecalciferol (vitamin D3), which aids in calcium absorption (Wacker & Holick, 2013). However, if exposure to solar radiation exceeds the skin's natural protection, it can lead to various health issues, including erythema, inflammation, premature aging, and cancer (Amaro-Ortiz et al., 2014).

Alongside its inherent defenses, the skin requires additional protection, such as sunscreen. *Sunscreen* is a cosmetic formulation designed primarily to absorb radiation from direct sunlight on the skin (Chao et al., 2010). Typically formulated as a cream, sunscreen allows for easy application, does not leave a sticky residue, acts directly on local tissues, and can be easily washed off with water compared to other formulations like gels or ointments (Sharon et al., 2013).

Two types of UV protection exist UV-A (ultraviolet-A) and UV-B (ultraviolet-B) absorbers (Holick, 2016). Oxybenzone serves as a filter for both UV-A and UV-B rays. However, oxybenzone has been associated with allergies and endocrine disruptors associated with Hirschsprung's disease and causes various toxic effects in coral and fish (DiNardo & Downs, 2018). Octylmethoxycinnamate functions as a UV-B absorber but does not protect against UV-A rays. Therefore, combining oxybenzone with octylmethoxycinnamate in the formulation can enhance sunscreen effectiveness (Tamara et al., 2019).

Recent findings have led to banning oxybenzone (BP-3) and octylmethoxycinnamate in Key West and Hawaii due to their harmful effects on marine life. However, their implications for human health still require thorough examination (Suh et al., 2020). Despite this, oxybenzone remains in popular sunscreen brands to achieve a higher SPF. Consequently, this research aims to utilize low concentrations of oxybenzone, octylmethoxycinnamate, and BMSO to improve SPF. BMSO, along with various vegetable oils such as coconut oil, sunflower oil, and avocado oil, typically has an SPF below 10 (Ranjithkumar et al., 2016), necessitating the combination with other chemical or physical agents to enhance SPF.

Oils have inherent properties that protect the skin from the adverse effects of sunlight (Montenegro & Santagati, 2019). BMSO contains conjugated α-linolenic acid and bioactive substances like tocopherols and polyphenolic compounds. Conjugated α-linolenic acid offers numerous potential benefits as an antioxidant, anti-inflammatory, anti-atherosclerotic, and antitumor. It can reduce serum lipid levels in vitro and in vivo (Yoshime et al., 2016). Both conjugated α-linolenic acid and bioactive compounds such as tocopherols and phenolic shielding prevent the development of free radicals induced by solar radiation (Rajaram, 2014). The inclusion of BMSO allows for a decrease in the concentration of oxybenzone needed, minimizing its adverse effects without compromising the photoprotective efficiency of the final formulation, as BMSO synergistically interacts with oxybenzone and octylmethoxycinnamate to absorb UV rays.

The application of BMSO in sunscreen cosmetic formulations has yet to be previously researched. Given this context, the researcher will assess the sunscreen cream formulations that combine BMSO with oxybenzone and octylmethoxycinnamate. The research aims to determine the effect of BMSO addition on sunscreen's physical characteristics and in vitro photoprotective effectiveness.The sunscreen cream will be tested for its effectiveness in vitro by calculating the SPF (Sun Protection Factor), %TE, and %TP values, as well as testing the physical characteristics of the sunscreen cream, which is composed of organoleptic tests, pH, viscosity, spreadability, and homogeneity.

MATERIALS AND METHOD

Materials

BMSO comes from Ethereal Ingredients Private Limite, India, oxybenzone (cosmeutical grade, Thornhill), octylmethoxycinnamate (cosmeutical grade, MFCI), propylene glycol, edetate sodium, triethanolamine, petrolatum, cetyl alcohol, stearic acid, glyceryl monostearate, and nipagin are technical grade.

Methods

Formulation

In this research, five formulations of sunscreen cream were prepared. Each formula is accompanied by the active ingredients of BMSO, oxybenzone, and octylmethoxycinnamate with a ratio of F1 (0:2:5), F2 (6:2:5), F3 (8:2:5), F4 (10:2: 5), and F5 (12:2:5) (Muliyawan & Suriana, 2013).

Sunscreen preparation

The ingredients for cream formulations are categorized into two sections: the water phase and the oil phase. The water phase includes edetate sodium, propylene glycol, nipagin, triethanolamine, and distilled water, while the oil phase contains petrolatum, glyceryl monostearate, stearic acid, cetyl alcohol, and oxybenzone. The oil phase is heated in a water bath to a temperature between 70-75˚C, after which oxybenzone is gradually incorporated until a uniform mixture is achieved. Next, the oil phase is transferred into a heated mortar and combined with the water phase while stirring continuously until a creamy texture is formed. Depending on the variants indicated in Table 1, octyl methoxycinnamate and BMSO oil are then added.

Table 1. BMSO formulation

Materials	Function	Concentration (%)				
		F1	F2	F3	F4	F5
BMSO	Chemical absorber	-	6.0	8.0	10.0	12.0
Oxybenzone	Chemical absorber	2.0	2.0	2.0	2.0	2.0
Octy lmetoxynamate	Chemical absorber	5.0	5.0	5.0	5.0	5.0
Sodium edetate	Chelating agent	0.05	0.05	0.05	0.05	0.05
Triethanolamine	Emulsifying agent	1.0	1.0	1.0	1.0	1.0
Stearic acid	Emulsifying agent	3.0	3.0	3.0	3.0	3.0
Glyceril monostearate	Emulsifying agent	3.0	3.0	3.0	3.0	3.0
Petrolatum	Emollient agent	5.0	5.0	5.0	5.0	5.0
Cetyl alcohol	Stiffening agent	3.0	3.0	3.0	3.0	3.0
Propylene glycol	Co-solvent	7.0	7.0	7.0	7.0	7.0
Methylparaben	Preservative agent	0.1	0.1	0.1	0.1	0.1
Distilled water	Vehicle	ad 100	ad 100	ad 100	ad 100	ad 100

Physicochemical characteristic evaluation

Organoleptic test

The organoleptic test for the type of sunscreen cream preparation was carried out visually by observing the color of, the texture, and the aroma of the cream.

Spreadabilty test

One gram of cream place into a round glass scale. Then on the top side of the material is placed a pair of round glass and added a load of 5 grams every 1 minute until constant diameter. Spreadability is measured based on the diameter of the preparation (Sabale et al., 2011).

Homogenity test

Homogeneity test was carried out by smeared the cream on the object glass and then observed for the presence or absence of coarse grains (Ardhany & Novaryatiin, 2019).

Viscosity test

This viscosity test was carried out by placing 100 grams of cream in a beaker glass, then installing rotor number 2. The test was carried out with a Viscotester VT-04 (Simões et al., 2018).

pH

The pH meter was dipped into the test cream. The number seen on the screen is stable or stagnant, recorded as the pH of the cream (Mukhlishah & Ningrum, 2019).

In vitro photoprotective effectiveness

Determination of SPF value

A 0.5-gram portion of cream was dissolved in isopropanol within a 25 mL volumetric flask to achieve a concentration of 20,000 ppm. The resulting sample solution was then diluted to a concentration of 10,000 ppm. Subsequently, the absorbance of the sample was recorded using a UV-Vis spectrophotometer over a wavelength range of 290-400 nm in 5 nm intervals (Fonseca & Nobre, 2013). The area under the curve (AUC) was computed using the formula provided in equation (1).

$$AUC = \frac{Aa + Ab}{2} \times dPa - b \quad \text{..............................(1)}$$

where Aa: λa absorbance (nm); Ab: λa absorbance (nm); dPa – b: a and b wavelenght difference.

The SPF value is calculated by formula in the equation (2) (Mulyani et al., 2015).

$$\log SPF = \frac{AUC}{\lambda_n - \lambda_1} \quad \text{..............................(2)}$$

where λ_n: higher absorbance; λ_1: smaller absorbance.

Determination of erythema transmission value (%TE)

Cream of 0.5 grams dissolved with isopropanol in a 25 mL volumetric flask to obtain a concentration of 20,000 ppm. Then the sample solution was diluted to a concentration of 10,000 ppm. The absorbance of the test solution was measured using UV-vis spectrophotometry at a wavelength of 292.5 – 337.5 nm, with an observation interval of 5 nm (Abdassah et al., 2015). The erytema transmision value calculated by formula in the equation (3).

$$\%TE = \frac{\sum T \times Fe}{\sum Fe} \quad \text{..............................(3)}$$

where T: transmision percentage; Fe: erytema effectivity constant.
The categories of erythema transmission capability of sunscreen cream preparations can be seen in Table 2.

Determination of pigmentation transmission value (%TP)

A 0.5-gram sample was dissolved in isopropanol within a 25 mL volumetric flask to achieve a concentration of 20,000 ppm. Subsequently, the solution was diluted to reach a concentration of 10,000 ppm. The absorbance of the test solution was measured using UV-vis spectrophotometry at wavelengths ranging from 322.5 to 372.5 nm, with measurements taken at 5 nm intervals, allowing for the absorption values to be obtained and calculated using the formula in equation (4) (Abdassah et al., 2015).

$$\%TP = \frac{\sum T \times Fp}{Fp} \quad \text{………………………..(4)}$$

where T: transmision percentage; Fp: pigmentation effectivity constant.
The categories of pigmentation transmittance for sunscreen cream preparations can be seen in Table 2.

Table 2. %TP and %TE value categories

%TE	%TP	Categori
< 1	< 1 – 2	Total block
1 – 6	3 – 40	Ultra protection
6 – 12	45 – 86	Suntan
12 – 18		Fast tanning

Data Analysis

Spreadability, pH, viscosity, SPF value, percentage of erythema transmission, and percentage transmission of pigmentation in the cream were tested for normality and homogeneity of the data. If it has a p-value > 0.05, data analysis is continued with One-Way ANOVA and Least Significantly Different (LSD) if ANOVA difference is significant. The results are said to be significantly different if they have a p-value <0.05.

RESULT AND DISCUSSION

Organoleptic test

Organoleptic test on sunscreen cream aims to determine the physical characteristics of the cream by visual testing of color, texture and aroma. Cream preparations are expected to have a white color, soft texture, and odorless aroma (Direktorat Jenderal Kefarmasian dan Alat Kesehatan, 2020) related to the aesthetics of the preparation. The results of organoleptic observations it is known that the results of sunscreen cream preparations on F1, F2, and F3 have a white color. In contrast to F4 and F5, it shows a slightly yellowish white color (Figure 1). This was due to the addition of high concentrations of BMSO hence the color of the cream became slightly yellowish white. In addition, the formula that is given BMSO also has a distinctive aroma.

Cream is a mixture of oil and water, and a dispersing agent can disperse the oil called an emulsifier. The highest BMSO concentration was obtained through preliminary studies. In this study, the highest oil concentration that could technically produce a stable emulsion was evaluated by centrifugation at 3500 rpm for 30 minutes. If the cream breaks or the oil phase separates, it indicates that the BMSO added was too high. Therefore, the highest BMSO concentration used in this cream formulation does not produce an oily cream because it can be accommodated by the water phase with the help of an emulsifier.

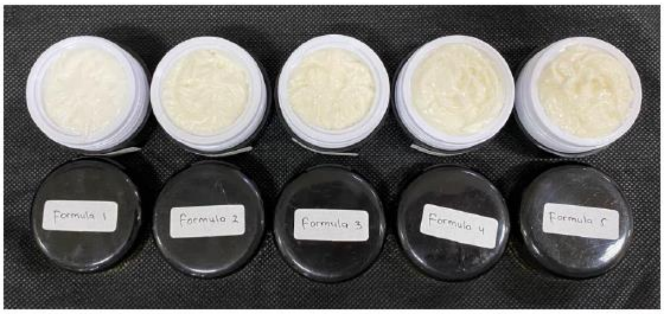

Figure 1. Cream formula appearance

Spreadability test

The diameter of each formula was 4.5 ± 0.1; 4.7 ± 0.1; 5.6 ± 0.1; 6.0 ± 0.1; and 6.6 ± 0.1 cm. Spreadability is said to be good if the results are 5-7 cm in diameter. Based on the tests, each formula meets the requirements. The addition of BMSO reducing the viscosity of the oxybenzone and octylmethoxycinnamate sunscreen cream, so that the lower the viscosity value, the thinner the cream, making it easier to spread when used ($p < 0.05$) (Widyaningrum et al., 2012).

Homogeneity evaluation

The homogeneity assessment is designed to verify that the ingredients in the sunscreen cream are distributed evenly without any lumps or coarse particles present. A homogeneous cream preparation signifies that all components are thoroughly blended. Cream formulations must be homogeneous to ensure comfort and prevent irritation during skin application. The findings from the homogeneity assessment indicated that all samples of sunscreen cream were homogeneous.

Viscosity evaluation

The viscosity assessment was conducted to gauge the thickness of the sunscreen cream. The thickness influences the cream's ability to spread uniformly when applied to the skin. The anticipated viscosity range is 50-150 dPa.s (Lachman et al., 1987). For formulations F1 to F5, the recorded viscosity values were 117.6 ± 2.5; 113.3 ± 1.5; 105.6 ± 5.1; 97.3 ± 2.5; and 88.3 ± 4.1 dPa.s, respectively. The observed reduction in viscosity of the preparations was attributed to the increased concentration of BMSO ($p < 0.05$) based on the LSD test. Consequently, while the SPF is expected to rise, the percentages of TP and TE are projected to decline, as the formulation with the highest BMSO concentration offers improved UV blocking. These outcomes align with the spreadability test results.

Acidity testing

The pH level of the sunscreen should correspond to that of the skin. Sunscreen with a highly acidic formulation can irritate the skin. Conversely, a pH level that is too alkaline can lead to dryness and flakiness of the skin (Ali & Yosipovitch, 2013). As the concentration of BMSO increases, the pH of the cream decreases due to an acidic pH (pH=4.0) of the BMSO. The pH values of the creams were respectively 6.96 ± 0.01, 6.84 ± 0.01, 6.75 ± 0.01, 6.66 ± 0.01, and 6.57 ± 0.01. All formulations met the quality standards for effective sunscreen cream, albeit with a p-value <0.05 in the LSD test.

In vitro effetiveness evaluation

In vitro effectiveness, assessment BMSO is incorporated into the sunscreen cream due to its content of antioxidants, such as conjugated α-linolenic acid, and bioactive components like tocopherols and phenolic compounds that help protect against and mitigate the generation of free radicals induced by light exposure (Yoshime et al., 2016). A limitation of using BMSO alone is its inability to achieve a high SPF rating. Moreover, combining BMSO with oxybenzone and octylmethoxycinnamate aims to minimize the adverse effects associated with these ingredients, which can lead to skin irritation and other toxic reactions (Serpone et al., 2002).

SPF value

Based on the SPF value, sunscreen creams are grouped into several categories, including Minimum SPF (2-3) can result in tanning, Moderate SPF (4-6) can cause tanning, Extra SPF (6-8) results in limited tanning, Maximum SPF (8-15) tanning does not occur, SPF Ultra (> 15) does not result in tanning (Osterwalder & Herzog, 2010). The increase in the SPF value indicated that the addition of BMSO is effective to give protection from tanning. The higher the SPF value, the better the effectiveness of the sunscreen preparation and the greater the absorption of UV radiation. Between formulas showed significant differences in LSD test due to variations in the concentration of BMSO ($p < 0.05$).

Table 3. *In vitro* effectiveness of BMSO with oxybenzone and octylmethoxycinnamate

Formula	SPF	SPF Categories	% TE	% TP	%TE and %TP Categories
F1	5.66 ± 0.24	Extra	0.990 ± 0.0002	0.991 ± 0.0001	Total block
F2	9.86 ± 0.36	Maximal	0.88 ± 0.0001	0.988 ± 0.0007	Total block
F3	11.49 ± 0.57	Maximal	0.986 ± 0.0001	0.987 ± 0.0005	Total block
F4	16.14 ± 0.28	Ultra	0.984 ± 0.0002	0.984 ± 0.0001	Total block
F5	24.27 ± 0.28	Ultra	0.931 ± 0.084	0.981 ± 0.0001	Total block

Various vegetable oils have been researched for their ability to absorb UV light. Thus, it is suggested to utilize vegetable oil to decrease the amounts of organic UV filters (octyl-methoxycinnamate, butyl methoxydibenzoylmethane, and bemotrizinol) found in sunscreen formulations. Studies have shown that pomegranate oil (1% w/w) and shea oil (1% w/w) achieve a higher SPF than formulations containing organic UV filter components. The physical properties of the cream remained consistent, as Montenegro and Santagati (2019) reported. Findings from the studies on pomegranate and shea oil support the idea that incorporating bitter melon seed oil into sunscreen formulations could be a practical approach for creating products with reduced levels of organic UV filters.

Erythema transmission value (%TE)

According to Table 3, all tested formulas protect total erythema, indicating that the cream serves as a sunblock against UV rays and can be understood as effectively preventing skin redness, as demonstrated by %TE values of less than 1%. A lower %TE value signifies superior effectiveness as a sunscreen in shielding the skin from erythema (Ahmad, 2015). The sunscreen formula with the highest concentration of bitter melon seed oil (BMSO) recorded the lowest %TE value, marking it as the most effective in protecting the skin from erythema. Significant differences were observed among the formulas in the LSD test, attributed to varying concentrations of BMSO ($p < 0.05$). The formula with the highest BMSO concentration contained elevated levels of conjugated α-linolenic acid and bioactive compounds such as tocopherols and phenolic compounds, which aid in guarding the skin from solar radiation.

Pigmentation transmision value (%TP)

According to Table 3, all formulas exhibit a pigmentation transmission percentage of less than 1-2%, all falling within the same total block category. A lower percentage of transmission for pigmentation implies a superior capacity of the sunscreen cream to inhibit pigmentation resulting from UV radiation (Ahmad, 2015). The reduction in pigmentation attributed to BMSO is linked to alpha-oleo stearic acid, which functions as an anti-UV agent by absorbing UV rays, thus preventing their penetration into the skin. There were significant differences among the formulas in the LSD test, attributable to the varying concentrations of BMSO ($p < 0.05$).

BMSO is composed of lipids, polyunsaturated fatty acids (PUFAs), phytosterols, and tocopherols (Aruna et al., 2016; Fernandes et al., 2015; Jing et al., 2012). The composition of BMSO includes 30%-60% of the α-allosteric acid (Aruna et al., 2016; Khoddami & Roberts, 2015; Saha et al., 2012). It also holds significant amounts of the conjugated fatty acid α-eleostearic acid, a positional and geometric isomer of α-linolenic acid. Conjugated α-linolenic acid represents a positional and geometric isomer of octadecatrienoic fatty acid with three conjugated double bonds (Melo et al., 2014). The UV absorbance of compounds with extended conjugated double bonds can be estimated using Woodward Fieser's rule. Shifts in the wavelength may occur in a bathochromic or hypochromic manner, influenced by the extent of conjugation, the presence of donating groups, and electron-withdrawing groups (Gauglitz & Vo-Dinh, 2003). Based on the Woodward–Fieser rule and the

Structure-Activity Relationship, the conjugated fatty acids in BMSO triglycerides are also noted for their UV absorption capabilities (Wagemaker et al., 2011), which can be advantageous in sunscreen formulations.

Additionally, α-linolenic acids offer several potential health benefits, such as antioxidant and anti-inflammatory properties. Furthermore, along with a high concentration of conjugated α-linolenic acids, BMSO contains tocopherols and polyphenolic compounds (Anjum et al., 2013; Nyam et al., 2009). Tocopherol aids in photoprotection by enhancing glutathione production and mitigating lipid peroxidation, as well as reducing levels of reactive oxygen species (ROS) and malondialdehyde (MDA) (Delinasios et al., 2018; Wu et al., 2014). Consequently, BMSO plays a vital role in sunscreen formulations by synergistically absorbing UV light, providing antioxidants, and exhibiting anti-aging and anti-inflammatory effects.

The UV absorption capability of BMSO can enhance the SPF value. Simultaneously, its antioxidant properties may help neutralize free radicals that lead to redness or erythema (Sutriningsih & Astuti, 2017), limit melanin production, and reduce the occurrence of skin pigmentation following UV exposure (Suhaenah et al., 2019). Therefore, an increase in the amount of BMSO within oxybenzone and octyl methoxycinnamate cream will decrease the % TP and % TE.

CONCLUSION

It is found that the greater the concentration of BMSO added to the formula, the greater the in vitro SPF value, while the % TE and % TP is getting smaller which indicate BMSO will give an addition protection to the skin by absorbed the radiation to be not transmitted into the skin. It will avoid the negative effect of UV radiation such as pigmentation, erythema, skin aging cause by free radicals, and reduce the content of organic sunscreen.

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