Indonesian Journal of Cosmetic
E-ISSN: 3026-3352

INESIA LOTION INSTABILITY: EFFECTS OF OPACIFIER AND THICKENER CONCENTRATION AND REFORMULATION

Veni Nurhayati[1*], Indah Puspita Sari[1], Dewi Asima Silaen[2]
1. Cosmetic Engineering, Institut Teknologi Sumatera, South Lampung, 35365
2. PT. Prioritas Jaya Indonesia, Tangerang, 15720

***Corresponding Email: veni.122500033@student.itera.ac.id**

ABSTRACT

This study aims to analyze the effect of opacifier (Titanium Dioxide) and thickener (Carbomer) concentrations on phase instability in Inesia Hand and Body Lotion Midsummer products, and to formulate reformulation solutions to improve their stability. Initial observations on the commercial product (Formula F1) showed severe phase instability, characterized by two-layer separation after 27 hot-cold cycle tests. To address this, three experimental formulas (F3, F4, F5) were designed by varying the concentrations of Carbomer and Titanium Dioxide, using F1 as an unstable control and F2 as a stable control. Accelerated stability test results over 27 cycles showed that Carbomer concentration was the dominant factor in determining emulsion stability. Formulas F1 and F4, with low Carbomer concentrations (0.12% and 0.14%), experienced significant instability (total separation in F1, slight creaming in F4) exacerbated by higher Titanium Dioxide concentrations. In contrast, Formula F5 (1,20% Carbomer, 0.09% TiO_2) showed emulsion stability, maintaining perfect homogeneity for 26 cycles. Interestingly, Formula F3 (0.16% Carbomer, 0.10% TiO_2) also proved to be very stable and equivalent to F2, indicating an effective threshold for optimal stability. Organoleptic evaluation supported the physical stability findings. Increasing Carbomer concentration proved to be an effective reformulation strategy in overcoming phase instability in Inesia body lotion. This research provides a scientific basis for the development of more stable cosmetic products.

Key words: Inesia, Emulsion, Stability, Carbomer, TiO_2.

INTRODUCTION

PT. Prioritas Jaya Indonesia (PJI) is one of the key players in the dynamics of the cosmetic manufacturing industry in Indonesia. The presence of PT. PJI is in line with the rapid growth of the national cosmetic industry, where data from the Central Statistics Agency for the period 2010-2023 shows significant market development, supported by the determination of the cosmetic industry as a mainstay sector by the Ministry of Industry in the National Industrial Development Master Plan (Pusat Komunikasi Publik Kementrian Perindustrian, 2015).

Despite its established reputation for producing high-quality products, PT. PJI, like other cosmetic manufacturers, can face technical challenges in the product development process, especially related to formulation stability. Hand and Body Lotion is a liquid emulsion preparation with several active ingredients consisting of an oil phase and an air phase and is stabilized by an emulsifier so that it does not separate (Deore et al., 2025). Emulsions are thermodynamically unstable systems due to the natural properties of the oil and air phases which are molecularly incompatible, causing separation between the two phases, resulting in the release of energy from the system and causing the emulsion to break down (Kabalnov, 1998). Emulsion based cosmetic products, such as hand and body lotions, are inherently thermodynamically unstable. This means that emulsions tend to revert to their original phase (separate oil and water) over time, which can lead to various forms of instability. The main mechanisms of phase instability in emulsions include creaming (migration of dispersed phase droplets to the surface due to differences in density), sedimentation (droplets settle), flocculation (aggregation of droplets without losing individual identity), coalescence (merging of droplets leading to permanent phase separation), and total phase separation (Cao et al., 2021). This instability not only reduces the aesthetics and consumer acceptance of the product, but can also affect the efficacy and safety of the product.

In this case study, Inesia Hand and Body Lotion Midsummer product produced by PT. PJI was found to have a clear phase separation after undergoing a hot-cold cycle test for 27 cycles. This condition indicates a weakness in the formulation that impacts the long-term stability of the product. This study highlights the importance of formula optimization and rigorous stability testing before scale production to prevent financial losses and maintain the company's reputation. Therefore, this study aims to analyze in depth the effect of opacifier (Titanium Dioxide) and thickener (Carbomer) concentrations on phase instability in Inesia Hand and Body Lotion Midsummer product, as well as formulate an effective reformulation solution to improve product stability. It is expected that this study will provide a significant contribution to the understanding of the factors causing instability in emulsion formulation and strategies to achieve more stable and high quality cosmetic products.

MATERIAL AND METHODS

This section of the report gives a detailed account of the procedure that was followed in completing the experiment(s) discussed in the report. Such an account is very important, not only so that the reader has a clear understanding of the experiment, but a well written Materials and Methods section also serves as a set of instructions for anyone desiring to replicate the study in the future.

Material

Product samples of Inesia Body Lotion Midsummer are unstable (F1), and Inesia Body Lotion Midsummer is stable (F2). Oil phase (BHT, Petroleum Jelly, Cetyl Alcohol, Cetearyl Alcohol & Ceteareth-20, C12-C15 Alkyl Benzoate, Isopropyl Myristate, and Stearic Acid), to form the oil phase in the emulsion. Water phase (Aqua Demineralisata, Na_2EDTA, Glycerin, Propylene Glycol) as the basic component of the water phase, Titanium Dioxide (opacifier). Triethanolamine as a pH adjuster, to adjust the pH of the formulation. Carbomer as a thickener, to increase the viscosity and stability of the system. Phenoxyethanol and DMDM Hydantoin as preservatives, to prevent microbial contamination. Fragrance oil to provide aroma to the lotion. Product samples and materials used are from the PT. Prioritas Jaya Indonesia Laboratory in cosmetical grades and 90-99% purity.

Methods

Inesia Body Lotion Sample Selection

The Inesia Body Lotion sample used in this study is a product that experiences phase instability, in 1 batch sample after passing a cycling test for 27 cycles. The Inesia Body Lotion used is the Midsummer variant. Furthermore, a dissection of the unstable Inesia product formula was carried out, to observe the causal factors, more specifically in the concentration of opacifier in the form of Titanium dioxide and thickener in the form of Carbomer.

Literature Study of the Effect of Opacifier Concentration (Titanium Dioxide) and Thickener (Carbomer) on the Instability of Lotion Emulsion Phase

This research method describes a systematic approach used to review and analyze scientific literature related to the effect of opacifier concentration (Titanium Dioxide) and thickener (Carbomer) on the stability of the emulsion system. This approach is designed to ensure the relevance and validity of the information collected, thus supporting the achievement of the research objectives. The data will be interpreted to understand the underlying mechanism of the effect of TiO_2 and Carbomer on the integrity of the emulsion system, such as its role in increasing the viscosity of the aqueous phase, the formation of a gel network, or the ability as a physical stabilizer. This information is then synthesized to produce a study on the effect of opacifier and thickener concentrations interpreted based on case study findings and improvement steps to produce products with stable emulsion systems.

A comprehensive literature search was conducted using leading scientific databases and academic search engines. The main keywords used in the literature study included: "emulsion stability," "cosmetic emulsion," "titanium dioxide," "TiO_2," "opacifier," "carbomer," "thickener," "emulsion viscosity," "phase separation," "creaming," and "flocculation." This combination of keywords was applied in both Indonesian and English to maximize the coverage of international literature. The databases used included ScienceDirect, PubMed, Google Scholar, Scopus, and relevant scientific journals in the fields of pharmacy, cosmetics, and materials science.

Product Reformulation (Experimental Formulation Design)

A series of body lotion formulas were developed with a basic composition identical to the commercial Inesia Midsummer product. The main variation in each formula lies in the concentration of opacifier and thickener, which are systematically arranged according to a predetermined design. Details of these concentration variations are presented in the Formula Design Table, in Table 1. The concentrations of titanium dioxide (TiO_2) used in this study were selected based on a rational design approach aimed at evaluating the impact of TiO_2 concentration on whitecast formation in day cream formulations.

Table 1. Formula Design

Sample Code	Carbomer (%)	Titanium Dioxide (%)
F1 (unstable control)	0.12	1.80
F2 (stable control)	0.18	0.09
F3	0.16	0.10
F4	0.14	1.20
F5	1.20	0.09

Making Lotion Samples

In analyzing the impact of opacifier and thickener concentrations on the stability of the emulsion phase, lotion samples were prepared in three variations of the reformulated formula (rework). In addition, a control formula was also prepared in the form of an unstable preparation and a stable preparation as a comparison. The formula and procedure for making the Inesia lotion sample are as follows. The sample formula is presented in Table 2.

Table 2. Sample Formula

Trade Name	Chemical Name	Concentration (%)	Use in Formulas
Aqua DM	Aqua Demineralisata	ad 100%	Solvent
Carbomer TC 21	Acrylates Crosspolymer	**varied**	Thickener
Na2EDTA	Natrium Ethylenediamine Tetra Acetate	0,1	Chelating agent
Glyserin	Glycerin	0,9	Humectant
TEA	Triethanolamine	0,3	pH adjuster
DMDM Hydantoin	DMDM Hydantoin	0,2	Preservative
BHT	Butyl Hydroxy Toluena	0,2	Antioxidant
Vaseline	Petroleum Jelly	0,2	Occlusive agent
Imex FC 1698	Cetyl Alcohol	0,6	Emollient
Vegarol EW 100	Cetearyl Alcohol & Ceteareth-20	1,2	Co-emulsifier
Crodamol AB	C12-C15 Alkyl Benzoate	0,2	Emollient
Crodamol IPM	Isopropyl Myrystate	0,5	Emollient

Propylene Glycol	Propylene Glycol	0,6	Co-solvent
Fragrance	Fragrance	1,06	Corrigen odoris
Titanium Dioxide	Titanium Dioxide	**varied**	Opacifier
Stearic Acid	Stearic Acid	3,6	Emulsifier
Sensicare C1000	Phenoxyethanol	0,7	Preservative

All formulas (F3, F4, and F5) as test samples, were made using the same method as the control/comparator preparations (F1 and F2). The product manufacturing process begins by accurately weighing all ingredients using an analytical balance. Next, prepare the Water Phase by dispersing titanium dioxide into a portion of Aqua until evenly distributed. In the remaining Aqua, develop carbomer until homogeneous. Mix other water-soluble ingredients, namely Na_2EDTA, Glycerin, and Propylene glycol, into the Aqua and carbomer mixture, then stir until homogeneous. Heat this water phase to a temperature of 70°C. In parallel, prepare the Oil Phase in a separate container. Melt and mix oil-soluble ingredients such as BHT, Petroleum jelly, Cetyl alcohol, Cetearyl alcohol & Ceteareth-20, C12-C15 Alkyl benzoate, Isopropyl myristate, and Stearic acid, then heat them to the same temperature as the water phase (70°C). Once both phases reach the same temperature, proceed with Phase Combination by slowly adding the oil phase to the water phase while continuously stirring with a stirrer until a homogeneous emulsion forms. Finally, continue stirring slowly as the emulsion cools. After the temperature drops below 40°C, add DMDM Hydantoin, Phenoxyethanol, and Fragrance, stirring until homogeneous. Conclude the process by adding TEA to adjust the pH to 4.5-5.5, matching the skin's pH.

The emulsifiers and oil-phase components, including stearic acid, cetyl alcohol, cetearyl alcohol with ceteareth-20, and emollients such as isopropyl myristate and C12–C15 alkyl benzoate, must be balanced carefully. An incorrect ratio may lead to phase inversion, coalescence, or creaming, especially during the cooling phase. Additionally, preservatives such as DMDM hydantoin and phenoxyethanol, while generally effective, may exhibit reduced antimicrobial activity if the final pH is not adequately controlled or if they interact with other formulation components. Fragrances, typically composed of volatile organic compounds, can also destabilize emulsions if introduced at elevated temperatures or in high concentrations.

Therefore, although the formulation design is rational and employs ingredients with established compatibility, the risk of physical or chemical instability remains if specific process parameters—such as temperature control, order of addition, mixing time, and pH adjustment—are not strictly monitored. Stability studies, both real-time and accelerated, are essential to confirm the long-term integrity of the emulsion, ensuring that separation, viscosity shifts, or microbial contamination do not occur during storage.

Organoleptic and Stability Testing

After the reformulation process, all product samples were retested to verify their phase stability. This test was carried out using exactly the same method as in the initial analysis stage, including organoleptic evaluation and cycling test.

- Organoleptic Evaluation: Observe and record the color, odor, texture, and general appearance of the emulsion for each formulation. Note the homogeneity and the presence or absence of particles.
- Hot-Cold Cycle Test (Cycling Test): Store the lotion sample (in a closed container) under temperature cycling conditions:
  Low temperature in the refrigerator: 24 hours at 0°C
  High temperature in the incubator: 24 hours at 40°C

Perform up to 27 cycles, then observe visual changes (phase separation, precipitation and color change) at the end of each cycle. Record any signs of phase instability.

Data Analysis

Data collected from all organoleptic and stability tests will be analyzed comprehensively. This analysis aims to identify the effect of opacifier (Titanium Dioxide) and thickener (Carbomer) concentrations on the stability of the emulsion phase. Furthermore, the data will be visualized using relevant graphs, to clearly show the relationship between the effect of material concentrations on the stability of the emulsion system.

RESULT AND DISCUSSION

Inesia Body Lotion Sample Selection

The sample selected for this study was a product discovery that showed significant phase instability in the cycling test for 27 cycles. The main characteristic of this selected sample was a clear phase separation into 2 layers, indicating emulsion degradation. This sample was then identified as Formula F1 in the experimental design, which had a Carbomer concentration of 0.12% and Titanium Dioxide of 1.80%. The selection of F1 as a key sample was based on its level of instability, which made it an ideal study case to analyze the causes of phase separation and formulate reformulation solutions. Formula F1, which was the control for instability analysis, had the following characteristics:

Organoleptic Evaluation:

Color: Separated into 2 phases (opaque white at the bottom, and yellow at the top)

Odor: Typical floral

Texture: Starts to feel liquid and when dispersed on the skin, phase separation is clearly visible

Homogeneity: The oil phase tends to separate at the top and the water-soluble phase is at the bottom.

Cycling Test: After going through about 27 cycles at 0°C and 40°C, Formula F1 showed a very real separation, in the form of a creaming event. Creaming is an event in which droplets of the dispersed phase (eg oil in an O/W emulsion) move upwards to form a more concentrated layer (He et al., 2024). The characteristics of instability that occur in F1 are: the emulsion is divided into two visually distinct layers, but the dispersed phase remains in the form of individual droplets and has not merged into a separate continuous phase. In O/W lotion, a thinner cream layer is visible on top and a thicker liquid layer below. The creaming event is often reversible, meaning that the emulsion can return to being homogeneous with light stirring. Creaming can generally be caused by differences in density between the dispersed phase and the continuous phase.

The selection of Formula F1 as an unstable control sample is crucial because it clearly shows the phenomenon of emulsion instability that is to be overcome in this study. The characteristics of the separation into 2 phases in 27 cycles indicate a significant deficiency in the emulsion stabilizer system. The combination of low Carbomer concentration with high Titanium Dioxide concentration (1.80%) worsens the instability, considering that TiO_2 requires very good dispersion and a strong matrix system to prevent agglomeration and separation. The rapid instability in the hot-cold cycle test of this emulsion makes it an ideal case study to identify. The Inesia Hand and Body Lotion product used as an unstable control is depicted in Figure 1.

Figure 1. Control Sample (Inesia Midsummer Lotion Unstable)

Literature Study Effect of Opacifier (Titanium dioxide) and Thickener (Carbomer) Concentration on Lotion Emulsion Phase Instability

The results of the literature review indicate that Titanium Dioxide, which mainly functions as an opacifier and UV filter in lotion formulations, has a complex effect on emulsion stability. At low to moderate concentrations (generally below 5%), TiO_2 contributes to the appearance of opaque and white products. TiO_2 particles suspended in the continuous phase can increase viscosity if there is interaction between particles or with the thickening polymer. The addition of solid particles can modify rheological properties and physical stability (Cot et al., 2024). Several studies, for example, Barilyuk et al. also reported that solid particles can fill space in the emulsion matrix, potentially increasing physical stability by limiting the movement of emulsion droplets (Barilyuk et al., 2024). However, at higher concentrations especially if the dispersion is not optimal or there is a mismatch with the emulsion system, TiO_2 has the potential to become a destabilizing agent.

The potential of Titanium Dioxide (TiO_2) to become a destabilizing agent in emulsions at higher concentrations, particularly when dispersion is not optimal, is discussed in the literature by Yu et al. explore the stability of emulsions, noting that nanomaterials can affect stability when they agglomerate due to improper dispersion or when interfacial tension is not properly controlled. They describe how agglomerated nanoparticles can lead to phase separation, impacting overall emulsion stability (Yu et al., 2025). Furthermore, Bordes-Diaz et al. discuss the role of TiO_2 nanoparticles in Pickering emulsions. They emphasize that the effectiveness of solid particles like TiO_2 in stabilizing emulsions depends heavily on their proper dispersion; otherwise, agglomeration can occur, leading to reduced stability. This highlights the necessity of optimizing dispersion and interfacial properties, correlating with the notion that excessive concentrations or improper interactions can lead to TiO_2 acting as a destabilizing agent. (Bordes et al., 2013) In addition, if TiO_2 particles disrupt the emulsifier interfacial layer, it can weaken the emulsion structure and trigger coalescence. The creaming phenomenon as observed in Formula F1, where 2 upper and lower layers are formed, is a strong indication of uncontrolled movement of emulsion particles or droplets. In the context of this Inesia lotion case study, especially in Formula F1 (with 1.80% TiO_2), the results of the literature study strongly support the hypothesis that TiO_2 plays a role in phase instability. In this case, the high concentration of TiO_2 solid particles that may not be optimally dispersed, coupled with a weak thickening matrix, causes these particles to function as destabilizing agents. Agglomerated TiO_2 particles can accelerate the flocculation of emulsion droplets and cause creaming by gravity. This shows that although TiO_2 at certain concentrations can stabilize, in non-optimal formulation conditions or excessive concentrations, TiO_2 is actually the main trigger for emulsion phase instability, especially through agglomeration mechanisms, accelerated creaming, and potential emulsification disorders. The importance of particle size and surface modification of TiO_2 is also highlighted. TiO_2 nanoparticles have different characteristics from micron-sized TiO_2 in terms of dispersibility and interaction with emulsions (Sztorch et al., 2023). Surface modification (coating) of TiO_2 particles is often required to improve their dispersion in the oil or water phase, thereby reducing the tendency for agglomeration and increasing compatibility with the emulsion matrix, which ultimately contributes to better stability (Bordes et al., 2013). Without proper surface modification or strong dispersion techniques, relatively high concentrations of TiO_2 as in Formula F1 can easily cause agglomeration, which directly contributes to instability.

Carbomer (polyacrylic acid) is a very effective thickener and emulsion stabilizer in water-based cosmetic formulations. Carbomer works by forming a strong three-dimensional gel network when neutralized (pH rises above 5.5-6.0). This gel network drastically increases the viscosity of the water phase (continuous phase in O/W emulsions), as described by (Sarfaraz K. Niazi, 2009) in the handbook of pharmaceutical formulations. This increase in viscosity directly reduces the rate of movement of the dispersed phase (oil) droplets due to gravity, making it very effective in preventing creaming and sedimentation phenomena. Creaming as seen in Formula F1, is the movement of droplets upward or downward due to differences in density, and Carbomer physically blocks this movement.

In addition to increasing viscosity, Carbomer also provides thixotropic properties and yield value to the emulsion. Yield value is the minimum stress required to initiate flow. The presence of yield value means that the emulsion can withstand gravity and light pressure without deforming or separating, providing excellent physical stability to the product at rest (on-shelf stability). Literature such as research by (Kolman et al., 2021) on rheology and flow properties, supports that adequate yield value is positively correlated with long-term emulsion stability. The effectiveness of Carbomer can also be influenced by the presence of electrolytes, surfactants, and other ingredients in the formula. Optimizing the concentration and neutralization of Carbomer is essential to achieve the desired gel structure and maintain its integrity in complex formulations (Pratiwi et al., 2023). In this Inesia lotion case study, the role of Carbomer concentration proved to be a dominant factor in emulsion stability. In Formula F1 which showed phase instability into 2 layers, the Carbomer concentration was only 0.12%. Based on the literature, this concentration is not sufficient to form a gel matrix strong enough to resist the movement of oil droplets and Titanium Dioxide particles. The low viscosity produced in F1, confirms this deficiency. As a result, the force of gravity is able to overcome the resistance provided by Carbomer, causing creaming and flocculation that leads to phase separation. The literature supports that increasing the Carbomer concentration has successfully created a stronger gel network, increased viscosity, and produced sufficient yield value to effectively stabilize the emulsion and prevent separation. This suggests that increasing the Carbomer concentration is a key strategy to overcome the instability observed in Formula F1.

Based on the literature review, the observed instability of the Inesia Midsummer lotion emulsion phase (in Formula F1) can be interpreted as a result of negative synergistic interactions between the concentrations of Titanium Dioxide and Carbomer. The Carbomer concentration of 0.12% in Formula F1, as indicated by the literature, is most likely not sufficient to build a strong gel matrix and provide sufficient viscosity to resist the force of gravity that causes creaming and separation. At this low concentration, the yield value is too low, making the emulsion susceptible to droplet movement (Xiao et al., 2021). In addition, although TiO_2 can contribute to viscosity, the concentration of 1.80% TiO_2 in Formula F1, especially in an emulsion system that is already weak due to low Carbomer, has the potential to worsen instability. Dense TiO_2 particles, if not perfectly dispersed or interact negatively with other components, can accelerate agglomeration and sedimentation/creaming (Ariyanti et al., 2022). Under conditions where the Carbomer matrix is unable to stabilize effectively, the particulate load of TiO_2 can trigger accelerated phase separation. The separation into two phases observed in Formula F1 is very consistent with the occurrence of partial coalescence or extreme creaming followed by separation of the continuous phase. The separated oil phase indicates coalescence of oil droplets on the top, while the layer of phase below is the continuous phase that comes out of the broken emulsion structure. Literature confirms that low viscosity of the continuous phase and weak interfacial layer (due to non-optimal thickener and particle interactions) are the main triggers of this phenomenon (Zembyla et al., 2019).

Product Reformulation (Experimental Formulation Design)

Initial studies on the commercial Inesia Midsummer body lotion product showed significant phase stability problems. After a cycling test under hot-cold conditions for 27 cycles, the product visually experienced a clear phase separation into two layers, namely a yellow oil phase on the top, and a white solid particle separation on the bottom. This phenomenon is known as creaming which leads to the breaking of the emulsion, indicating that the initial formulation had a critical deficiency in its stabilizer system. Phase instability problems like this are certainly very crucial in cosmetic products. Products that experience phase separation will cause: decreased sensory quality such as texture, appearance and homogeneity of the product will be disturbed, thereby reducing consumer appeal. In addition, the distribution of active ingredients or important components becomes uneven, potentially reducing product effectiveness. Not only that, consumers tend to consider products that separate phases as damaged, expired, or low-quality products, which can damage the brand image. Therefore, reformulation is an essential step to overcome this problem and ensure that Inesia Midsummer products are more stable, high-quality and acceptable to the market.

Based on the initial literature study and component analysis of Inesia body lotion products, Titanium Dioxide (TiO_2) as an opacifier and Carbomer as a thickener were identified as two main ingredients that have a significant effect on emulsion stability. Carbomer functions as a gelling agent and thickener that increases the viscosity of the water phase, thereby inhibiting the movement of dispersed droplets and preventing creaming and sedimentation. Suboptimal Carbomer concentrations can cause the emulsion to become too thin and unable to withstand the force of gravity. While Titanium Dioxide, although it functions as an opacifier, solid TiO_2 particles at high concentrations or poor dispersion can trigger agglomeration and worsen emulsion instability (creaming), especially if the thickening system is inadequate. Given that the initial commercial Inesia product showed severe instability, it is assumed that Formula 1 (F1), which represents this instability condition with a Carbomer concentration of 0.12% and TiO_2 of 1.80%, is the starting point (negative control). To find the optimal concentration combination, an experimental formulation design was made to test variations in Carbomer and Titanium Dioxide concentrations both above and below the

F1 concentration, and to compare them with Formula 2 (F2) which functions as a positive control, representing a preparation that has been proven stable from the rework results. At this stage, a series of body lotion formulas were made with a basic composition referring to the commercial Inesia Midsummer product, but with systematic variations in the concentration of Titanium Dioxide as an opacifier and Carbomer as a thickener. The variations of the test samples are described in Table 3.

Table 3. Test Sample Variation

Sample Code	Carbomer (%)	Titanium Dioxide (%)	Information
F1 (unstable control)	0.12	1.80	Unstable Control: An early commercial Indonesian product that has been shown to be unstable. Intended to replicate and confirm the problem, and as a basis for comparison for reformulation formulas.
F2 (stable control)	0.18	0.09	Stable Control: Represents the concentration of Carbomer and TiO_2 that has been proven to produce stable emulsions from previous reworks. Serves as a positive control to measure the success of reformulation. The concentration of Carbomer is higher than F1, while TiO_2 is lower.
F3	0.16	0.10	The Carbomer concentration is slightly below F2, but still higher than F1. The TiO_2 concentration is slightly higher than F2. This design aims to evaluate whether stability can still be maintained at a Carbomer concentration slightly lower than F2, as well as to see the minor effect of increasing TiO_2 in a relatively stable system. This

			formula is deliberately made to determine the stability threshold below F2.
F4	0.14	1.20	The Carbomer concentration is lower than F3 and F2, but slightly higher than F1. The TiO_2 concentration is lower than F1 but still relatively high. This formula is designed to investigate the point at which the emulsion begins to exhibit serious instability again, similar to F1, by gradually decreasing the Carbomer concentration and increasing the TiO_2 concentration, to see any adverse synergistic effects.
F5	1.20	0.09	The highest Carbomer concentration among all formulas, aims to produce the strongest gel matrix and very high viscosity. The TiO_2 concentration is kept the same as F2 to isolate the maximum Carbomer effect. This design is expected to produce a formula with the best stability, even surpassing F2.

Making Lotion Samples

The formulation of the three test lotion samples (F3, F4, and F5) followed a standard oil-in-water (O/W) emulsification protocol, which involved separate heating of the oil and aqueous phases, gradual mixing, cooling, and homogenization. During the heating stage, all ingredients in both the oil and water phases were fully dissolved and formed homogeneous solutions at approximately 70 °C, with no solubility issues observed. Upon gradual addition of the heated oil phase to the equally heated and stirred aqueous phase, emulsification was observed across all formulations. Emulsion formation occurred rapidly in F3, F4, and F5, with immediate visual homogeneity. However, in F4, the emulsification process required a slightly longer time to reach initial stability, displaying a mild tendency for phase separation if constant stirring was not maintained.

The dispersion of titanium dioxide and carbomer was also monitored during the preparation process. Carbomer was successfully dispersed in the aqueous phase of all formulations and formed a gel network upon addition of triethanolamine (TEA) as a neutralizing agent. The resulting viscosities varied depending on the carbomer concentration: F3 (0.16% carbomer) exhibited moderate viscosity, F4 (0.14%) produced a thinner consistency than F3, while F5 (1.20%) yielded the highest viscosity and gel thickness. Titanium dioxide was successfully incorporated into the emulsion bases of all formulations; however, in F4 which contained the highest TiO_2 concentration (1.20%) a longer mixing time and more intensive homogenization were necessary to eliminate visible agglomerates. In contrast, F3 and F5, with lower TiO_2 concentrations (0.10% and 0.09%, respectively), showed easier dispersion and integration. Following the cooling and final homogenization steps, all formulations resulted in stable, homogenous lotion products with an opaque white appearance and a consistency aligned with their respective design goals.

The making of the three lotion test sample formulas (F3, F4, and F5) was carried out following the standard procedure for making oil-in-water (O/W) emulsions, which involves heating the oil phase and the water phase separately, mixing, cooling, and homogenizing. At the heating stage, all ingredients in the oil phase and the water phase were successfully dissolved completely and formed homogeneous phases at a temperature of 70°C each. No solubility problems were observed at this stage. When the heated oil phase was added to the water phase which had also been heated and stirred gradually, emulsion formation was seen in all formulas. In Formulas F3, F4 and F5, the emulsion began to form quickly and showed good homogeneity immediately after the initial mixing. In Formula F4, although the emulsion was formed, it was seen that the emulsification process took a little longer to reach a stable initial homogeneity or in other words there was a slight tendency to separate if stirring was not constant. Carbomer was successfully dispersed well in the water phase in all formulas. Carbomer also immediately formed a gel network that thickened the preparation when a neutralizing agent (TEA) was added. Different Carbomer concentrations provided varying levels of viscosity directly after neutralization:

F3 (0.16% Carbomer): Medium viscosity.

F4 (0.14% Carbomer): Thicker than F1, but still relatively thin.

F5 (1.20% Carbomer): Produced the thickest gel.

Titanium Dioxide was well dispersed into the emulsion base. However, in formulas with higher TiO_2 concentrations (F4 with 1.20%), a slightly longer stirring time and more intensive homogenization were required to ensure that no particle agglomerates were visually visible. In F3 and F5 (with TiO_2

concentrations of 0.10% - 0.09%), dispersion was more easily achieved. After the cooling process and final homogenization, all samples showed a homogeneous lotion preparation, opaque white in color and had a consistency that was in accordance with the design of the formula.

Direct observation of the difference in Carbomer gel viscosity after neutralization in each formula is in line with the working principle of Carbomer as a polymeric thickener. Higher Carbomer concentrations allow the formation of a denser and stronger gel network, which directly increases the initial viscosity of the emulsion. This supports the literature stating that Carbomer is a very efficient thickener in increasing the viscosity of the continuous phase, thus becoming the key to stabilizing the emulsion (Islam et al., 2004). Meanwhile, the need for more intensive homogenization for formula F4 (with high TiO_2) underlines the challenge in dispersing solid particles in the emulsion system. If not perfectly dispersed, TiO_2 particles have a tendency to form agglomerates that not only affect the appearance of the product but can also act as an initial point of physical instability. Large agglomerates can accelerate creaming or sedimentation due to the greater density difference and the ability to trap oil droplets. This is consistent with the findings from study by Jonas et al. solid particle agglomeration can be a destabilizing factor (Jonas et al., 2021). Overall, this manufacturing process confirms that variations in Carbomer and Titanium Dioxide concentrations directly affect the rheological properties and initial homogeneity of the emulsion. The results of this manufacturing stage provide a valid basis for proceeding to stability testing to validate the urgency of reformulation and experimental design.

Organoleptic and Stability Testing

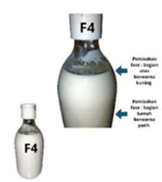
Stability evaluation through 27 cycles of hot-cold cycle test provided insight into the resistance of formulations F3, F4 and F5 to thermal stress, simulating extreme storage conditions. The results showed that Formula F5 (Carbomer 1.20%, TiO_2 0.09%) and Formula F3 (Carbomer 0.16%, TiO_2 0.10%) displayed excellent stability. Both maintained perfect homogeneity without any signs of phase separation, creaming, or particle precipitation even after undergoing 27 cycles of drastic temperature changes. Organoleptically, both F3 and F5 maintained a consistent opaque white color, stable aroma, and thick texture (unchanged) throughout the test. The excellent stability of F5, with the highest Carbomer concentration, is very consistent with the theory that increasing the viscosity and yield value of the continuous phase directly inhibits the mobility of emulsion droplets, trapping them in a strong gel matrix. More specifically, F3 also showed stability equivalent to F5, despite having a lower Carbomer concentration (0.16%

versus 1.20% in F5) and a slight increase in TiO_2 (0.10% versus 0.09%). This indicates that the Carbomer concentration of 0.16% has reached the effective threshold to form a robust gel network, strong enough to withstand temperature fluctuations and effectively stabilize the TiO_2 dispersion at a concentration of 0.10%. This shows flexibility in the formulation to achieve stability without always requiring the highest thickener concentration.

In contrast, Formula F4 (Carbomer 0.14%, TiO_2 1.20%) showed less satisfactory results and tended to be unstable, although not as severe as F1 which experienced total failure. In the hot-cold cycle test, F4 began to show significant signs of creaming at cycles 15-18, followed by clear oil separation at the top at cycles 25-26. This physical degradation is also reflected in the organoleptic observation of F4, where the color becomes inhomogeneous or mottled, and the texture gradually becomes less viscous with signs of lumps or sedimentation. This instability of F4 can be explained by a combination of two main factors, namely: the less than optimal concentration of Carbomer and the relatively high concentration of Titanium Dioxide. Carbomer 0.14% may not be enough to build a gel network that has adequate yield value and viscosity to withstand creaming forces and thermal fluctuations effectively. As a result, oil droplets and TiO_2 particles become more mobile. In addition, the higher concentration of TiO_2 in F4 (1.20%) compared to F3 and F5, in this weak thickener system, is likely to worsen the emulsion system. TiO_2 particles tend to agglomerate if they are not well dispersed or if the interfacial tension is not optimally regulated (Li et al., 2010). These particle agglomerates can act as weak points, accelerating the flocculation process of emulsion droplets and ultimately creaming. Thus, F4 is at a critical point where the Carbomer matrix is no longer able to compensate for the destabilizing potential of the Titanium Dioxide and environmental stresses, causing the emulsion to progressively lose its integrity. The results of the cycling test and organoleptic observations on F3, F4 and F5 are described in Table 4 below.

Table 4. Cycling Test Results (26 cycles) and Organoleptic Characteristics

Sample Code	TiO_2 Concentration (%)	Carbomer Concentration (%)	Stability Observation Cycle (Visual)	Detailed Observation Description	Documentation
F3	0.10	0.16	Cycle 1-26	**Stability:** Cycle 1-26: Remains homogeneous, no significant phase	

				separation or creaming. **Organoleptic characteristics:** relatively stable, (white opaque, aroma remains, but texture is slightly more liquid (minor viscosity) compared to initial conditions).	
F4	1.20	0.14	Starting at cycle 15	**Stability:** Cycle 15: Creaming signs begin to appear, possibly followed by the precipitation of TiO_2 particles and the water-soluble phase at the bottom. **Cycle 18:** Clear oil separation begins to appear at the top (around 0.5 cm), color separation is faint (yellow at the top	

and white at the bottom).

Cycle 25-26: Separation of water and oil is increasingly clear, the emulsion color layer above becomes more concentrated, approaching F1 conditions but the phase separation that occurs is around 1 cm.

Organoleptic Characteristics: Initial condition: Opaque white, homogeneous, distinctive floral aroma, texture according to commercial Indonesian standards.

Condition after phase instability occurs:

				Yellow at the top and white at the bottom (separates into 2 phases but better than F1 control), not homogeneous, aroma remains, texture is more liquid and when applied to the skin, the separation of the oil, water and solid particle phases is clearly visible.	
F5	0.09	1.20	Cycle 1-26	**Stability:** Cycle 1-26: Remains perfectly homogeneous, no phase separation, no creaming, no precipitation. **Organoleptic characteristics:** Opaque white, homogeneous, distinctive floral aroma, texture	

		according to standards and no physicochemical changes.

Data Analysis

The graph in Figure 2 (a) and (b) visualizes the comparison of the stability levels of five experimental body lotion formulas (F1, F2, F3, F4 and F5), which are represented through a stability scale measured from the heat-cold cycle test.

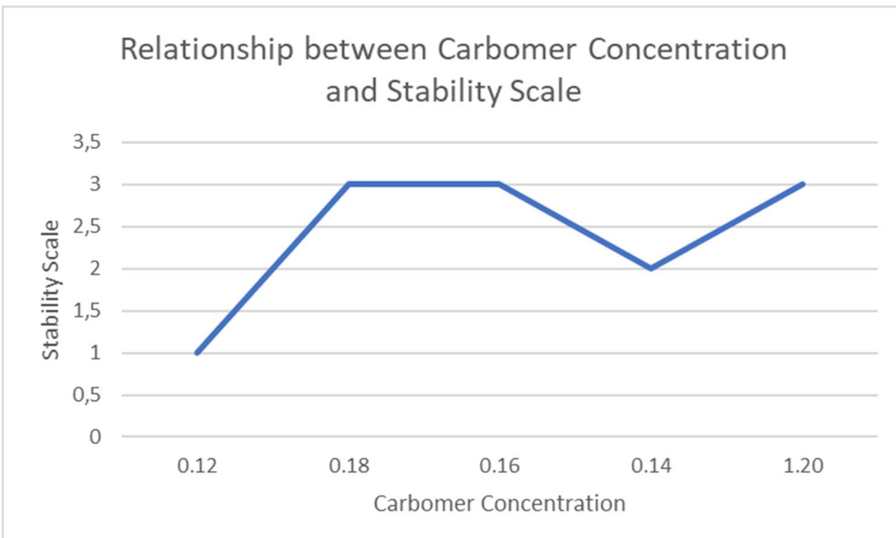


Figure 2. (a) Relationship between Carbomer Concentration and Stability Scale Graph

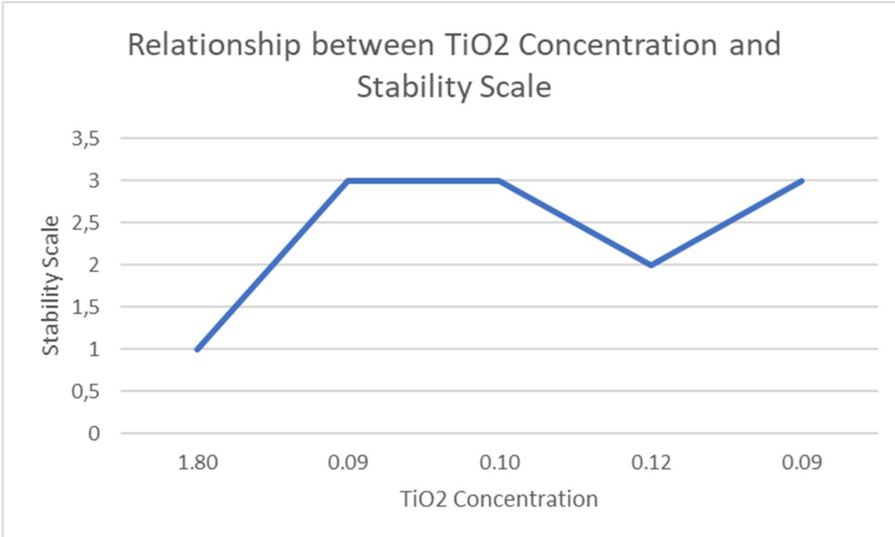


Figure 2. (b) Relationship between TiO_2 Concentration and Stability Scale Graph

Stability Scale Description:
1 : Unstable; phase rupture
2 : Less stable; light creaming
3 : Stable

The higher the bar on the graph, indicates a better level of product stability. From this visualization, there is a strong correlation between variations in Carbomer and Titanium Dioxide concentrations and the stability performance of each formula. Formula F5 shows the highest level of stability among the test samples (F3 and F4) reaching a scale value of 3 which confirms its success in producing a stable preparation. This stability is very consistent with its design which uses the highest Carbomer concentration (1.20%), which forms the strongest gel matrix to withstand thermal fluctuations and prevent phase destabilization. Formula F5 shows stability that is in line with F2 as a stable control. The results also proved that Formula F3 exhibited high stability and was comparable to F2 and F5, achieving a scale value of 2. Although F3 had a slightly lower Carbomer concentration (0.16%) compared to F2 (0.18%), and a slightly higher Titanium Dioxide concentration (0.10% compared to 0.09% in F2 and F5), its ability to maintain perfect integrity and homogeneity during 27 heat-cold cycles was a significant finding. This indicated that the Carbomer concentration of 0.16% had reached a sufficient threshold to form a robust gel network, which was effective in stabilizing the Titanium Dioxide dispersion and resisting thermal stress, providing flexibility in the formulation without sacrificing stability. In contrast to these stable formulas, Formula F4 showed a significant decrease in stability, with a scale value of 2 (less stable). The less than optimal stability of F4 can be attributed to the combination of the lower Carbomer concentration (0.14%) and the higher Titanium Dioxide concentration (1.20%). The reduction of Carbomer to 0.14% makes the gel matrix not strong enough to fully withstand creaming forces and thermal fluctuations. Additionally, the higher TiO_2 concentration in F4, in an already weak thickener system, likely exacerbates instability by promoting particle agglomeration. These agglomerates can act as weak points, accelerating flocculation and creaming, and contributing to phase separation. Finally, Formula F1 shows the lowest stability rating drastically, with a scale value of 1, indicating total instability. This is due to the combination of the lowest Carbomer concentration (0.12%) and the highest Titanium Dioxide (1.80%). Collectively, reading this graph visually reinforces that Carbomer concentration is the dominant factor in determining lotion emulsion stability, with optimal concentrations compensating for the potential destabilizing effects of Titanium Dioxide and ensuring the product remains stable under extreme storage conditions.

CONCLUSION

Based on the results of the analysis and experimental studies on the formulation of Inesia Hand and Body Lotion Midsummer, it can be concluded that the concentration of opacifier (Titanium Dioxide) and thickener (Carbomer) significantly and interactively affect the stability of the emulsion phase. Carbomer is a dominant factor in determining emulsion stability, where low concentrations (0.12% and 0.14%) fail to maintain stability, even in the early stages of the cycling test, causing phase failure and creaming due to viscosity and yield values that are not capable. High concentrations of Titanium Dioxide exacerbate instability at low Carbomer concentrations, triggering agglomeration and accelerating the destabilization process. Conversely, at strong Carbomer concentrations (0.16% to 1.20%), Titanium Dioxide (0.09% - 0.10%) is well dispersed and does not cause instability problems, indicating that the destabilizing role of Titanium Dioxide is highly dependent on the strength of the emulsion thickener system. Therefore, adjusting the Carbomer concentration proves to be a very effective reformulation solution. Formulations with Carbomer concentrations of 1.20% (F5) and 0.16% (F3) showed superior stability comparable to the stable control (F2, Carbomer 0.18%), with no signs of phase separation or organoleptic changes after 27 cycles of cycling test, due to the formation of a strong gel matrix and optimal viscosity. This conclusively shows that the reformulation with a focus on increasing the Carbomer concentration and decreasing the Titanium Dioxide concentration successfully transformed the

Inesia product from unstable to highly stable, even under extreme cycling test conditions.

ACKNOWLEDGEMENT

The author would like to express his deepest gratitude to the Sumatera Institute of Technology (ITERA), the Faculty of Industrial Technology (FTI) and the Cosmetic Engineering Study Program for the support provided for the internship activities. Special thanks to PT. Prioritas Jaya Indonesia and the Research and Development Laboratory for providing access to important instruments and technical assistance during the experimental procedures. The author would also like to thank all laboratory staff, academic supervisors, and fellow researchers who contributed directly or indirectly to the completion of this research.

REFERENCES

Ariyanti, D., Purbasari, A., Lesdantina, D., Saputro, E. A., & Gao, W. (2022). Sedimentation Process of TiO2 Nanoparticles in Aqueous Solution. *Reaktor*, *22*(2), 70–76. https://doi.org/10.14710/reaktor.22.2.70-76

Barilyuk, D. V., Korol, A. A., Chikanova, E. S., Lomakina, M. A., & Shtansky, D. V. (2024). Highly Hydrophilic TiO 2 Nanoparticles as Stabilizers of Pickering Emulsions with Photosensitive Lipophilic Compounds: Synthesis and Application. *The Journal of Physical Chemistry B*, *128*(32), 7903–7911. https://doi.org/10.1021/acs.jpcb.4c03315

Bordes, M. C., Vicent, M., Moreno, A., Moreno, R., Borrell, A., Salvador, M. D., & Sánchez, E. (2013). Microstructure and photocatalytic activity of APS coatings obtained from different TIO2 nanopowders. *Surface and Coatings Technology*, *220*, 179–186. https://doi.org/10.1016/j.surfcoat.2012.08.059

Cao, G., Du, T., Bai, Y., Yang, T., & Zuo, J. (2021). Effects of surfactant molecular structure on the stability of water in oil emulsion. *Journal of Petroleum Science and Engineering*, *196*, 107695. https://doi.org/10.1016/j.petrol.2020.107695

Cot, M., Mijas, G., Prieto-Fuentes, R., Riba-Moliner, M., & Cayuela, D. (2024). The Influence of Titanium Dioxide (TiO2) Particle Size and Crystalline Form on the Microstructure and UV Protection Factor of Polyester Substrates. *Polymers*, *16*(4), 475. https://doi.org/10.3390/polym16040475

Deore, R. K., Surana, K., Mahajan, S. K., Bachhav, R. L., & Sonawane, D. D. (2025). Development and Evaluation of Moisturizing Cream containing Salvia hispanica and Aloe vera and its Antioxidant Potential. *Ars Pharmaceutica (Internet)*, *66*(3), 276–287. https://doi.org/10.30827/ars.v66i3.32785

He, Y., Wang, C., Liu, Y., Chen, J., Wei, Y., & Chen, G. (2024). Pickering emulsions stabilized by cellulose nanofibers with tunable surface properties for thermal energy storage. *International Journal of Biological Macromolecules*, *280*, 136013. https://doi.org/10.1016/j.ijbiomac.2024.136013

Islam, M. T., Rodríguez-Hornedo, N., Ciotti, S., & Ackermann, C. (2004). Rheological Characterization of Topical Carbomer Gels Neutralized to

Different pH. *Pharmaceutical Research*, *21*(7), 1192–1199. https://doi.org/10.1023/B:PHAM.0000033006.11619.07

Jonas, F., Lebeau, B., Michelin, L., Carteret, C., Josien, L., Vidal, L., Rigolet, S., Gaudin, P., & Blin, J.-L. (2021). Thermal stability and phase transformation of semi-crystalline mesostructured TiO2 in the presence of heteroelements. *Microporous and Mesoporous Materials*, *315*, 110896. https://doi.org/10.1016/j.micromeso.2021.110896

Kabalnov, A. (1998). Thermodynamic and theoretical aspects of emulsions and their stability. *Current Opinion in Colloid & Interface Science*, *3*(3), 270–275. https://doi.org/10.1016/S1359-0294(98)80071-X

Kolman, M., Smith, C., Chakrabarty, D., & Amin, S. (2021). Rheological stability of carbomer in hydroalcoholic gels: Influence of alcohol type. *International Journal of Cosmetic Science*, *43*(6), 748–763. https://doi.org/10.1111/ics.12750

Li, G., Lv, L., Fan, H., Ma, J., Li, Y., Wan, Y., & Zhao, X. S. (2010). Effect of the agglomeration of TiO2 nanoparticles on their photocatalytic performance in the aqueous phase. *Journal of Colloid and Interface Science*, *348*(2), 342–347. https://doi.org/10.1016/j.jcis.2010.04.045

Pratiwi, P. D., Gusti, D. R., & Angraini, R. I. (2023). The optimization of gelling agent and humectant in antioxidant gel formula with Carica papaya Linn. leaf extract based on simplex lattice design method. *Journal of Pharmaceutical and Sciences*, 283–291. https://doi.org/10.36490/journal-jps.com.v6i5-si.430

Pusat Komunikasi Publik Kementrian Perindustrian. (2015). *RENCANA INDUK PEMBANGUNAN INDUSTRI NASIONAL REPUBLIK INDONESIA*. www.kemenperin.

Sarfaraz K. Niazi. (2009). *S a r f a r a z K. N i a z i Pharmaceutical Manufacturing Formulations Sterile Products*.

Sztorch, B., Nowak, K., Frydrych, M., Leśniewska, J., Krysiak, K., Przekop, R. E., & Olejnik, A. (2023). Improving the Dispersibility of TiO2 in the Colloidal System Using Trifunctional Spherosilicates. *Materials*, *16*(4), 1442. https://doi.org/10.3390/ma16041442

Xiao, Q., Chen, G., Zhang, Y.-H., Chen, F.-Q., Weng, H.-F., & Xiao, A.-F. (2021). Agarose Stearate-Carbomer940 as Stabilizer and Rheology Modifier for Surfactant-Free Cosmetic Formulations. *Marine Drugs*, *19*(6), 344. https://doi.org/10.3390/md19060344

Yu, H., Zhang, X., Zhao, J., Sun, T., & Zhu, Y. (2025). Mechanism of TiO2 nanotube UV-photocatalytic degradation of antibiotic resistance genes in the wastewater sludge and blocking of the transfer. *Frontiers in Environmental Science*, *13*. https://doi.org/10.3389/fenvs.2025.1590101

Zembyla, M., Lazidis, A., Murray, B. S., & Sarkar, A. (2019). Water-in-Oil Pickering Emulsions Stabilized by Synergistic Particle–Particle Interactions. *Langmuir*, *35*(40), 13078–13089. https://doi.org/10.1021/acs.langmuir.9b02026