



## Formulation, Characterization, and Total Phenolic Content of Moringa (*Moringa oleifera* L.) Leaf Extract Sunscreen Cream with Triethanolamine Base Comparison

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### ABSTRACT

Moringa (*Moringa oleifera* L.) leaves contain secondary metabolites such as flavonoids, phenols, tannins, saponins, and alkaloids. The phenolic and flavonoid compounds show strong antioxidant activity that can neutralize free radicals and protect the skin from oxidative damage. Despite its known photoprotective potential, the use of Moringa leaf extract in stable sunscreen cream formulations is still limited. Moreover, the influence of extract and emulsifier (triethanolamine) concentrations on the cream's physical properties and their relation to total phenolic content has not been well studied. This study aimed to develop and evaluate Moringa leaf extract-based sunscreen creams with extract concentrations of 1%, 1.5%, 2%, and 2.5%, and triethanolamine concentrations of 1% and 1.5%. Eight formulas were prepared and evaluated for organoleptic characteristics, spreadability, homogeneity, pH, viscosity, phase separation, and emulsion type. The total phenolic content was also determined using the Folin-Ciocalteu method. Results showed that increasing the concentration of extract and triethanolamine significantly affected the pH, spreadability, and viscosity of the cream ( $p < 0.05$ ), while all remained within acceptable ranges for topical preparations. The total phenolic content increased proportionally with extract concentration, with Formula 8 (2.5% extract) showing the highest phenolic content of 25.12 mg GAE/g. These findings indicate that Moringa leaf extract has strong potential as a natural antioxidant and photoprotective agent for sunscreen cream formulations.

**Keywords:** *Moringa oleifera*; Sunscreen cream; Triethanolamine; Total phenolic content; Formulation characterization

### INTRODUCTION

Medicinal plants have been widely used according to their properties empirically and are developing rapidly in the current era of globalization. The back-to-nature trend is increasingly promoted, especially in the fields of medicine and aesthetics, one of which is looking for cosmetic preparation formulations that are durable, practical, easy, and fast to apply to modern humans today. In line with the increasing attention to nature-based

product innovation, medicinal plants are now seen as an alternative treatment and a significant focus in developing various products, including in the cosmetics industry.<sup>1</sup>

Indonesia is one of the countries that has very abundant biodiversity, especially plants. One of them is Moringa (*Moringa oleifera* L.). This plant is rich in bioactive compounds such as phenolic acids, flavonoids, organic acids, terpenes, alkaloids, tannins, fatty acids, saponins,

and sterols. Its bioactive composition has been shown to provide a variety of health benefits, including antioxidant, immunomodulatory, anticancer, antispasmodic, antimicrobial, antifungal, and antidiabetic activities.<sup>2,3</sup> In addition, Moringa's phenolic and flavonoid content can function as a UV light antidote and is known to have antioxidant activity that is effective in neutralizing free radicals. This activity helps prevent oxidative damage to most biomolecules, such as lipids, proteins, and nucleic acids.<sup>4</sup> Previous research related to secondary metabolite tests of moringa leaf extracts showed that ethanol extracts of moringa leaves contain flavonoids, phenols, tannins, saponins, and alkaloids. The total flavonoid content is 10.477 mg QE/g extract, so this causes moringa leaves to have photoprotective potential.<sup>5</sup>

Ultraviolet light plays an important role in human life, but excessive exposure to ultraviolet light can have adverse effects on the skin. Excessive UV exposure is a major cause of various skin problems, such as sunburn, oxidative stress, and other degenerative processes, including premature aging, inflammation, and skin diseases such as erythema, hyperpigmentation, and skin cancer.<sup>6</sup> UVB radiation, with its shorter wavelength and higher energy, is the leading cause of sunburn (erythema). It is also highly carcinogenic as it can interact directly with biological macromolecules and cause damage to DNA and RNA. Meanwhile, UVA radiation has lower energy but can penetrate deeper into the skin and is a significant factor in skin aging through a photodegradation process that affects collagen fibers and hyaluronic acid.<sup>7</sup> The cosmetic industry has found several ways to prevent this by formulating cosmetic preparations in topical sunscreen preparations, and one example is sunscreen cream which has functions to ward off ultraviolet rays.

Cream preparations are defined as thick liquid or semisolid emulsions of either oil in water or water in oil, whose consistency varies depending on the ratio

of oil and water.<sup>8</sup> Most people prefer oil-in-water emulsions because the outer phase is water, which provides a cooling sensation upon application.<sup>9</sup> Triethanolamine (TEA) functions as an emulsifying and pH-adjusting agent in cream bases, reacting with fatty acids (e.g., stearic acid) to form salts that contribute to emulsion formation and stability. Variations in TEA concentration can therefore alter emulsion type, droplet size distribution, viscosity, pH, and sensory properties (e.g., spreadability and homogeneity), which in turn affect physical evaluation parameters such as viscosity, pH stability, spreadability, and phase separation.<sup>10,11</sup> Hence, this study aims to investigate the effect of varying concentrations of Moringa leaf extract (1.0%, 1.5%, 2.0%, and 2.5%) and triethanolamine (1.0% and 1.5%) as an emulsifier on the physical characteristics of Moringa (*Moringa oleifera* L.) leaf extract-based sunscreen cream. In addition, the total phenolic content of the sunscreen cream formulations was also evaluated to determine the correlation between phenolic content and antioxidant potential.

## METHODS

This research used an experimental design. The first stage was to optimize the formula of the preparation of moringa leaf extract sunscreen cream with extract concentrations of 1%; 1.5%; 2% and 2.5% and triethanolamine concentrations of 1% and 1.5%. Then, an evaluation of the physical properties and total phenol content test of the preparation is carried out.

### Equipment and Materials

The materials used in this study are dry extract of moringa leaves (*Moringa oleifera* L.) (PT. Phytochemindo Reksa), triethanolamine (PT. Brataco, Indonesia), stearic acid (PT. Brataco, Indonesia), lanolin (PT. Brataco, Indonesia), cetyl alcohol (PT. Brataco, Indonesia), tween 80 (PT. Brataco, Indonesia), sorbitol (PT. Brataco, Indonesia), glycolic acid (PT. Brataco, Indonesia), methyl paraben (PT. Brataco, Indonesia), propyl paraben (PT.

Brataco, Indonesia), NaOH (PT. Brataco, Indonesia), folin-ciocalteu's reagent (Merck, Germany), gallic acid (Sigma-Aldrich, USA), alcohol pro analysis (p.a) (Merck, Germany), methylene blue (PT. Brataco, Indonesia), and distilled water (PT. Brataco, Indonesia). Meanwhile, the equipment used for the preparation of moringa leaf extract sunscreen cream includes a Measuring cup (Iwaki, Japan), Beaker glass (Iwaki, Japan), Micropipette (DLAB, China), Analytical balance (OHAUS Pioneer PX224, USA), pH meter (OHAUS, USA), Water bath (Stuart SWB15, UK), magnetic stirrer (VITLAB, Germany), UV-Vis Spectrophotometry (K-Lab, Japan), hot plate (IKA C-MAG HS 7, Germany), Centrifuge (Hettich EBA 270, Germany), Microscope (Olympus CX23, Japan) and Brookfield viscometer (Anton Paar ViscoQC 100 R, Austria), Object glass (Iwaki, Japan), Apatial (Iwaki, Japan),

steam cup (Iwaki, Japan), watch glass (Iwaki, Japan), Parchment paper.

**Procedures**

**1. Formulation of the sunscreen cream of moringa leaf extract**

Sunscreen preparations of moringa leaf extract were made in 8 (eight) formulations. Table 1 shows the constituent components of the cream formula.

**2. Preparation of Sunscreen Cream of Moringa Leaf Dry Extract**

The preparation of moringa leaf extract sunscreen cream began with weighing all the ingredients used. The oil phase (stearic acid, cetyl alcohol, lanolin, and propylparaben) was melted at 70°C, while the water phase (sorbitol, triethanolamine, Tween 80, methylparaben, and distilled water) was heated in a water bath at the same temperature. Next, the oil phase was gradually added to the water phase while

**Table 1.** Sunscreen Cream Formula of Moringa Leaf Dry Extract (*Moringa oleifera* L.).

Ingredients	Function	Sunscreen Cream Formula (%)							
		F1	F2	F3	F4	F5	F6	F7	F8
Moringa leaf dry extract	Active ingredient	1	1.5	2	2.5	1	1.5	2	2.5
Triethanolamine	Emulsifier	1	1	1	1	1.5	1.5	1.5	1.5
Stearic acid	Emulsifier, thickener	2	2	2	2	2	2	2	2
Lanolin	Emollient	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Cetyl alcohol	Emulsifier, emollient	3	3	3	3	3	3	3	3
Tween 80	Emulsifier	3	3	3	3	3	3	3	3
Sorbitol	Humectant	3	3	3	3	3	3	3	3
Glycolic acid	Antioxidant	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Methyl paraben	Preservative	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Propyl paraben	Preservative	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NaOH	pH adjuster	ad	ad	ad	ad	ad	ad	ad	ad
Aquadest	Solvent	ad 100%	ad 100%	ad 100%	ad 100%	ad 100%	ad 100%	ad 100%	ad 100%

stirring at 250 rpm with a magnetic stirrer until the cream base formed. After the base was formed, glycolic acid was added while stirring until homogeneous. Subsequently, Moringa leaf extract was added and stirred until homogeneous. The cream was then evaluated for its physical characteristics, such as organoleptic properties, spreadability, homogeneity, pH, viscosity, phase separation, and emulsion type, as well as its total phenol content.

### 3. Evaluation of physical properties Sunscreen Cream of Moringa Leaf Dry Extract

#### Organoleptic test

Organoleptic tests were carried out by observing moringa leaf sunscreen cream preparations' shape, odor, consistency, and color.<sup>8</sup>

#### pH measurement

The pH value of the sample was determined with a previously calibrated pH meter, where the electrode was immersed in the sample and the reading was recorded.<sup>12</sup>

#### Spreadability test

The spreadability was examined by compressing 0.5 g of the sample between two glass plates under a 100 g weight for one minute. The diameter of the spread was recorded as the mean of measurements taken from several points.<sup>13</sup>

#### Homogeneity test

The homogeneity of the cream was evaluated by placing 1 g of the sample between two glass slides. The preparation was considered homogeneous when it appeared even in consistency and free from any granules or clumps.<sup>13</sup>

#### Viscosity test

The viscosity test was carried out by measuring 100 grams of sunscreen cream directly with a ViscoQC 100 R viscometer (Brookfield, USA) at 100 revolutions/minute using spindle no. 3. The scale visible on the device after showing a stable number was the viscosity value of the cream preparation.<sup>8</sup>

#### Phase separation test

Around 5 g of cream was taken and centrifuged in a tube at 3750 rpm for 5 hours, or at 5000–10000 rpm for 30 minutes, according to the procedure.<sup>14</sup>

#### Determination of type of cream

Identification of the cream system was carried out by adding a drop of methylene blue dye to a microscope slide, followed by microscopic observation. When the globules appear uniformly distributed, the formulation is classified as oil-in-water (o/w); otherwise, it belongs to the water-in-oil (w/o) type.<sup>8</sup>

### 4. Determination of total phenolic content using Folin-Ciocalteu method

#### Preparation of moringa leaf extract test solution

The moringa leaf extract test solution was prepared by weighing approximately 0.2 grams of moringa leaf extract and placing it into an Erlenmeyer flask. Then, 25 mL of methanol P was added, and the mixture was stirred for 30 minutes using a magnetic stirrer. The resulting solution was filtered into a 25 mL volumetric flask, and methanol P was added up to the calibration mark. Subsequently, 1 mL of the test solution was transferred into a 10 mL volumetric flask, followed by the addition of 5 mL of diluted Folin-Ciocalteu reagent (7.5% in water). The mixture was left to stand for 8 minutes before adding 4 mL of 1% NaOH and incubating for 1 hour. Finally, the absorbance of the solution was measured at the maximum absorption wavelength, approximately 730 nm.<sup>15</sup>

#### Comparator solution

The comparator solution was prepared by weighing approximately 10 mg of the comparator, then put into a 25 mL measuring flask and dissolved using methanol P until the limit mark. Subsequently, a series of dilutions of the comparator solution were prepared with concentrations of 70, 50, 30, 15, and 5 µg/mL. Take 1 mL of each series of

comparison solution and then put it into a 10 mL metered flask. Add 5 mL of folin-ciocalteu LP dilution (7.5% in water). Allow it to rest for 8 minutes, add 4 mL of 1% NaOH, incubate for 1 hour. After that, measure the absorption of the solution at the maximum absorption wavelength of approximately 730 nm and make a calibration curve to calculate the level of moringa leaf extract test solution.<sup>15</sup>

#### Blank solution

To prepare the blank, 5 mL of a 7.5% Folin-Ciocalteu LP solution in water was placed into a 10 mL volumetric flask. After standing for 8 minutes, 4 mL of 1% sodium hydroxide was added, and the mixture was incubated for 1 hour. The absorbance of the solution was then measured at approximately 730 nm, corresponding to its maximum wavelength.<sup>15</sup>

#### Data analysis

Statistical evaluation included the Shapiro-Wilk test for normality and a homogeneity assessment, both with acceptance criteria of  $P > 0.05$ . Data sets meeting these assumptions were analyzed using one-way ANOVA, whereas those violating normality ( $P < 0.05$ ) were processed using the Kruskal-Wallis non-parametric test.

## RESULTS AND DISCUSSION

Moringa leaves are known as a plant rich in bioactive compounds. One of these compounds contains phenolics and flavonoids, which can be used as a barrier for UV rays. The antioxidant content of Moringa leaves also effectively wards off free radicals.<sup>4</sup> The Moringa leaves were used in the current research as a sunscreen lotion due to its potential. Some potential compounds contained in Moringa leaves that can be useful as skin protection from sunlight are ellagic acid, chlorogenic acid, ferulic acid, rutin, and quercetin. Ellagic acid can suppress oxidative stress caused by UV-A and reduce the inflammatory response caused by UV-B. Chlorogenic acid can protect human skin from photoaging due to its antioxidant properties and ferulic acid have some

function as a protective agent against erythema caused by UV rays. Meanwhile, rutin and quercetin which are flavonoids have antioxidant and photoprotective activity capabilities.<sup>16</sup>

This study aims to determine the optimal formulation of sunscreen cream with a comparison of dry extract concentrations of Moringa leaves of 1%; 1.5%; 2%; and 2.5% and a comparison of triethanolamine concentrations of 1% and 1.5%. The optimal formula is determined based on the results of physical properties tests and total phenol content tests contained in the sunscreen cream preparation using dry extract of Moringa leaves. The cream was then evaluated for its physical characteristics, including organoleptic, pH, spreadability, viscosity, homogeneity, emulsion type, phase separation, and total phenol content tests. Physical characteristics of moringa sunscreen cream shown at Table 2.

According to organoleptic test, all formulation of sunscreen creams has typical semisolid form, moringa extract leaf odor, white - yellowish color and have smooth texture. There is a slight color difference between the formulas due to concentration of moringa's leaf extract. Formulas with lower extract concentrations, the cream were light yellow, meanwhile formulas with higher extract concentrations have yellow color. Results of organoleptic test shown in Figure 1.

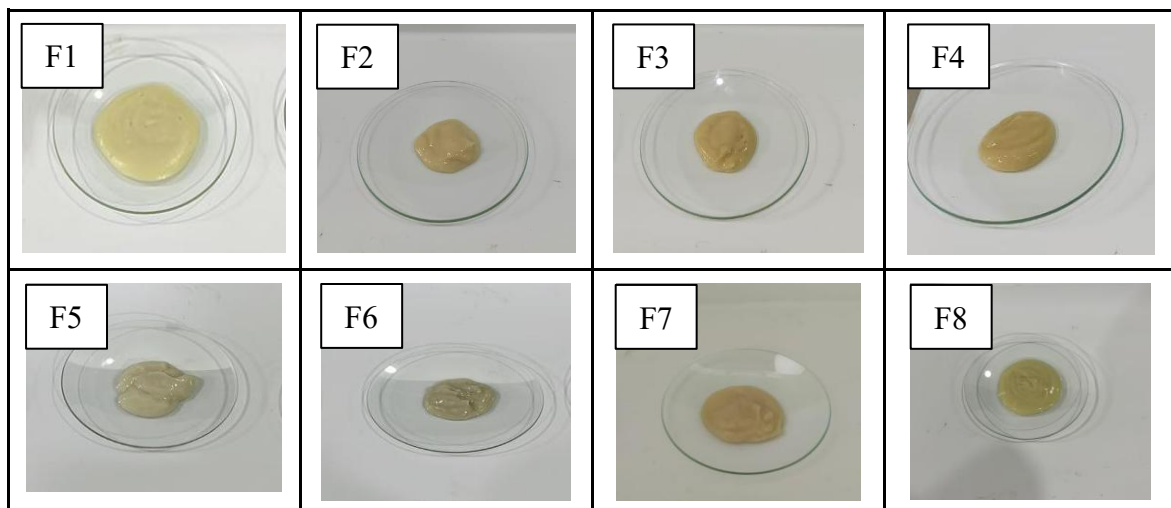
The next evaluation is measuring the pH of cream sunscreen. The results showed that all formulas have pH value ranging from 4.5 - 6.5 that meets the pH requirements of skin care products, so the cream sunscreen won't change or interfere with the structure and function of the skin.<sup>17</sup> The highest pH value was found in F8 with value of  $6.09 \pm 0.01$  that using 1.5% triethanolamine. Triethanolamine has function as an alkalizing agent, increasing its concentration could accelerate the neutralization process and formula with higher concentration of triethanolamine and extract tend to increase in pH value.<sup>18</sup> Based on the results of the Kruskal Wallis

statistical analysis P value of the pH was 0.026, so there was a significant difference between the formulas with variations in the concentration of extract and triethanolamine which was marked by a P

value <0.05. However, each formula was still within the pH range of skin care products.

**Table 2.** Physicochemical Characteristics of Dry Extract Moringa (*Moringa oleifera* L.). Cream Sunscreen

Parameters	F0	F1	F2	F3	F4	F5	F6	F7	F8
Organoleptic	Cream with white color, odorless	Yellowish cream with extract odor	Yellowish cream with extract odor	Yellowish cream with extract odor	Yellowish cream with extract odor	Yellowish cream with extract odor	Yellowish cream with extract odor	Yellowish cream with extract odor	Yellowish cream with extract odor
pH	5.13 ± 0.03	5.53 ± 0.01	5.54 ± 0.03	5.53 ± 0.01	5.64 ± 0.03	5.85 ± 0.02	5.88 ± 0.02	5.97 ± 0.06	6.09 ± 0.01
Spreadability (cm)	6.50 ± 0.00	6.50 ± 0.00	5.93 ± 0.06	6.37 ± 0.06	7.00 ± 0.00	6.57 ± 0.06	6.57 ± 0.06	6.67 ± 0.06	6.77 ± 0.06
Viscosity	3.517 ± 2.89	3.493 ± 2.89	3.220 ± 5.00	2.932 ± 5.77	2.257 ± 2.89	3.115 ± 5.00	2.907 ± 5.77	2.872 ± 5.77	2.825 ± 5.00
Homogeneity	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous
Cream Type	o/w	o/w	o/w	o/w	o/w	o/w	o/w	o/w	o/w
Phase Separation	Not occur	Not occur	Not occur	Not occur	Not occur	Not occur	Not occur	Not occur	Not occur



**Figure 1.** Result of Organoleptic Test from Dry Extract Moringa (*Moringa oleifera* L.). Cream Sunscreen

Spreadability test of formula F0 - F8 showed that all formulas meet the requirement of cream dosage forms, 5 - 7 cm. The spreadability test determines how easily cream spreads when it applied on the skin. The spreadability test is related to the results of the viscosity test that carried out on the preparation of sunscreen cream from dry extract of moringa leaves. The higher viscosity value, the lower spreadability of the sunscreen cream.<sup>19</sup> The result of this research showed that cream with lower viscosity value had higher spreadability value. The viscosity of a cream preparation must be in accordance with the requirements of SNI 16-4399-1996, which is in the range of 2.000 - 50.000 cPs and all formulations have a meet the requirements for good viscosity of cream dosage forms. Viscosity value indicated the resistance of the dosage form. The greater resistance of the dosage form, the greater possibility that the viscosity will affect the distribution of the preparation.<sup>20, 21</sup>

The spreadability value is inversely proportional to the concentration of triethanolamine. Formula F4 with 1% triethanolamine showed highest spreadability value  $7.00 \pm 0.00$  and viscosity value  $2.257 \pm 2.89$ , meanwhile in F8 with 1.5% triethanolamine showed lower spreadability value  $6.77 \pm 0.06$  and viscosity value  $2.825 \pm 5.00$ . Differences in extract concentration also affected in cream viscosity. Extract with lower concentration had higher value in viscosity, as shown in F1 and F5, with 1% extract had viscosity value of  $3.493 \pm 2.89$  dan  $3.115 \pm 5.00$ , respectively. Meanwhile F4 and F8 with higher extract concentration (2.5%) had viscosity value of  $2.257 \pm 2.89$  dan  $2.825 \pm 5.00$ , respectively. These results showed that increasing triethanolamine and extract concentration will have an impact in spreadability and viscosity of cream. Based on the results of the Kruskal Wallis statistical analysis, the spreadability showed a P value of 0.001 and the viscosity had a P value of 0.009, so that there was a significant difference between the formulas marked by a P value of <0.05. However,

each formula still meets the requirements for spreadability and viscosity of the cream preparation.

The next evaluation was homogeneity test. The purpose of this test is to determine the distribution of ingredients in the formula.<sup>22</sup> The result it showed that all formulations (F0 - F8) showed homogenous cream without any visible particles in object glass. It can be concluded that the preparation was homogeneous with no secondary particle aggregation.<sup>23</sup>

Determination of type of cream also conducted in this research for all formulation. The results showed that methylene blue used in the test homogeneously dispersed in all creams formulation within observation using optical microscope, thus it confirmed as oil in water (o/w) type creams. All sunscreen cream formulations were stable with no phase separation of water and oil after centrifugation for 30 minutes at a speed of 5000 rpm.

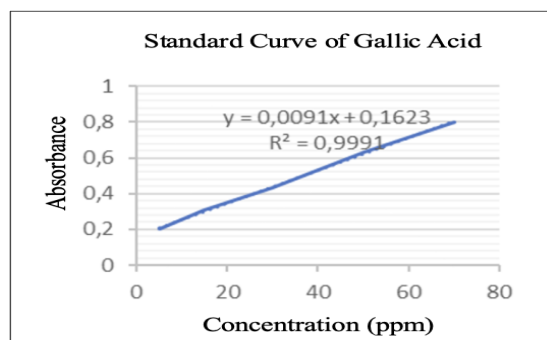
The next evaluation was total phenolic content test, using Folin-Ciocalteu method. This evaluation was conducted to determine the phenolic content in formula, F5 - F8 with concentration of each extract 1%; 1.5%; 2%; and 2.5%. These formulations were selected because the main variable examined in this test was the extract concentration. Formulations F1-F4 contained the same extract concentrations but differed only in triethanolamine (TEA). Result of total phenolic content test showed at Table 3.

**Table 3.** Result of Gallic Acid Standard Absorbance Measurement

No.	Concentration (ppm)	Absorbance
1.	5	0.2021
2.	15	0.3060
3.	30	0.4329
4.	50	0.6288
5.	70	0.7966

The absorbance value obtained was used to create a standard curve for gallic acid as shown in Figure 2. This standard

curve of gallic acid aims to determine the relationship between solution concentration and its absorbance value so that the sample concentration can be determined.<sup>24</sup>



**Figure 2.** Standard Curve of Gallic Acid

The results of the study obtained a linear regression equation  $y = 0.0091x + 0.1623$  with an R2 value of 0.9991. This equation will be used to determine the total phenol content in the sunscreen cream with dry extract of Moringa leaves. The total phenolic content in the sunscreen cream with dry extract of Moringa leaves can be seen in Table 4 and Figure 3.

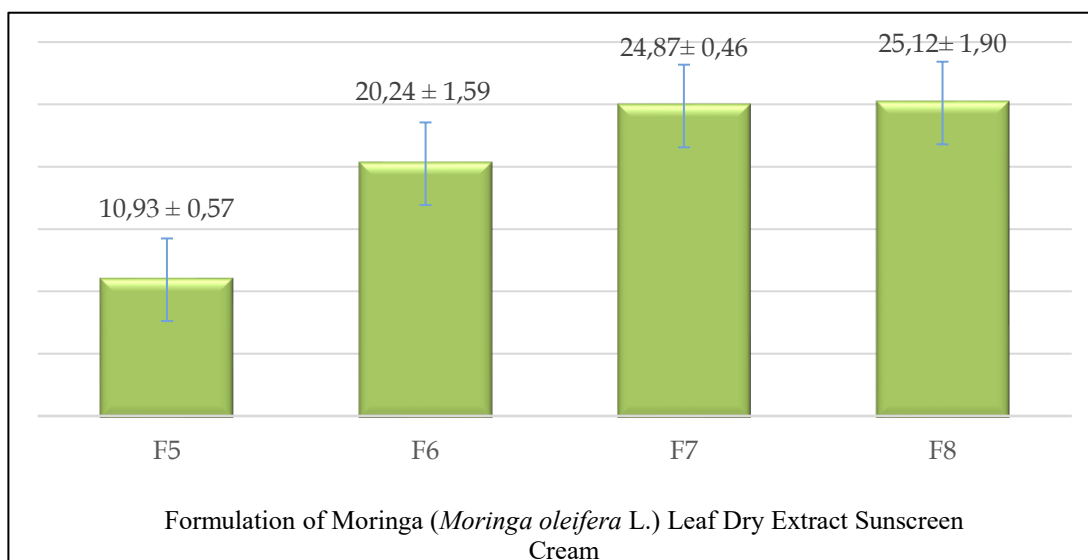
Based on the results of the study, F8 with an extract concentration of 2.5% has the highest total phenol content with a value of  $25.12 \pm 1.90$  mg GAE/g and the lowest in formula F5 with an extract concentration of 1% with a value of  $10.93 \pm$

$0.57$  mg GAE/g. The results of the one-way ANOVA statistical analysis showed significant differences in each formula with a value of  $P = 0.00$  ( $P < 0.05$ ). Thus, this shows that the extract concentration is directly proportional to the content of phenolic compounds in the formula. Formulas with higher extract concentrations, such as F8, have greater potential in providing antioxidant benefits in the preparation of dry extract cream from Moringa leaves. This result is consistent with a previous study by Tran et al. (2024), which reported that Moringa oleifera leaf extract exhibited moderate antioxidant activity and contributed synergistically to UV protection when incorporated into sunscreen cream formulations, with polyphenol compounds playing a major role in enhancing the cream's antioxidant and photoprotective effects.<sup>25</sup> Likewise, Damayanti et al. (2024), also demonstrated that increasing the concentration of Moringa leaf extract in cream formulations significantly enhanced antioxidant activity and improved product stability. These findings collectively support that higher extract concentrations contribute to stronger antioxidant potential and better functional properties in Moringa-based cosmetic formulations.<sup>26</sup>

**Table 4.** Total Fenolic Content of Sunscreen Moringa Leaf Dry Extract (*Moringa oleifera* L.)

Formula	Replication	Absorbance	Content (mg/mL)	Total Fenolic Content (mg GAE/g)	Average Total Phenolic Content (mg GAE/g)	SD
F5	1	0.4039	0.027	10.620	10.93	0.57
	2	0.4259	0.029	11.587		
	3	0.4028	0.026	10.571		
F6	1	0.6225	0.051	20.229	20.24	1.59
	2	0.5869	0.047	18.664		
	3	0.6592	0.055	21.842		
F7	1	0.7234	0.062	24.664	24.87	0.46
	2	0.7401	0.063	25.393		
	3	0.7207	0.061	24.545		
F8	1	0.7577	0.065	26.171	25.12	1.91
	2	0.6836	0.057	22.914		
	3	0.7597	0.066	26.259		

GAE: Galic Acid Equivalent



**Figure 3.** Total Fenolic Content of Cream Sunscreen Moringa Leaf Dry Extract (*Moringa oleifera* L.)

## CONCLUSION

Based on the results of the study, it can be concluded that increasing the concentration of extract and triethanolamine has a significant effect on the characteristics of the sunscreen cream preparation of dry extract of Moringa leaves, including organoleptic, pH, spreadability, and viscosity. Statistical analysis showed that there was a significant difference ( $p < 0.05$ ) between formulations containing 1% TEA (F1-F4) and those containing 1.5% TEA (F5-F8), particularly in pH and viscosity parameters. However, all results remained within the acceptable range for topical preparations, indicating that both TEA concentrations can produce stable and acceptable formulations. The results of the total phenolic content test for F5-F8, with extract concentrations of 1%, 1.5%, 2%, and 2.5%, showed that F8 had the highest total phenolic content (25.12 mg GAE/g  $\pm$  1.90). Formulations with higher extract concentrations, demonstrated the best potential for antioxidant-based product applications. The highest pH value was found in F8 (6.09  $\pm$  0.01). Triethanolamine acts as an alkalizing agent, and increasing its concentration accelerates the neutralization process, leading to slightly higher pH values in formulations.

## Conflict of Interest

This investigation was carried out without any declared conflicts or competing interests from the authors.

## Authors' Declaration

This manuscript is declared by the authors as their own independent scholarly work. They take complete accountability for all contents in accordance with the principles of academic honesty.

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