Research Article
DOI : 10.33751/jf.v13i1.6196

FITOFARMAKA: Jurnal Ilmiah Farmasi
Vol.13, No.1, June 2023 : 31-41
p-ISSN : 2087-9164 e-ISSN : 2622-755X

Application of Alkyletanolamide Surfactants Based on Nyamplung (*Callophylum Inophylum* L.) Seed Oil in Cream Base

Dita Auliya Nurfalah[1], Erin Ryantin Gunawan[1*], Dedy Suhendra[1], Wahidah Fajrin[2]
[1] *Department of Chemistry, Faculty of Matematics and Natural Sciences, University of Mataram, Indonesia*
[2] *Department of Pharmacy, Medical School, m University of Mataram, Mataram, Indonesia*
**Corresponding author: erinryantin@unram.ac.id*

Submit: October 10th, 2022 Revised: May 5th, 2023 Accept: June 10th, 2023

ABSTRACT

Cream preparation is cosmetic preparation consisting of aqueous and oil phases that immiscible. Thus, a surfactant with hydrophilic and lipophilic groups is needed to reduce the interfacial tension between the two phases. Petroleum-based surfactants such as Triethanolamine (TEA) are often used in the cosmetic industry. In this study, however, alkyletanolamide surfactant synthesized from vegetable oil was used. Nyamplung, *Callophylum inophylum* L. (*C. inophylum*) oil is one of non-commercial vegetable oil that can be used as a substitute to produce surfactants. The aims of this study was to apply surfactant synthesized from *C. inophylum* oil on the cream preparation and to characterize the alkylethanolamide surfactant by determining the value of hydrophilic-lipophilic balance (HLB). Four different surfactant concentration, 1.5%, 2.0%, 2.5% and 0% were tested as base for the cream preparation. The best surfactant concentration for the cream-based formulation obtained in this study was 2.5% and the surfactant HLB value obtained was 14.40 indicating that alkyletanolamide surfactants can be applied to the oil-in-water (O/W) type of cream base formula.
Keywords: cream; alkylethanolamide surfactant; nyamplung oil

INTRODUCTION

Cream is a semi-solid preparation containing not less than 60% of water and is applied for external use. The cream base formulation consists of an oil phase and a liquid phase that cannot be combined so that a surfactant is needed to reduce the interfacial tension. Commercial surfactants are used in many products in the cosmetic industry. They are nowadays are derived from petroleum, such as triethanolamine (TEA). In general, surfactants are produced from petroleum, so they are non-renewable and less friendly to the environment. Surfactants from petroleum widely used in cosmetic products, detergents, body care products such as shampoo, soap, toothpaste which are effective for making foam and cause irritation to the face and skin when used for a long time and continuously and are carcinogenic (Nagtode et al., 2023). An alternative to overcome this is to replace raw materials in the manufacture of surfactants from petroleum derivatives with renewable natural resources that are environmentally friendly, such as raw materials derived from vegetable oils (Qadariyah, et al., 2021).

Alkyletanolamide surfactants synthesized from vegetable oil in this study can be used as a substitute for commercial surfactants synthesized from petroleum. Surfactants synthesized from vegetable oils have offer much added advantages such as high biodegradability, lesser

toxicity, ease of raw material availability, and easy applicability (Nagtode et al., 2023). The manufacture of cosmetics preparations using vegetable oil surfactants has previously been carried out, but the vegetable oil used is still in the form of commercial oil and food oil. Thus, alternative vegetable oils that are not used for commercial and food commodities are needed.

One of alternatives that can be used is *C. inophylum* oil. The high composition of fatty acids contained in *C. inophylum* oil makes it very potential to be developed as a raw material for the synthesis of alkylethanolamides. The oil is nonpolar, meaning they are suitable to be used as alkyl groups in alkyletanolamides. The main fatty acids in *C. inophylum* oil are dominated by long-chain fatty acids or unsaturated fatty acids which have nonpolar properties making them suitable for use as alkyl groups in alkylethanolamides.

The purpose of this study was to characterize the alkylethanolamide surfactant obtained from synthesizing *C. inophylum* oil triglycerides with ethanolamine using enzymatic reaction and the application of the alkylethanolamide surfactant that was sythesized to a cream base.

METHODS

Apparatus

The apparatus used in this study were soxhlet extraction (Pyrex), vacuum chromatography column, reflux (Pyrex), capillary pipette, hotplate stirer (DLAB (MS-H280), desiccator (Duran), Buchner (Pyrex), oven (Memmert), refrigerator, horizontal shaker waterbath (SWB 30 Memmert), glassware, pH meter (AS 218, Lamotte), rotary evaporator (Dlab RE-1000 VN), chamber, analytical balance (Fujitsu FS-AR210), Magnetic stirrer.

Materials

The materials used in this study were *C. inophylum* fruit core, anhydrous sodium sulfate (Na_2SO_4) (Merck), ethanolamine (C_2H_7NO) (Merck), Lipozyme TL IM (Novozyme), *n*-hexane (C_6H_{14}) (Merck), TLC plate (Merck), methanol (CH_3OH) (Merck), Whatman filter paper No.42 (Sigma/Aldrich), hydrochloric acid (HCl) 6 M, silica gel 60 G (Merck KGAa), potassium hydroxide (KOH) in ethanol (C_2H_5OH) 0.5 N, ethanol (C_2H_5OH) 95%, sodium hydroxide (NaOH) 40%, phenolphthalein indicator (Merck), acetonitrile (C_3H_6O), stearic acid (Wilmar), 0.1 N sodium hydroxide (NaOH) (Merck), and aquadest.

Extraction and Purification of Nyamplung Oil

Extraction and purification of oil from Nyamplung fruit core was carried out according to methods used by Suhendra et al., (2019) with simple modifications. The dried Nyamplung core was pulverized. After that, 60 g of the powder was wrapped using a filter paper which then was placed in a Soxhlet for 6 hours on a water bath. The solvent used was 500 mL of n-hexane. Fifty grams of purified Nyamplung oil was placed on a vacuum chromatography column. The stationary phase used was silica gel while the mobile phase used was *n*-hexane. The purification product was separated from the solvent using a rotary evaporator at a temperature of 40°C and a speed of 125 rpm.

Characterization of Nyamplung Oil

Characterization of Nyamplung oil was conducted by calculating acid number and TLC test, and FTIR (Suhendra et al., 2019).

Preparation of Standard Ethanolamine

A total of 15,401 mL of ethanolamine was measured with a volume pipette and was put into a 250 mL volumetric flask, 6 M HCl was added slowly until the pH was neutral. The mix was then diluted with distilled water (Suhendra et al., 2020).

Synthesis and Purification of Alkyletanolamide

Alkylethanolamide was synthesized using previous research methods by Suhendra et al., (2020) that was conducted using lipozyme and 100 mL of the 7.5% (w/w) hexane solvent, *C. inophylum* oil 10 g, 50 mL of n-hexane, 125 mL of ethanolamine. The mixture was incubated

in a *horizontal water bath shaker* at 150 rpm at a temperature of 40° C for 2 hours. The amount of alkyletanolamide formed was calculated using an analytical scale.

The formed alkyletanolamide was separated from the water and the enzyme layers. The enzymes were first separated using filter paper. The organic layer (*n*-hexane and alkyletanolamide) was above the water layer and then the alkyletanolamide was separated from the water layer using a separating funnel. The solid alkyethanolamide obtained from the the organic layer that was cooled in a freezer (<5°C) for 24 hours and filtered. The alkyletanolamide obtained on filter paper was washed with *n*-hexane and dried in a desiccator filled with phosphorus pentaoxide for 24 hours.

Characterization of Alkyletanolamide

Alkyletanolamide characterization was carried out using FTIR and determination of total nitrogen. Characterization using FT-IR was carried out to identify the functional groups in the synthesized alkyethanolamides. The determination of total nitrogen was conducted by following a method used by Nirwana et al., (2022). A total of 0.25 g of alkyletanolamide was weighed and put into a Kjeldhal flask. Alkyletanolamide was added with 2 g of Na_2SO_4-$CuSO_4$ (20:1) along with 5 mL of concentrated H_2SO_4.The mixture was then heated on an electric heater until a clear blue solution (destruction) was formed. After that, 150 mL of distilled water, 25 mL of 40% NaOH and 3 boiling stones were added to the mixture. The mixture was distilled destructively. The distillate was then poured into a 150 mL Erlenmeyer flask containing 10 mL of 2% borax acid in which a mixed indicator was added beforehand. The mixture was next titrated with 0.1 M HCl until the equivalence point was reached. Blanks were made with the same treatment as the sample. The equation to determine the percentage of total N shown in equation (1).

Determination of HLB (*Hydrophilic Lipophilic Balance*) Alkyletanolamide Surfactant Cream Base

The determination of the HLB value can be obtained from the value of the saponification number and the acid number of the surfactant using the Griffin method. The HLB value is calculated using equation (2).

Cream Base Formulation

The cream was processed by following a method used by Supomo et al., (2018). The method was modified slightly by replacing the triethanolamine surfactant with alkylethanolamide surfactant that was synthesized and liquid paraffin with *C. inophylum* oil. Starting the manufacture of cream was done by separating the ingredients into an oil phase and a water phase.

There were four different cream formulations formulated (Table 1). Ratio of alkyletanolamide surfactant in each cream was 0; 1.5; 2.0; 2.5 % respectively. The amount of stearic acid used varies because based on previously research by Widiyati et al., 2015, stearic acid can affect the physical properties of cream. The oil phase consisting of stearic acid and nyamplung oil was put into a beaker glass and was heated on a hotplate at 80°C until all the ingredients melted. The aqueous phase which consisted of alkylethanolamide surfactants and aquadest was put into a beaker and was heated on a hotplate at 80°C. The melted oil phase was poured and stirred slowly into a beaker containing the water phase to produce a homogeneous cream.

$$\% N = \frac{(V\ H_2SO_4 \text{ for sample} - V\ H_2SO_4 \text{ for blanko}) \times [H_2SO_4] \times 14{,}01}{\text{Massa Sample} \times 1000} \times 100\% \quad (1)$$

$$HLB = 20\ (1 - \frac{S}{A}) \quad (2)$$

Description:
A: Acid number
S: Saponification number

Table 1. Cream Base Formulation

Ingridients	Formula (%)			
	1	2	3	4
Stearate Acid	14.5	10	10	20
C. inophylum Oil	25	25	25	20
Alkylethanolamide (Surfactant)	1.5	2	2.5	0
Aquadest (ad.)	100	100	100	100

Cream Evaluation

Organoleptic

Organoleptic testing is a physical characteristic test of cream bases. The test was performed to assess shape, colour, and smell of the cream. The test was done with the help of human five senses. The creams were observed for homogeneity, color, and odor for 14 days. Changes that occurred were recorded (Supomo et al., 2018).

pH Value

pH value was determined using pH meter. pH evaluation was carried out by following a modified Kartini et al., (2017) method. Cream and water were mixed with a ratio of 1 g:10 mL of water. The mixture wasthen stirred and was allowed to settle until it settles. After that, the pH of the water was measured with a pH meter. According to Lambers et al., (2006), the pH of cosmetics must have the same pH as the physiological pH of the skin, which is between 4.5-6.5.

Spreadability

The dispersion test was carried out using the Rahman and Herdiningsih (2021) method. However, the amount of time and weight of the cream used were modified slightly. The weight used was 0.5 g of cream base which was placed on a glass slide. On the top the cream, another glass slide was placed. Above the glasses, a load of 150 g was put for 1-2 minutes. The diameter of the spreaded cream was measured to determine its spreadability.

Adhesiveness

To test the adhesiveness of the cream, the modified Rahman and Herdiningsih (2021) method was used. As much cream base is placed on the slide (smear on the smooth part) on the test instrument as much as 0.5 g. Another slide (smooth surface) was placed on top of the cream, then a 1000 g load was placed for one minute. Another weight of 80 g will pull the bottom slide while recording the time it takes for both slides to come off.

RESULTS AND DISCUSSION

C. inophylum Oil

The average oil percentage obtained from the extraction process with three repetitions with a sample weight of 60 g was 51.19%. Previous research stated that the oil content in nyamplung ranges from 40-75% (Fadhlullah et al., 2015). Yield difference from may be caused by geographical conditions where the plant grows which can also affect the amount of oil the plant produces (Manzoor et al., 2007).

Figure 1. *C. inophylum* oil

Oil Purification of nyamplung oil aims to obtain pure triglycerides. The properties of impurities in nyamplung oil are polar. As a result, they will stick to the stationary phase which also is polar. The stationary phase used was silica gel because the surface of the silica gel

contains hydroxyl groups that can form strong hydrogen bonds with compounds that need to be separated.

(a) (b)

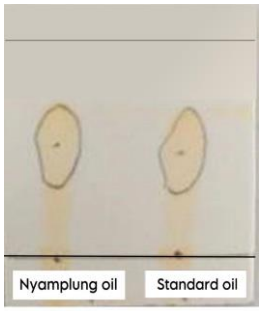
Figure 2. Oil before purification (a) and after purification (b)

After the oil was purified, the color turned into pale yellow, which was lighter than the color of the impure *C. inophylum* oil. This is because after the oil purification process, the impurities contained in the nyamplung oil are bound by the stationary phase (silica gel) so that the oil changes color to a brighter one.

Characterization of Nyamplung Oil

Acid number is one of the most important parameters to determine oil quality because acid number can predict the amount of free fatty acids in an oil or fat. The acid number of nyamplung oil was determined twice. The acid number before the purification was carried out was 20.6 mgNaOH/g oil while the acid number after the oil was purifiedwas 1.04 mgNaOH/g. The difference of the acid number of nyamplung oil before purification and after purification occurs because of the amounts of impurities that were attached to the stationary phase (silica gel) used during purification through VLC. Thin layer chromatography test was carried out using two different eluent mixtures in order to increase the desired spot resolution. Based on the R_f value, nyamplung oil Rf value is similar with the R_f value of the oil standard.

The R_f value of standard oil is 0.52 while the R_f value nyamplung oil is also 0.52, which means this indicates that the composition of nyamplung oil is the same as the standard. Qualitative analysis of nyamplung oil using FTIR will be explained later in the sub-chapter of alkylethanolamide FTIR analysis.



(a) (b)

Figure 3. TLC of nyamplung oil (a) and standard oil (b)

Alkyletanolamide

Recently, Alkyletanolamide are mostly synthesized using the *Schotten Baumann* reaction with chemical catalyst. Usually, in this kind of reaction, fatty acids or fatty acid methyl esters is reacted with monoethanolamine or diethanolamine using zinc oxide (ZnO) as a catalyst at a temperature of 150^o C for 6 to 12 hours (Maag, 1984). In recent years, however, synthesis of alkyethanolamides through enzymatic reactions has experienced a rapid development The production process using an enzymatic reaction can produce a purer alkyethanolamide product and can be operated in low temperature and pressure. A study by Suhendra et al., (2019) successfully synthesized Ethanolamide using an enzymatic reaction.

In enzymatic reaction, after the reactants were mixed, it can be seen that the two phases of the solution were immiscible. The reaction for the formation of alkyletanolamide occurs when nyamplung oil triglycerides broke down into fatty acids with the help of lipase enzyme (Simone, 2016). The lower phase in the product was an aqueous phase containing ethanolamine, while the upper phase was an n-hexane phase containing oil. The formation of these two phases was due to differences of polarity and density between the two phases.

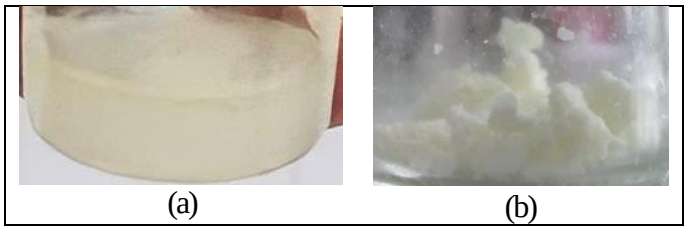


Figure 4. Alkyletanolamide gel (a) and solid alkyletanolamide (b)

The organic phase or the n-hexane phase has nonpolar properties while the aqueous phase has polar properties. The density of n-hexane is 0.66 g/cm^3 which is smaller than the density of water 0.997 g/cm^3. This can affect the position of the formed phase layers (Tikhonov, 2010). After the reactants began to react in the waterbath shaker, the mixture became cloudier compared to the colour of the reactants before being reacted. This indicates that the expected reaction occurred. In addition to the incubation time, the reaction temperature also affected the amount of fatty alkanolamide produced. For the enzymatic reaction, temperature has a significant effect on the activity or stability of the enzyme, reaction rate and solubility of the substrate (Suhendra et al., 2019). In addition, the concentration of enzymes on a fixed substrate will lead to a higher reaction rate (Cruz et al., 2018).

Characterization of Alkyletanolamide

Table 2 present spectrum absorption differences of nyamplung triglycerides, synthesized alkylethanolamides, and ethanolamide reference. Figure 5 shows the difference of nyamplung oil and the alkylethanolamide that was synthesized by the nyamplung oil spectrum.

Determination of Total Nitrogen

Average total N value contained in 1g of the synthesized alkyletanolamide sample was 0.084% obtained from the calculation in equation (1). This shows that there are 0.084% amide groups. The low value of total N obtained was due to the alkylethanolamide from nyamplung oil having long alkyl groups such as oleate.

Table 2. Wavenumber of Nyamplung Oil and Alkyletanolamide

Bond Type	Wavenumber (cm^{-1})		
	Nyampung Oil	Alkylethanolamide synthesized	Alkylethanolamide reference (*)
C-C	722.60	720	723
C-O	1163.20	-	-
C=O	1747.21	1705	1690-1650
C-N	-	1187.2	1296
C=C	1655.55	-	-
C-H	2854.31-2924.65	2850-2918	2940
N-H	-	3190.5	3012-3450
O-H	-	3434.82	3450
=C-H	3007.80	-	-

*Ethanolamide Reference: Suhendra et al. (2019)

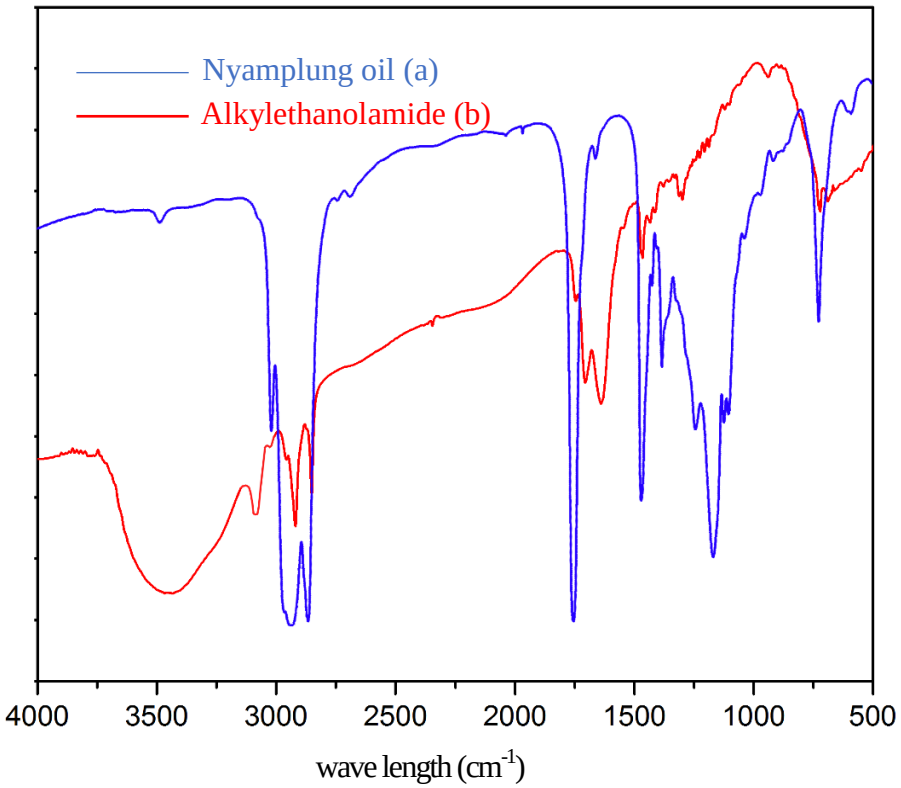


Figure 5. Spectrum of nyamplung oil (a) and alkylethanolamide (b)

Characterization of Alkyletanolamide Surfactants

The HLB value of the alkyletanolamide surfactant obtained from this study was 14.40, in which the HLB value was included in the range of HLB values that could be used to become an o/w (oil/water) cream emulsion. According to Ashish (2014) the determination of the type of oil-in-water (w/w) emulsion requires HLB values ranging between 8-18. The HLB value of 14.40 was obtained after previously calculating the value of the acid number and the value of the saponification number using equation (2). The acid value obtained was 198 mgKOH/g and the saponification number was 56 mg KOH/g.

Cream Base Test

There were four different formulations of the cream base. The difference of each cream was the concentrations of alkylethanolamide surfactant used which were 1,5%, 2%, and 2,5%, 0%, respectively. The cream was formulated by following Supomo et al., (2018) method. The method, however, was slightly modified by substituting triethanolamine surfactant with alkylethanolamide surfactant (Table 1). The characteristics of the cream carried out in this study were organoleptic, pH, dispersibility, and adhesion. Table 3 presents the form of evaluation results of cream:

Table 3. Test Data for Evaluation Cream Base

No.	Formula	Observation			
		Organoleptis*	pH	Spreadibility (cm^2) ± SD	Adhesiveness (Sec)
1.	F1	changed	5.30± 0.09	3.57 ± 1,09	0.75
2.	F2	No change	5.36 ± 0.12	5.01 ± 0,01	0.97
3.	F3	No change	5.30 ± 0.09	5.48 ± 0,10	6.51
4.	F4	No change	4.20 ± 0.09	-	-

Organoleptic

Organoleptic test was carried out by observing whether the cream base changed for 14 days. The organoleptic test was carried out by observing the stability of the cream base regarding its odor, color, and homogeneity. During 14 days of the observation, homogeneity of F1 cream changed on the 8th day. Meanwhile, there was no change of homogeneity, colour, or smell of F2, F3, and F4 cream. Changes that occur in the F1 cream base can be caused by the small emulsion concentration used (1,5%) According to Sarmah (2020), when the amount of surfactant used was too little, the cream would become unstable. This happened because the surfactant concentration affects the binding strength of various liquid compositions in the emulsion liquid. The occurrence of hydrophilic-lipophilic imbalance will result in the emulsion granules not being completely dispersed which causes disruption of emulsion stability. Guzman et al., (2022) argues that the complexity of the interface and the rheological properties of the emulsifying agent will affect the stability of the emulsion, so the preparation of the emulsion must be carefully considered.

A homogeneous and stable cream is indicated by the distribution of colour and mixing of the cream base which remains evenly distributed with no coarse grains. Homogeneous cream indicates that the ingredients used in this study were mixed perfectly. However, in this study, F4 cream texture, which did not contain any surfactant concentration (0%), was not homogeneous and was shaped like a granule. Thus, the cream cannot be categorized as a good cream. The absence of surfactant concentration caused the oil and water phases cannot blend properly. Concentration of stearic acid used also affected the texture of the cream formed. Stearic acid is a saturated fatty acid that does not have double bonds in its structure resulting the compound to have high density. This in turn causes the texture of the cream to be less liquid.

Spreadability

Test was carried out to determine the ability of the cream to be applied or applied to the skin. Perfect spreadability is needed to create wider contact between the skin and the cream, to ensure the cream can be absorbed faster. The dispersion standard of the cream is 5-7 cm with a semisolid consistency that is comfortable to be used (Joshi et al., 2019). Based on the results of the spreadability test of the four cream base formulations (Table 4), it can be seen that the F2 and F3 cream bases with three repetitions met the dispersibility test standards with the average test values of 5.013 cm and 5.479 cm, respectively. While the F4 cream base with a surfactant concentration of 0% was not tested for dispersibility because the F4 cream base was not homogeneous and the cream texture did not blend. The F1 cream base with a surfactant concentration of 1.5% had a spreadability test value of only 3.561 cm, which means that the F1 cream base did not meet the cream spreadability value standard.

Adhesiveness

The test was conducted to find out how long the cream can stick to the skin. The longer the sticking time of the cream the better because it allows the cream to be absorbed into the skin perfectly. The result of the test varied, in which different surfactant concentration produce different result. The F4 cream could not be tested because the texture of the cream was not homogeneous. Based on this study, only F3 cream base with a surfactant concentration of 2.5% met the cream stickiness test standard, which was not less than 4 seconds. The longer the slide is removed, the higher the adhesion of the cream to the skin

pH Value

Results of pH measurements obtained on the basis of cream F1, F2, F3, and F4 showed that the formulations of cream base F1, F2, and F3 had the same pH value of 5.2. Normal skin has a pH value ranging from 4.5 to 6.0 (Akhtar et al., 2011). The pH values of the F1, F2, and F3 cream bases obtained from this study were still

in the pH range that met the standards and was safe for the skin. This is in accordance with what was stated by Sharma et al., (2021) that the difference in surfactant concentration had no effect on the pH of the cream.

However, pH of the F4 cream with 0% surfactant was 4.3 which is outside of the pH range that can be applied on the skin. The low pH of the F1 cream base can be caused by several factors. The concentration of stearic acid also affects the pH level of a cream. The higher stearic acid contained in a cream formulation, the lower the pH of the cream. According to Sari et al., (2021) that the low pH may irritate the skin.

CONCLUSION

Characterization of nyamplung oil-based alkylethanolamide surfactant was carried out by determining the value of HLB (*Hydrophilic Lipophilic Balance*). Based on this study, the HLB value of the alkyletanolamide surfactant obtained was 14.40. The best percentage of alkylethanolamide surfactant was in the cream base formula 3 (2.5% surfactant). This was indicated by the physical characteristics test of the organoleptic cream base, pH, spreadability and adhesion which met the standards.

Suggestion

It is suggested to carry further research on the application of alkyletanolamide surfactants based on *C. inophylum* oil in cosmetic preparations and in drug dosage forms.

ACKNOWLEDGMENTS

Thank you to the Directorate General of Higher Education (DIKTI) for research funding assistance through the National Competitive Basic Research Scheme.

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