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Research Article

Development and Evaluation of Microemulsion-Based Sunscreen Cream Containing Lycopene from Tomato (*Solanum lycopersicum* L.)

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ABSTRACT

This study aimed to formulate and determine the sun protection factor (SPF) of sunscreen made from tomato lycopene microemulsion creams. Lycopene was used as the active ingredient with varying concentrations in each formula, namely F1 5%, F2 7.5%, and F3 9%. The preparation of each formula was evaluated by conducting the globule size, polydisperse index, organoleptic test, homogeneity test, pH test, spreadability test, viscosity test, and determination of SPF value. The average globule size was 119 nm which had a uniform size distribution. The physical characteristics test of the cream preparations showed the three had a bright yellow color and lacked odor. The pH test results were 3.2 ± 0.12, 5.54 ± 0.25, 6.48 ± 0.22 for F1, F2, F3, respectively. Viscosity test results were F1 40,893.33 cPs, F2 41,746.67 cPs, and F3 43,106.67 cPs. The values obtained from the dispersion test were F1 6.71±0.63, F2 5.58±0.15, and F3 4.81±0.11. Moreover, F3 with a concentration of 9% tomato lycopene microemulsion met the acceptance criteria for all of the physical properties including low viscosity to promote good spreadability, pH that does not irritate the skin, aesthetic appeal, small particle size, and non-odorous and an SPF value of 4.9. The obtained microemulsion-based sunscreen cream exhibited a good physical property of lycopene besides showing sufficient SPF value.

INTRODUCTION

Sunscreen contains one or more active ingredients that can protect the skin from the effects of ultraviolet (UV) rays emitted by the sun by absorbing UV rays. The occurrence of aging due to continuous UV rays can cause several symptoms such as rough skin, freckles, pigmentation, and wrinkles on the skin (Matta *et al.,* 2019)

Some of the active compounds commonly used in sunscreen products include avobenzone, oxybenzone, and octocrylene. However, they may cause unwanted reactions or sensitivities in some people to provide adverse side effects such as skin irritation. To reduce the harmful effects of chemicals on sunscreens, sunscreens from herbal ingredients are developed, safer, and have lower toxicity than chemicals. Herbal ingredients from plants can act as a potential source of photoprotection because of their ability to absorb UV (Liu *et al.,* 2011)

According to research conducted by Mansuri *et al.* (2021), the use of herbal ingredients containing antioxidants can prevent various diseases from UV radiation. Groups of active antioxidant compounds include carotenoids, cinnamates, flavonoids, tannins, quinones, and lycopene. One example of a natural ingredient used as sunscreen is lycopene. Lycopene is a class of antioxidants that can overcome the effects of free radicals due to UV rays. This compound is a natural color-forming pigment found predominantly in tomatoes. Lycopene can control free radicals 100 times more efficiently than vitamin E. The antioxidant activity of tomato lycopene extract cream has a very strong IC_{50} value of 2.69% (Swastika *et al.,* 2013).

Lycopene has many unsaturated bonds that make it susceptible to isomerization and oxidation reactions during processing and storage, leading to a decrease in lycopene concentration and biological activity (Martínez-Hernández *et al.,* 2016). In addition, lycopene also has poor solubility in water. Microemulsions increase the stability of lycopene as it features as a physical barrier of the core against the effects of the external environment such as light, moisture and oxygen (Rocha *et al.,* 2012). Then the microemulsion is also more effective in dissolving lycopene due to a decrease in the particle size of the lycopene microemulsion system (Cooper *et al.,* 2007). Hence lycopene is formulated inside the form of microemulsions. According to Sulastri *et al.*, (2017), tomato lycopene extract microemulsions stored for 28 days had good stability at room temperature. Tomato lycopene extract microemulsion has robust antioxidant activity with IC_{50} of 20.07 ppm (Sulastri *et al.,* 2017). Those IC_{50} value determined as a potential antiaging agent in skin care (Madan and Nanda, 2018).

To test the effectiveness of sunscreen on a product, it is necessary to determine the value of sun protection factor (SPF) as a parameter of sunscreen efficacy. SPF is defined as the amount of UV energy required to achieve the minimum erythema dose in sunscreen-protected skin divided by the amount of UV energy required to achieve minimum erythema dose in unprotected skin (Latha *et al.,* 2013). The cream dosage form was chosen to be developed in lycopene-containing microemulsions because of its ease of application rather than only in microemulsion form as well as the its ability to form a continuous layer on the skin surface which provides UV protection (Geoffrey *et al.,* 2019). Based on the description above, research was conducted on the formulation of sunscreen preparations microemulsion cream of tomato lycopene extract and the determination of its SPF value. This study aimed to determine the potential of tomato lycopene extract which has antioxidant activity as a sun protection thereby reducing the formation of oxygen free radicals due to UV rays which are involved in pathological conditions such as photo aging and skin cancer (Ebrahimzadeh *et al.,* 2014).

Table 1. Composition of different microemulsion cream formulations

Ingredients	Formulation (%) w/v		
	F1	F2	F3
Lycopene from tomato	5	5	5
Tween 80	20	25	30
Glycerine	15	15	15
VCO	10	10	10

Table 2. Composition of the tomato lycopene microemulsion creams

Ingredients	Formulation (%) b/v		
	F1	F2	F3
Tomato lycopene microemulsion	5	7.5	9
Stearic acid	4.5	4.5	4.5
Cetyl Alcohol	2.5	2.5	2.5
Methyl Paraben	0.3	0.3	0.3
Propyl Paraben	0.02	0.02	0.02
Aquadest	Ad 100	Ad 100	Ad 100

Table 3. Characteristic of tomato lycopene-containing microemulsion cream (n=3). Each value represents the mean ± SD of three experiments.

Parameter	F1	F2	F3
Organoleptic	smooth and creamy with pale yellow and pleasant odor	smooth and creamy with pale yellow and pleasant odor	smooth and creamy with pale yellow and pleasant odor
Homogeneity	Homogeneous	Homogeneous	Homogeneous
pH	3.2 ± 0.12	5.54 ± 0.25	6.48 ± 0.22
Viscosity (cPs)	40893.33± 9557.433	41746.67±9713.688	43106.67±8812.204
Spreadbility (cm)	6.71±0.63	5.58± 0.15	4.81± 0.11
SPF	2.0±0.2025	4.03±0.403	4.9±0.4997

METHODS

Materials

Tomato fruit samples were taken from a tomato plantation from Biromaru District, Sigi Regency, Central Sulawesi Province. The tomatoes taken are fresh ripe tomatoes (60-80 days old after planting, medium red with some orange spots, and have a slightly sour-sweet taste. The ingredients for making microemulsions are stearic acid, cetyl alcohol, and triethanolamine/TEA (Merck, Germany). Tween 80, glycerin, Virgin coconut oil (VCO), aquadest were purchased from Brataco, Indonesia

Meanwhile propylparaben and methylparaben were obtained from Alpha Chemika, India and Ab Mole, USA, respectively. The instrument used for SPF and globule size are UV-VIS Spectrophotometer (Cecil® Series CE 2021) and Dynamic Light Scattering method (Malvern Instruments®), respectively.

Sample Extraction

Production of crude lycopene powder from tomatoes followed the method of *(Roh et al.,* 2013), which is as follows: tomatoes were washed using running water to separate the tomatoes from impurities such as sand and dust, then split, separated between the flesh and seeds, then cut into small pieces to facilitate the crushing process with a blender, then put into a stainless steel pan, add water with a ratio of water/tomato flesh (1.5:1) based on volume/weight (v/w, L/Kg). Tomato flesh was heated at 70 °C for 60 minutes, then filtered, and the resulting pulp or residue was dried using a vacuum oven at 40 °C for 2 days or under a solar dryer (sunlight). The resulting dry residue is crude lycopene. To produce lycopene powder, the coarse residue was crushed with a blender and then weighed.

Lycopene purification

Crude lycopene purification was carried out by extracting lycopene from tomato pulp. One-gram coarse lycopene is added to the Erlenmeyer tube gradually, and 30 mL of N-hexane is added. Then shaken for 30 minutes and then decanted. The treatment was done repeatedly until the resulting extract was colorless; the collected solution was separated from the solvent by vacuum using a rotary vacuum evaporator (Sulastri *et al.,* 2017).

Preparation of microemulsion

The microemulsion was prepared by mixing the VCO, tomato lycopene extract, surfactant (tween 80) and co-surfactant (glycerine) by weight ratio using a magnetic stirrer at medium speed for 30 minutes. The resulting mixture was added with distilled water to form a microemulsion system, a formula capable of producing a microemulsion system with clear visuals was selected for further characterization. The results obtained were put in a container and tightly closed. Composition of different microemulsion cream formulations presented in Table 1.

Measurement of globule size and polydispersity index

The average globule size and polydispersity index (PDI) of lycopene containing microemulsion was evaluated using Dynamic Light Scattering method (Nano ZS, Malvern Instruments, U.K.). 0.1 ml of microemulsion was diluted to 10 ml of doubled distilled water and analyzed for three times at 25 °C.

Formulation of sunscreen cream

The manufacturing process begins with weighing the ingredients used in the manufacture of microemulsion preparations of tomato lycopene extract cream. The material used consists of an oil phase and a water phase. Materials comprised in the water phase (triethanolamine, methylparaben, and distilled water), were heated to 70°C. Materials, which include the oil phase (stearic acid, cetyl alcohol, and propylparaben), were melted on a water bath to a temperature of 70°C in a separated vessel. The oil phase is added slowly into the water phase, and then the stirring process was done until a cream base was formed. After that, a microemulsion of tomato lycopene extract was added and stirred until homogeneous, followed by cooling down to 35°C. The composition of the different sunscreen creams is given in Table 2.

Physicochemical evaluation of microemulsion cream

Organoleptic test

The organoleptic examination includes visually observable consistency, color, and odor. The specifications of the cream that must be met are having a soft consistency and homogeneous preparation color (Yuliastuti *et al.,* 2020).

Homogeneity test

Several creams to be observed are applied to a clean and dry slide to form a thin layer, then covered with a cover glass. The cream is declared homogeneous if on observation using a microscope. The cream has a texture that looks even and does not clot (Yuliastuti et al., 2020).

pH measurement

An adequate amount of cream is taken, and the pH is measured using a digital pH meter (WALKLAB TI9000) that has been calibrated using a standard buffer solution. The pH that is safe for the skin is around 4.5-8.0 (Yuliastuti *et al.,* 2020).

Viscosity measurement

Viscosity and rheological measurements for cream preparations were carried out using a HAAKE 6R viscometer and spindle number 7 with varying speeds of 2 rpm, 4 rpm, 10 rpm, and 20 rpm and then reversed to 20 rpm, 10 rpm, 4 rpm, and 2 rpm. The flow properties are obtained by making a rheogram curve between the shear stress and the shear rate. Measurements were carried out every week for 21 days. A suitable viscosity requirement is 4,000-40,000 cPs (Genatrika *et al.,* 2016).

Spreadability test

Sunscreen creams must also qualify for ease of use or application. The diameter obtained in this test was observed because the more significant the diameter, the easier the cream being tested for application. The dispersion requirement for topical preparations is 5-7 cm (Lailiyah *et al.,* 2020).

In vitro SPF determination

In this study, the sunscreen activity test was conducted in vitro. Sunscreen activity was determined from the SPF value of the sample, which was analyzed using a UV-Vis spectrophotometer. Determination of the SPF value through a UV-Vis spectrophotometer can be seen from the absorption characteristics of sunscreen samples at a wavelength of 290-320 nm with 5 nm intervals. The calculation of the SPF value used the following equation (Sharma *et al.,* 2020):

$$SPF = CF \cdot \sum_{290}^{320} Abs \cdot EE \cdot I$$

Note:
CF : Correction factor (10)
Abs : Sample absorbance
EE : spectrum of eurythermal effects
I : spectrum of intensity from the UV lights

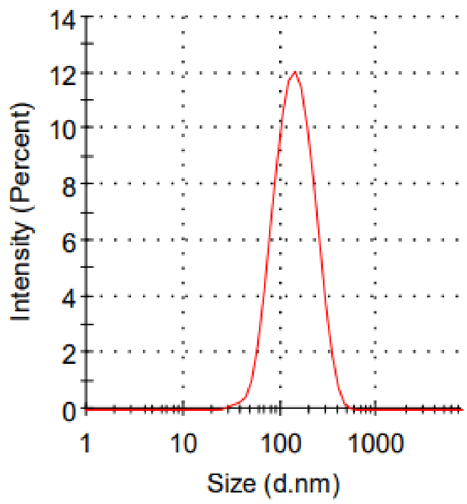

Figure 1. Size distribution curve of tomato lycopene microemulsion

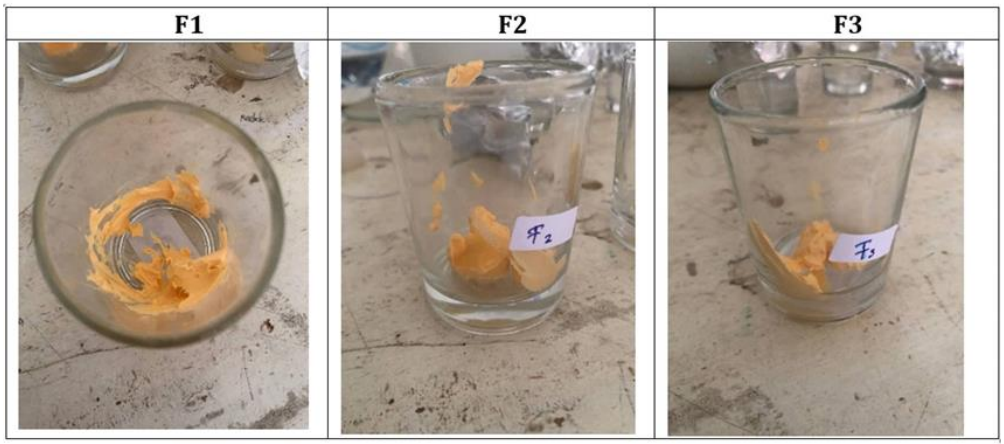

Figure 2. Tomato Lycopene Microemulsion Cream Preparation

RESULTS AND DISCUSSION

Plant identification was conducted by UPT and the Biological Resources of Central Sulawesi, Tadulako University stated the plant used was a tomato fruit (*Solanum lycopersicum* L.) obtained from Biromaru District, Sigi Regency, Central Sulawesi Province. Up to 210.21 grams of tomato fruit simplicia (*Solanum lycopersicum* L.) were extracted with a shaker method using 6 liters of n-hexane as a solvent. The result of thick tomato lycopene extract was 14.2 grams and the yield was 6.755%.

Before being formulated into a sunscreen cream, the microemulsion is first characterized for globule size and polydispersity index (PDI). The average globule size is 119 nm. Meanwhile, the PDI result smaller than 0.3, which is an average of 0.178 (Figure 1). This has confirmed the homogeneity of the droplet size distribution in the formulation which was further formulated as a microemulsion based sunscreen cream (Shukla *et al.,* 2018).

Cream preparations were made by adding various tomato lycopene microemulsions to each formula. This microemulsion was used with a different concentration of each formula aimed to observe the effect of variations in concentration on the physical quality of the preparation and to determine the cream's SPF value. The characteristic of tomato lycopene microemulsion cream can be seen in Table 3.

An organoleptic test was conducted to visually determine the consistency, color, clarity, and smell of the formula. The results showed there were no significant differences in terms of texture and aroma in each microemulsion cream formula, while the preparations formed can be seen in Figure 2.

The microemulsion cream preparations of tomato lycopene extract (*Solanum lycopersicum* L.) homogeneity test conducted produced positive results. These results were homogeneous because each formula showed a homogeneous composition, and no coarse grains were seen.

The viscosity test observed the cream preparations' level of viscosity which was measured using a Brookfield viscometer. The results for each formulation of tomato lycopene microemulsion cream showed the following values: F1 40,893.33 cPs; F2 41,746.67 cPs; and F3 43,106.67 cPs. This indicates that the higher the concentration of tomato lycopene microemulsion in cream preparations, the higher the viscosity value because the cream is produced as o/w (oil-in-water). Therefore, the increase in the amount of extract causes a reduction in the water content to ensure the viscosity becomes higher (thick). The ability to adhere to cream is influenced by viscosity, meaning the higher the viscosity, the longer the cream sticks to the skin. According to SNI 16-4399-1996 regarding the quality standard of sunscreen creams, the viscosity of a good preparation ranges from 4000-40,000 cPs (Genatrika *et al.*, 2016), hence the three creams can be said to have met good viscosity standards.

The spreadability test determined the cream softness to observe the ease of applying the preparation to the skin (Joshi *et al.,* 2017). Good dispersion causes the contact between the cream and the skin to be broad thereby promoting absorption into the skin. The dispersion requirement for topical preparations is 5-7 cm (Wibowo *et al.,* 2017). The spreadability test of the cream showed the respective results, namely F1 6.71, F2 5.58, and F3 4.81. These indicate that the higher the concentration of tomato lycopene microemulsion in cream, the smaller the spreadability. However, F3 did not meet the spreadability requirements because its value was less than the standard for good topical preparations. Sugihartini and Wiradhika (2017) also showed that the addition of extract tends to reduce the spreadability of the cream. The higher the concentration of the extract added to the base, the higher the consistency of the cream and the lower the spreadability.

The pH test was carried out on the three samples to determine the safety of the cream during usage to prevent the skin from being irritated. The skin pH is 4.5-6.5 (Hariyadi *et al.,* 2020) therefore to ensure safety and suitability, the preparation needs to be in this pH range. The test results of the three preparations were F1 3.2, F2 5.54, and F3 6.48 which showed the F1 pH value was too small or acidic i.e. 3.2. It is due to the pH of the tomato lycopene microemulsion used was acidic so that the increase in the concentration of the lycopene microemulsion into the cream base increases the pH of the cream. Furthermore, other studies have shown that the pH of tomato lycopene is approximately 4.0-4.6 (Panthee *et al.,* 2013; Thompson *et al.,* 2000). The smaller the value or, the more acidic it is, the easier the preparation irritates the skin, hence the pH requires adjustment to minimize irritation (Yuliastuti *et al.,* 2020).

The mechanism of sunscreen depends on its ability to absorb, reflect or scatter sunlight. The SPF measurement is the primary way to determine a sunscreen formulation's effectiveness. In this study, we use a simple method to determine the SPF value of sunscreen because it demonstrated a high level of reproducibility and reliability compared to the US FDA-guided in vivo SPF testing method (Yang *et al.,* 2018). Based on the SPSS output, the pH, viscosity, dispersibility and SPF values showed the same or no difference with p>0.05 among the formulations. The efficacy of the microemulsion sunscreen creams against UV rays is expressed by the SPF values. The classification of the sunscreen ability based on their SPF is divided into 5 categories: 2-4 minimal, 4-6 moderate, 6-8 extra, 8-15 maximum, and ultra-protection if the SPF is more than 15.(Franyoto *et al.,* 2020; Maharini *et al.*, 2019; Sipahutar *et al.,* 2019). Based on the SPF value displayed in Table 3, the cream in F1 (SPF value of 2.0±0.2025) belongs to the minimal protection group, while F2 (SPF value of 4.03±0.403) and F3 (SPF value of 4.9±0.4997) are in the moderate protection group (Shetty *et al.,* 2015). In general, the FDA recommends to use broad spectrum sunscreen with a moderate protection (FDA, 2022). As the SPF value increases, sunburn protection increases (FDA, 2021).

CONCLUSION

Based on the research conducted, it can be said that the three creams with different concentrations of tomato lycopene microemulsion (5%, 7.5%, and 9%) were potentially developed as sunscreen as they provide appropriate SPF values according to the FDA (Food Drug Administration). However, according to the results of physical properties, F2 and F3 met the acceptance criteria including low viscosity to promote good spreadability, pH that does not irritate the skin, has aesthetic appeal, small particle size, and is non-odorous.

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