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Effect of Storage Temperature and Oil Palm Leaf Ethanol Extract (OPLEE) on Shelf Life of PKO and VCO Body Lotion

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ABSTRACT

Body lotions based on Palm Kernel Oil (PKO) and Virgin Coconut Oil (VCO) are susceptible to oxidation which can cause tarnishness, changes in smell and color, as well as decreased physical and chemical stability of the product. The addition of natural antioxidants such as oil palm leaf ethanol extract (OPLEE) is one of the efforts to increase this stability. This study used a two-factor design, namely OPLEE concentration (1.5%; 2%; 2.5%) and storage temperature (4°C, 25°C, 40°C) for 35 days. The results showed that the preparations remained homogeneous at 4°C and 25°C, but experienced phase separation at 40°C from day 28. The pH value tends to increase during storage with the best stability at the C treatment with the lowest slope of 0.0191-0.0371. Antioxidant activity decreased, with treatment B showing the best stability at the lowest slope value of 0.1646-0.8123, while the peroxide value increased with the increase in temperature with the lowest slope value at high temperature of 0.0971. The results of *ANOVA's Repeated Measures analysis* showed that the pH, antioxidant activity, and peroxide value changed significantly ($p<0.05$), while the physical parameters were relatively stable. Overall, the low storage temperature (4°C) and OPLEE concentration of 2.5% (B) provide the best stability in maintaining the quality of the body lotion during storage. Therefore, OPLEE as a natural antioxidant in cosmetic formulations can be an alternative active ingredient that supports the development of more stable and value-added body lotion products.

INTRODUCTION

The national cosmetics industry is showing significant growth as public awareness of the importance of self-care and appearance increases. Based on the report Ministry of Industry (2024), the value of Indonesia's cosmetics market increased by 48% during the period 2021-2024, from USD 1.31 billion to USD 1.94 billion, with a projected average annual growth of 5.35% until 2028. Meanwhile, the market value of the national beauty industry in 2024 is estimated to reach IDR 146 trillion with more than 1,500 cosmetic SMEs (Geni & Budiyanti, 2025).

Therefore, product formulation innovations such as body lotions are becoming relevant as the demand for natural moisturizers continues to increase. Body lotion is an oil-in-water (O/W) type emulsion preparation that functions to maintain moisture and softness of the skin. The stability of the lotion is greatly influenced by the formulation and storage conditions. Research Puspita *et al*. (2025) reported that storage at high temperatures (≥50°C) led to a decrease in viscosity of up to 74.12%, while Praise & Christianity (2019) found discoloration and creaming due to

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emulsion degradation. Therefore, controlling physical and chemical stability is an important factor in maintaining product quality during the shelf life.

Antioxidants play an important role in maintaining the stability of cosmetic preparations by preventing fat oxidation that causes rancid odor and decreased quality. Synthetic antioxidants such as Butyl Hydroxyanisol (BHA) and Butyl Hydroxytoluene (BHT) are effective at suppressing oxidation, but have a risk of toxicity and skin irritation (EFSA et al., 2018). The trend of the modern cosmetic industry then shifted to the use of natural antioxidants such as flavonoids, phenolics, and tocopherols which are safer to use. Some Indonesian tropical plants such as moringa leaves, rosella, and senggani are known to have strong antioxidant activity with IC values$_{50}$ < 10 ppm, but the potential for the use of other biomass that is more abundant such as oil palm leaves is still not widely researched. Olive oil palm leaves extracted by OPLEE contain bioactive compounds such as phenolics, flavonoids, tannins, tocopherols, carotenoids, and saponins that function as antioxidants and antibacterials (Khairunnisa, 2019). OPLEE antioxidant activity shows IC value$_{50}$ 81,84-133,58 µg/mL (Idawati et al., 2024; Zumaro et al., 2021) With a total phenolic content of 168,400 ppm and flavonoids of 58,604 ppm. In addition, palm leaf waste is abundant in Indonesia with production reaching ±40 million tonnes per year from 16 million hectares of oil palm plantations (GAPKI, 2024). The use of oil palm leaves as an active ingredient in natural antioxidants is not only of high economic value, but can also support the optimization of by-products of the oil palm plantation industry.

The basic ingredients of lotions in the form of Palm Kernel Oil (PKO) and Virgin Coconut Oil (VCO) contain lauric, mirista, and caprylate acids which function as natural emollients that quickly absorb and moisturize the skin (Putri *et al.*, 2025; Squirrelly *et al.*, 2017). However, both are easily oxidized so they need antioxidant protection to maintain stability. Based on the guidelines COLIPA Guidelines (2004) The European Cosmetic and Perfumery Association and BSN (1996) In SNI 16-4399-1996, cosmetic stability tests are performed at temperatures of 4°C, 25°C, and 40°C to assess changes in pH, viscosity, and color. Therefore, it is necessary to conduct research on the effect of variations in OPLEE concentration and storage temperature on the shelf life of PKO and VCO-based body lotions. In addition, research on PKO and VCO-based body lotions has generally only focused on the physical characteristics and moisturizing capabilities of the product, while research related to OPLEE has focused more on the identification of bioactive compounds and antioxidant activity in vitro. Therefore, the novelty of this research lies in the use of oil palm leaf waste as a natural source of antioxidants in body lotion preparations so that it is expected to produce more stable and value-added body lotion for the development of the sustainable cosmetics industry.

RESEARCH METHODS

This research was designed using a two-factor perfect random design (RAS) method by analyzing critical parameters during the storage period (5 weeks). The first factor is the variation in OPLEE concentration with 3 levels (A 1.5 %; B 2%; C 2.5%). The second factor is the Storage Temperature Variation which consists of 3 levels (4°C; 25°C; 40°C). From these two factors combined, there were 9 experimental units without repeats. The tests that will be carried out on each treatment every week during the storage period include storage capacity tests on variations in storage temperature factors (Lestari *et al.,* 2022). In addition, pH tests, adhesion tests, dispersion tests, homogeneity tests, antioxidant activity tests, viscosity tests and peroxide value tests were also carried out (Salsabila *et al.,* 2020; Snoop Dogg *et al.,* 2023).

Creation of OPLEE

Oil palm leaf samples were obtained from oil palm plantations in the Indragiri Hilir area, Riau Province. A total of 3 kg of fresh oil palm leaves are sorted to separate dirt and damaged parts, then washed thoroughly. After that, the leaves are cut into small pieces (3-5 cm) and dried using an oven at 60°C for 22 hours (Kartiko & Fanani, 2021). The dried leaves produced are then weighed to determine the weight of simplicia, then mashed using a blender until they become a

fine powder. The extraction process is carried out by the maceration method with a ratio of 1:10, where 600 g of palm leaf powder is soaked in 6 L of 96% ethanol solvent for 2 × 24 hours covered using aluminum foil. After the soaking process is complete, the mixture is filtered to separate the filtrate (mafiber) from the pulp. Maserat is then evaporated using a rotary evaporator with a temperature below 50°C until a thick extract of palm leaves is obtained. The resulting extract is then stored in a tightly sealed dark bottle at a temperature of 4-8°C until it is used at the lotion formulation stage (Idawati et al., 2024; Zumaro et al., 2021).

Body Lotion Manufacturing

This body lotion manufacturing research uses a modified formulation of Widyasanti et al. (2023), by making modifications in the form of adding OPLEE and PKO. Details of the formulation can be seen in the following table:

Table 1. Formulation of Basic *Lotion* Preparation 100 g

Sections	Ingredients	Composition (grams)
Oil Phase	*Virgin Coconut Oil*	10
	Palm Kernel Oil	15
	Glyceryl Monostearate	5
	Stearic Acid	3
	Acetyl Alcohol	2,5
Water Phase	Tween 80	2,5
	Aquadest	61,5
	OptipHen	0,5

Table 2. Body Lotion *Formulation*

Treatment	Types of Additives		
	***Oil Fragrance* (mL)**	**OPLEE (grams)**	***Basic Lotion* (grams)**
A	2	1,5	100
B	2	2	100
C	2	2,5	100

The manufacture of body lotion begins with the preparation of basic lotion preparations through two main phases, namely the oil phase and the water phase. The oil phase is heated in a waterbath at 70-75°C while stirring until homogeneous. Furthermore, the water phase consists of being heated at the same temperature until it is evenly mixed. After both phases reach a uniform temperature, the oil phase is gradually introduced into the water phase while homogenizing at a speed of 3000 rpm until a stable emulsion is formed (Kusumaningtiyas et al., 2024). The process continues with cooling until the temperature reaches 30-35°C to obtain a base lotion that is ready to use. The next stage is the manufacture of body lotion with the addition of OPLEE according to the combination of treatments in the experimental design. A basic lotion of 100 g is heated to a temperature of ±40°C then OPLEE is added according to the level of treatment (1.5%, 2%, 2.5%). The mixture is then homogenized for 10 minutes until the extract is completely dispersed in the lotion matrix, then the temperature is lowered back to 35°C. After achieving these conditions, the lotion is packaged into a sterilized container (Widodo, 2025).

Evaluation of Body Lotion Preparations

Antioxidant Activity Test

The master solution is made using as much as 1 gram of sample weighed and put into a test tube, then 10 mL of methanol is added, divortex and closed using aluminum foil. Then 1 mL of the parent solution was taken into the test tube and 1 mL of DPPH was added, then it was vortex and incubated in a dark room for 30 minutes and 3 mL of methanol was added to the vortex again. Blank samples are also made in the same way but without the addition of the parent solution. Furthermore, the absorbance of the sample and blank was measured with a UV-Vis spectrophotometer at a wavelength of 519 nm, and the percent inhibition was calculated using a predetermined calculation formula.

Peroxide value Test (Sigh) *et al.*, 2023).

A total of 10 g of *body lotion* samples are put into a sealed erlenmeyer. Next, 30 mL of a mixture of glacial acetic acid and chloroform solvents was added in a ratio of 3:2 (v/v). The mixture is macerated and then filtered using filter paper to remove the oil or fat in the *body lotion*. After that, 0.5 mL of saturated KI solution is added and the mixture is left to sit for 1 minute while shaking. Then 30 mL of aqueducts are added. Iodine formed due to the presence of peroxide is titrated using a solution of sodium thiosulfate ($Na_2S_2O_3$) until the solution turns yellow. Once the yellow color appears, an amylum indicator is added and the titration continues until the blue color disappears. The volume of sodium thiosulfate solution used is then recorded. Repeat three times on each sample to take the average, so that the peroxide value value produced is more accurate.

RESULTS AND DISCUSSION

Yields OPLEE

The yield is calculated based on data from the production of OPLEE using 3 kg of fresh oil palm leaves that are dried using an oven until 1,260 grams of dried oil palm leaves are obtained. The dried oil palm leaves that have been obtained are then mashed and sifted until 1,149 grams of oil palm leaf simplicia are obtained. The simplicia obtained were then extracted using the maceration method and continued with solvent evaporation using a rotary evaporator until a thick extract of 205 grams was obtained. Based on this data, the yield (%) can be calculated by comparing the weight of the extraction produced with the weight of simplicia so that a yield of OPLEE of 0.3422% is obtained.

Homogeneity Test

Based on the data in Table 3, the homogeneity test results showed that the entire sample remained in a homogeneous condition for 35 days of storage at temperature 4°C and 25°C. Nevertheless, at 40°C Instability begins to occur characterized by inhomogeneous conditions (separation of oil and water phases) on days 28 to 35 for the entire treatment. This suggests that higher temperatures can lead to an acceleration of emulsion instability in the preparation *Body Lotion*. The standard for the appearance quality or homogeneity of body lotion has also been regulated in SNI 16-4399-1996 with homogeneous conditions, so Table 3 also shows that at the temperature 4℃ and 25℃ The whole body lotion treatment is still qualified, but not for temperature. In addition to the requirements for SNI, the characteristics of a homogeneous body lotion are evenly distributed colors, no clumping granules and no phase separation 40℃(Rasydy et al., 2021). These findings are in line with research Praise & Christianity (2019) which states that the increase in storage temperature accelerates emulsion degradation due to the weakening of the emulsifier's ability to maintain oil phase dispersion and water phase during storage.

Table 3. Homogeneity Characteristics *of Body Lotion* During Storage

Treatment		Day To					
		0	7	14	21	28	35
A		H	H	H	H	H	H
B	4℃	H	H	H	H	H	H
C		H	H	H	H	H	H
A		H	H	H	H	H	H
B	25℃	H	H	H	H	H	H
C		H	H	H	H	H	H
A		H	H	H	H	NH	NH
B	40℃	H	H	H	H	NH	NH
C		H	H	H	H	NH	NH

Description: H (Homogeneous); NH (Not Homogeneous)

pH Test

Figure 1 shows the increase in pH of body lotion during storage at 4°C, 25°C, and 40°C for all treatments (A, B, and C), with differences in the slope in each condition. At 4°C, the successive slope values were A = 0.2306, B = 0.0683, and C = 0.0191, indicating that the C treatment had the most stable pH change. A similar pattern was seen at 25°C with slopes A = 0.1109, B = 0.0571, and C = 0.0371, as well as at 40°C with slopes A = 0.0683, B = 0.0497, and C = 0.0229. Visually, lines with smaller slopes appear more sloped, indicating better pH stability, while rising temperatures tend to increase the slope of the line so that the rate of pH change becomes faster. Thus, this graph shows that C treatment and storage at low temperatures provides the best pH stability. The standard parameter for body lotion pH values has also been set in SNI 16-4399-1996 which ranges from 4.5-8, so figure 1 also shows that all body lotion treatments are still eligible.

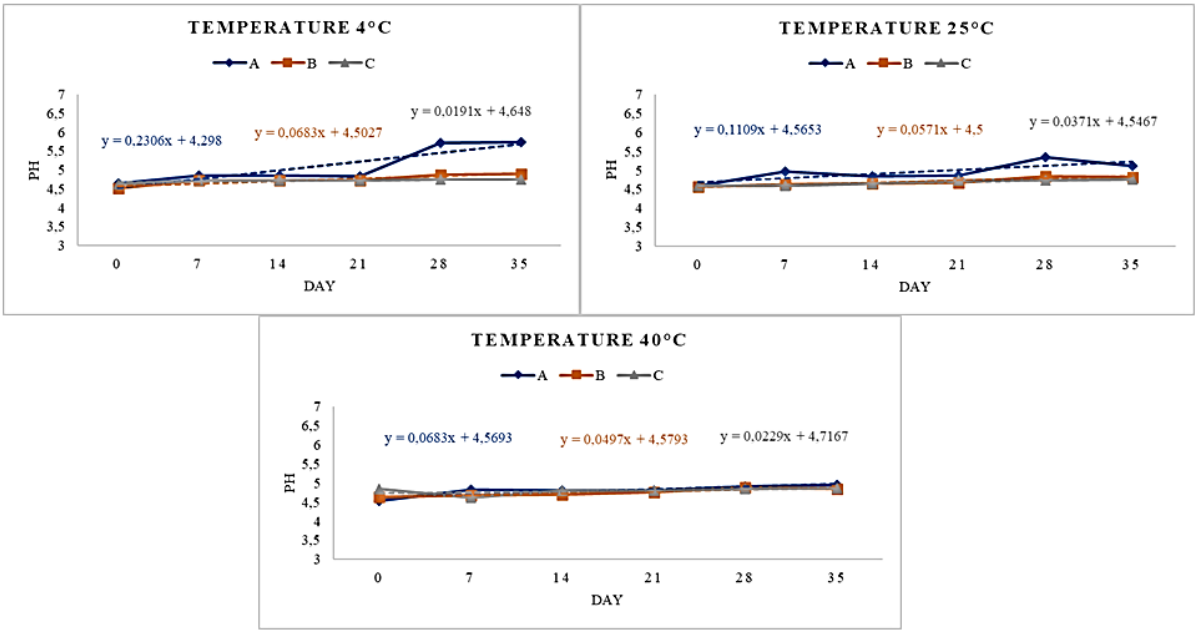

Figure 1. Graph of pH changes over time at various storage temperatures and OPLEE concentrations

Adhesive Strength Test

Figure 2 shows changes in the adhesion of body lotion during storage at temperatures of 4°C, 25°C, and 40°C for the entire treatment (A, B, and C) which generally tend to decrease with some fluctuations. Based on the slope, at 4°C the values of A = 0.3714, B = 0.2429, and C = 0.2514 were obtained, where treatment B showed the slowest decrease. At 25°C, the successive slope values were A = 0.1486, B = 0.0371, and C = 0.8229, indicating that the C treatment experienced the greatest decrease in adhesion. Meanwhile, at 40°C, slopes A = 0.2571, B = 0.1543, and C = 0.5914 were obtained, with treatment B still showing the best stability. Visually, lines with greater slopes appear steeper which signals a faster decrease in adhesion, especially at higher temperatures. This graph confirms that the increase in temperature accelerates the decrease in adhesion, while the B treatment provides the best stability during storage. This finding is in line with previous research, where after cycling tests on body lotion there was a decrease in adhesion (Azima et al., 2025). The quality requirements for body lotion adhesion are not less than 4 seconds (>4 seconds) (Rasydy et al., 2021).

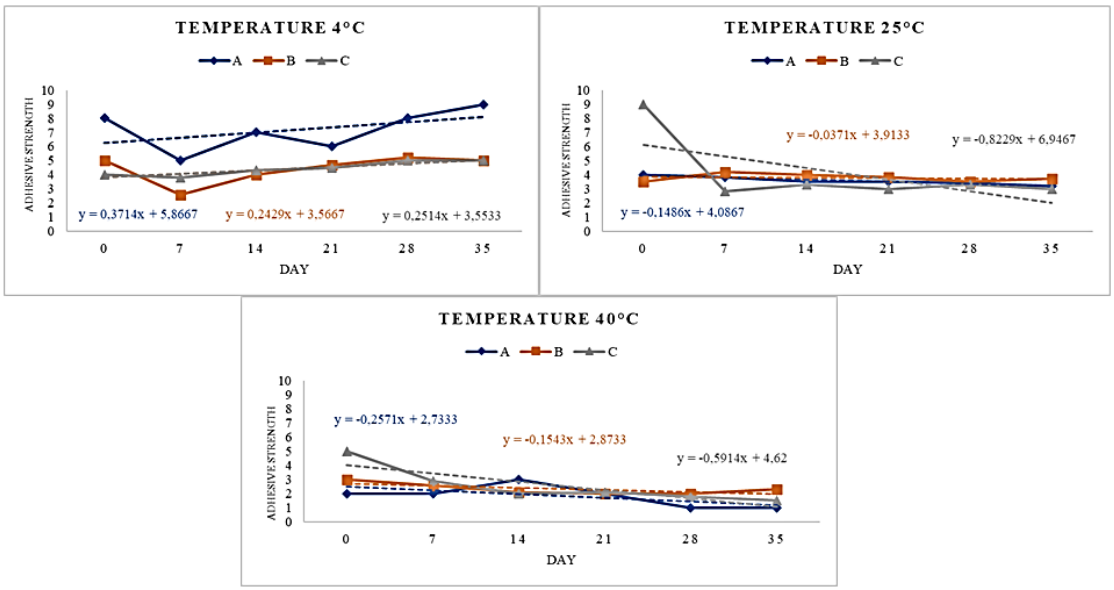

Figure 2. Graph of the change in adhesion(s) over time at various storage temperatures and OPLEE concentrations

Dispersion Test

Figure 3 shows the change in the dispersion of body lotion during storage at 4°C, 25°C, and 40°C for the entire treatment (A, B, and C) with different trend directions in each condition. At 4°C, the entire treatment experienced a decrease in dispersion with slope values A = 0.5557, B = 0.4614, and C = 0.5543, indicated by the slope of the descending line. At 25°C, the pattern formed was more varied, where treatment A had a slope of 0.3229 (downward), while B = 0.0471 and C = 0.2186 showed a tendency for smaller and relatively stable changes. Meanwhile, at 40°C the entire treatment showed an increase in dispersion with slope values A = 0.4429, B = 0.3729, and C = 0.3829, which can be seen from the increased line slope. Visually, the graph confirms that low temperatures produce a downward trend, while high temperatures result in an increasing trend of dispersion. Thus, this graph shows that the storage temperature and concentration of OPLEE have an effect on the change in dispersal power, with treatment B at 25°C showing the best stability because it has the smallest line slope. The change in dispersion during storage is inversely proportional to the change in the viscosity of the lotion due to the influence of temperature. At low temperatures, the viscosity tends to increase so that the spreadability decreases, while at high temperatures the viscosity decreases so that the lotion becomes easier to spread.

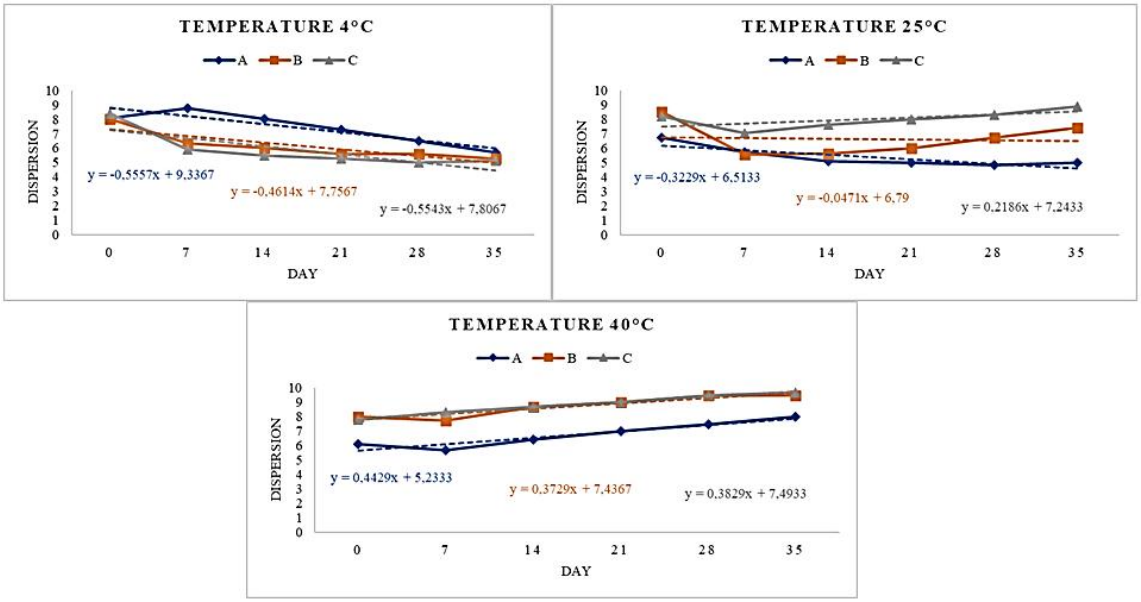

Figure 3. Graph of changes in dispersion power (cm) over time at various storage temperatures and OPLEE concentrations

Viscosity Test

Figure 4 shows the change in viscosity of body lotion during storage at 4°C, 25°C, and 40°C for all treatments (A, B, and C) with different patterns in each condition. At 4°C, the entire treatment experienced an increase in viscosity with slope values A = 431.51, B = 431.51, and C = 447.8, which can be seen from the increased line slope. At 25°C, the viscosity change is relatively small with slopes A = 2.2, B = 0.0286, and C = 32.286, where treatment B shows the best stability because it has the slope of the most sloping line. Meanwhile, at 40°C the entire treatment showed a decrease in viscosity with slope values A = -91.543, B = -164.03, and C = -7.9429, which was indicated by the slope of the line descending, with the most stable C treatment. Visually, the graph confirms that low temperatures tend to increase viscosity, moderate temperatures are relatively stable, and high temperatures decrease viscosity. Thus, this graph reinforces that the storage temperature and concentration of OPLEE have an effect on viscosity stability, with treatments B (25°C) and C (40°C) showing the best stability. Changes in viscosity during storage show a close relationship with the effect of temperature on the structure of the body lotion emulsion. At low temperatures, the viscosity increases because the particle movement becomes slower so that the emulsion system is thicker, while at high temperatures the viscosity decreases due to weakening interactions between particles and decreasing emulsion stability.

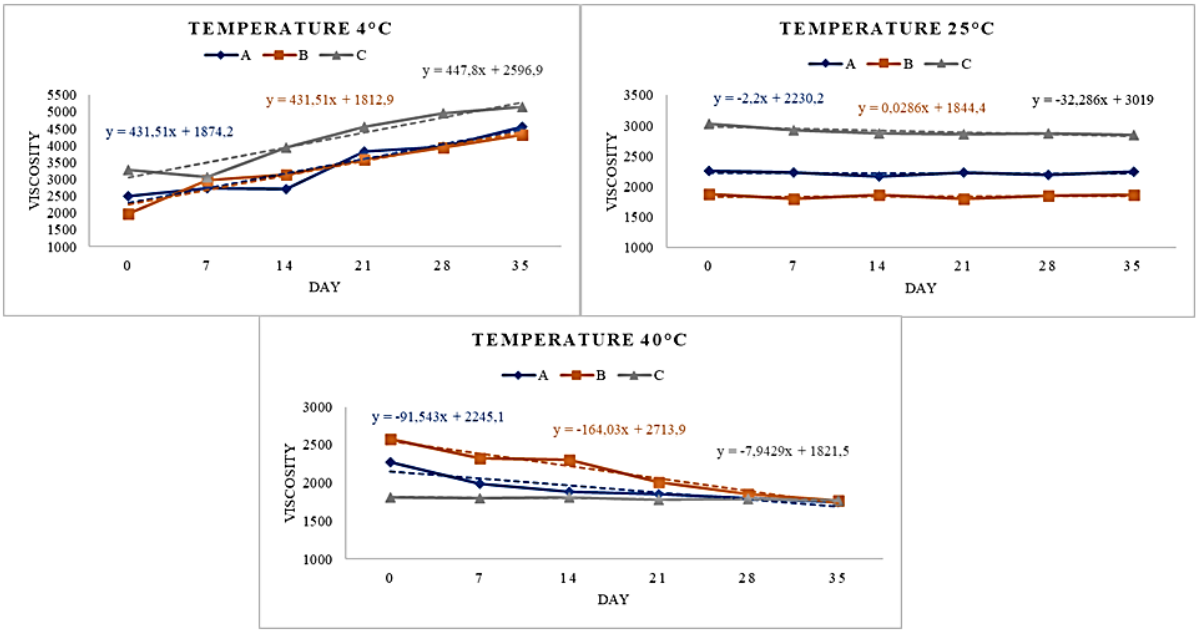

Figure 4. Graph of viscosity change (cP) over time at various storage temperatures and OPLEE concentrations

Antioxidant Activity Test

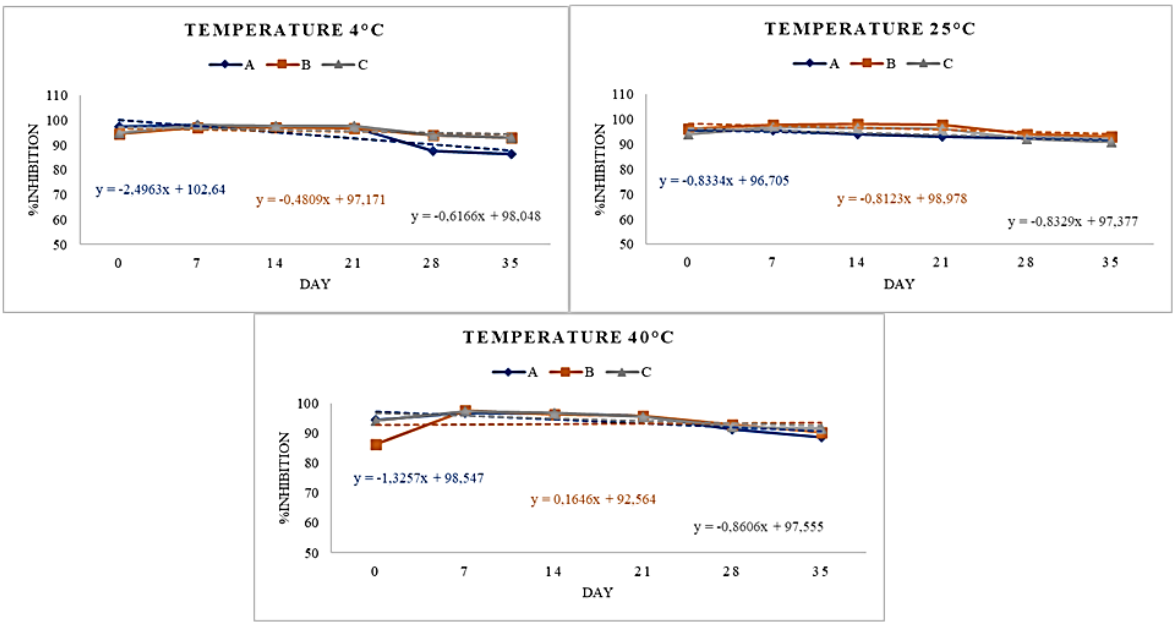

Figure 5. Graph of changes in antioxidant activity (%inhibition) over time at different storage temperatures and OPLEE concentrations

Figure 5 shows changes in antioxidant activity (% inhibition) of body lotion during storage at 4°C, 25°C, and 40°C for all treatments (A, B, and C) which generally tend to decrease over time, although there was a slight improvement at the beginning of observation. Based on the slope, at 4°C the values of A = -2.4963, B = -0.4809, and C = -0.6166, where treatment B shows the smallest decrease to be the most stable. At 25°C, the relative slope values were uniform at A = -0.8334, B = -0.8123, and C = -0.8329, indicating almost the same rate of decline across treatments. Meanwhile, at 40°C, slopes A = -1.3257, B = -0.1646, and C = -0.8606 were obtained, with treatment B again showing the best stability. Visually, lines with a greater (more negative) slope

appear steeper which signals a faster decline in antioxidant activity, especially at high temperatures. Thus, this graph confirms that the increase in temperature accelerates the decrease in antioxidant activity, while treatment B is able to maintain the stability of antioxidant activity best during storage. The decrease in antioxidant activity during storage is thought to occur due to the degradation of phenolic compounds and flavonoids that are sensitive to temperature and oxidation. The higher the storage temperature, the faster the breakdown rate of antioxidant compounds so that inhibition ability decreases.

Peroxide Value Test

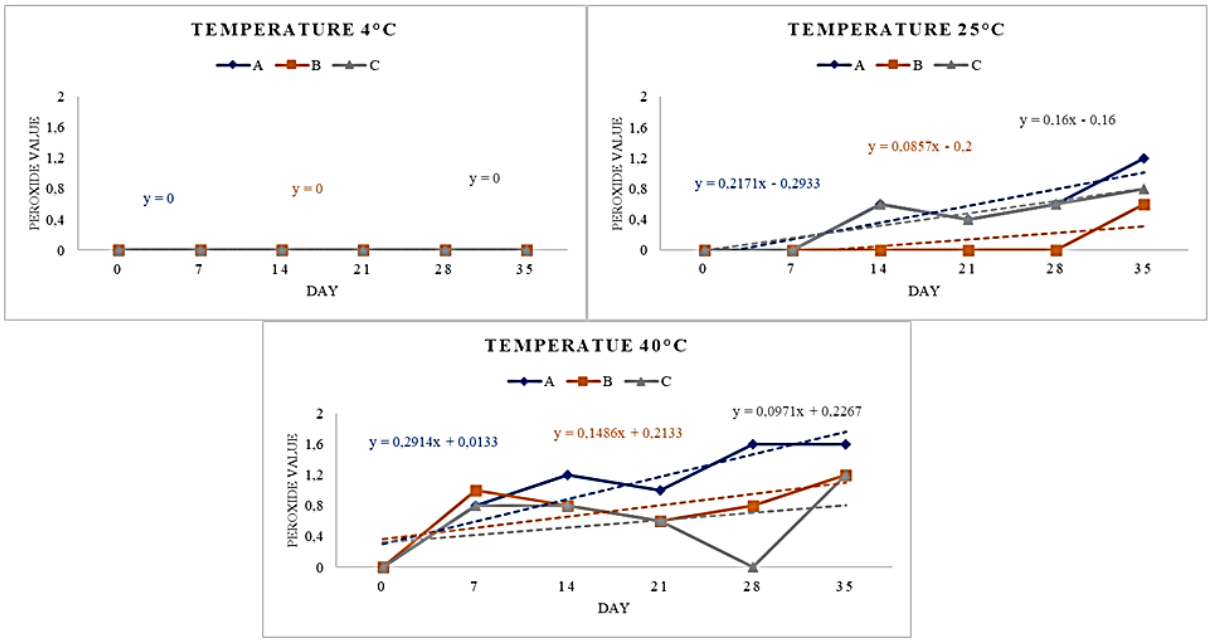

Figure 6. Graph of changes in peroxide values over time at various storage temperatures and OPLEE concentrations

Figure 6 shows the change in the number of peroxide body lotion during storage at 4°C, 25°C, and 40°C for all treatments (A, B, and C) with different patterns in each condition. At 4°C, the entire treatment showed a slope value of 0 (A = 0; B = 0; C = 0), which is marked with a horizontal line and indicates the absence of peroxide formation during storage. At 25°C, the peroxide value begins to increase with slope values A = 0.2171, B = 0.0857, and C = 0.1600, where treatment B shows the lowest rate of increase. Meanwhile, at 40°C the improvement occurred faster with slope values A = 0.2914, B = 0.1486, and C = 0.0971, where the C treatment was the most stable because it had the slope of the most sloping line. Visually, lines with larger slopes appear steeper, especially at high temperatures, which indicates an acceleration of peroxide formation. Thus, this graph confirms that the increase in temperature accelerates oxidation, while the C treatment shows the best ability to suppress the rate of peroxide formation during storage. An increase in the number of peroxides during storage indicates the occurrence of lipid oxidation processes in the body lotion oil phase, especially at higher temperatures. High temperatures can accelerate the formation of free radicals and hydroperoxide so that the oxidation rate increases, while at 4°C the oxidation reaction takes place very slowly so that no peroxide is formed.

Table 4. Repeated *Measures ANOVA Test* Results Various Parameters

Parameters	Corrections	F	Sig.
pH	*Greenhouse-Geyser*	8,124	0,012*
Adhesion	*Greenhouse-Geyser*	2,227	0,136
Dispersability	*Greenhouse-Geyser*	1,349	0,287
Antioxidant activity	*Greenhouse-Geyser*	17,494	0,000*
Viscosity	*Greenhouse-Geyser*	1,753	0,221
Number of Peroxides	*Greenhouse-Geyser*	6,526	0,004*

Remarks: * shows significant difference ($p < 0.05$)

Based on Table 4, it is known that storage time exerts a different influence on each parameter tested. pH parameters ($F = 8.124$; $p = 0.012$), antioxidant activity ($F = 17.494$; $p < 0.001$), and peroxide value ($F = 6.526$; $p = 0.004$) showed significant changes during the storage period ($p < 0.05$). This indicates a change in the chemical properties and stability level of the product over time. Antioxidant activity has the highest F-value, so it is the most sensitive parameter to the effect of storage time. In contrast, the adhesion ($F = 2.227$; $p = 0.136$), dispersability ($F = 1.349$; $p = 0.287$), and viscosity ($F = 1.753$; $p = 0.221$) parameters showed no significant change ($p > 0.05$), which means that the physical properties of the preparations tended to be stable during storage. Overall, these results suggest that storage time affects the chemical characteristics more than the physical properties of the preparation.

CONCLUSION

Based on the results of the study, it can be concluded that the variation in storage temperature and OPLEE concentration shows an interaction with the shelf life of body lotion physically and chemically. Chemical parameters such as pH, antioxidant activity, and peroxide values show significant changes, while physical parameters such as adhesion, dispersibility, and viscosity tend to be more stable. A storage temperature of 4°C provides the best stability, characterized by no peroxide formation, smaller pH changes, and homogeneous emulsion stability. Meanwhile, a temperature of 40°C accelerates the deterioration of quality, mainly characterized by emulsion instability and an increase in the number of peroxides. The concentration of OPLEE in the C treatment (2.5% OPLEE) showed the best stability in the pH parameters and peroxide value, while the B treatment (2% OPLEE) was more stable in antioxidant activity, adhesion, and viscosity. Overall, the combination of 4°C temperature and OPLEE concentration of 2-2.5% is the best condition for increasing the shelf life of body lotion. Therefore, OPLEE as an antioxidant in cosmetic formulations can be an alternative active ingredient that supports the development of more stable and value-added body lotion products. Further research is recommended to conduct tests with longer storage times, microbiological tests, accelerated stability, and skin irritation.

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