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Experimental Observation of Phase Behavior and Turbidity in Oil–Water–Sodium Hypochlorite Ternary Systems

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ABSTRACT

This study experimentally examines the phase behavior of ternary mixtures composed of oil, distilled water, and sodium hypochlorite (NaOCl) solution using a turbidity (cloud-point) observation method rather than numerical liquid–liquid equilibrium calculations. Three oils—coconut oil, olive oil, and baby oil—were tested to evaluate how their physicochemical properties influence visible phase behavior. Oil and NaOCl were first mixed at different ratios, followed by the gradual addition of distilled water until turbidity appeared, marking the boundary between temporary dispersion and phase separation. The required water volume was recorded as an indicator of this boundary. Coconut oil separated rapidly into two layers, olive oil formed short-lived cloudy dispersions, and baby oil showed similar behavior with slight temperature changes, possibly due to slow interaction with hypochlorite. The results confirm that both oil type and composition ratio strongly govern observable phase behavior in oil–water–NaOCl ternary systems.

Keywords: ternary system, turbidity boundary, phase behavior, sodium hypochlorite, oil–water system

1. INTRODUCTION

Oil and water are fundamentally immiscible because of strong differences in polarity and hydrogen-bonding ability. Consequently, mixing nonpolar oils with polar aqueous media typically yields phase separation; however, the transient behavior of oil droplets (dispersion, coalescence, creaming) is strongly dependent on composition, hydrodynamics and the physicochemical properties of the oil and aqueous phase. Understanding these observable phase phenomena is important for practical applications such as liquid–liquid extraction, formulation science and wastewater treatment.[1,2]

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In ternary liquid systems (oil–water–solvent/ionic aqueous phase), phase boundaries can be determined either by thermodynamic modelling and numerical LLE computation or by experimental cloud-point/turbidity mapping. While rigorous LLE calculations (for example using arc-length continuation) provide thermodynamically consistent binodals, experimental turbidity methods (visual titration, turbidimetry or laser scattering) remain a widely used practical approach to locate the observable cloud-point and to map regions of temporary dispersion versus macroscopic phase separation. For systems where full activity models are not available, cloud-point mapping is a robust first step.[3,4]

The presence of dissolved ions or reactive oxidants in the aqueous phase modifies the interfacial environment and can influence dispersion stability. Although sodium hypochlorite (NaOCl) is not an amphiphilic surfactant, its ionic character and oxidative reactivity can change aqueous properties (ionic strength, pH, redox potential) and affect droplet interactions, coalescence kinetics, or even chemically alter oil components. Therefore, the effect of NaOCl on oil–water mixtures should be interpreted as a combination of ionic/environmental effects and potential chemical reactivity rather than as surfactant-like emulsification.[5,6]

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Cloud-point/turbidity mapping combined with simple thermal observation (monitoring sample temperature during mixing) provides a practical experimental protocol to compare observable phase behavior across oil types and mixture ratios. This experimental mapping does not replace rigorous thermodynamic LLE analysis, but it provides relevant operational information for applications where visible dispersion stability, phase separation timescales, or potential chemical interactions with oxidants (e.g., NaOCl) matter. In this work, we apply an incremental water-addition (visual cloud-point) protocol to oil–NaOCl mixtures across a range of oil/bleach ratios and compare the phase behavior of coconut oil, olive oil, and baby oil.[9,10]

2. EXPERIMENTAL

2.1. Chemicals, Equipment and Instrumentation

The materials used in this study consisted of coconut oil (Cocos nucifera oil), olive oil, and commercially available baby oil (mineral oil based) as the oil phase, sodium hypochlorite solution (household bleach) as the ionic aqueous phase, and distilled water (aquades) as the dilution medium. All chemicals were used as received without further purification. The equipment employed included burettes for precise volume measurement, Erlenmeyer flasks and beakers for mixing, a thermometer for monitoring temperature changes during the experiment, and an analytical balance for determining the density of each liquid prior to mixing. All glassware was thoroughly cleaned and dried before use to avoid contamination and to ensure the reliability of turbidity observations.

2.2. Research Procedure

In this study, A series of oil–sodium hypochlorite mixtures were prepared by varying the volume ratios of oil and NaOCl solution using a burette to ensure precise measurement. Each mixture was placed in a clean

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Erlenmeyer flask and gently agitated by manual inversion to promote uniform contact between the phases. This preparation approach follows common emulsion and dispersion preparation procedures reported in regional experimental studies, where controlled mixing and systematic variation of component ratios are essential to observe changes in phase behavior and stability. No surfactant was added in this experiment in order to specifically examine the influence of the ionic NaOCl solution on the dispersion behavior of the oils, as recommended in previous methodological discussions on emulsion and microemulsion preparation.[11-13]

Distilled water was then added dropwise into each oil–NaOCl mixture while the flask was gently shaken. The addition was continued until the mixture exhibited visible turbidity (cloud point), which was taken as an indicator of the boundary between temporary dispersion and phase separation. The volume of water required to reach turbidity was recorded for each composition. Visual observation was complemented by recording the temperature before and after mixing to detect any possible thermal effect during the process. This turbidity-based observation method is consistent with practical approaches used in local studies for evaluating emulsion stability and for detecting changes in mixture clarity, and it is also supported by recent developments in image-based and sensor-based turbidity measurements for future quantitative validation.[14,15]

3. RESULTS AND DISCUSSION

3.1 Analysis of Characterization Results

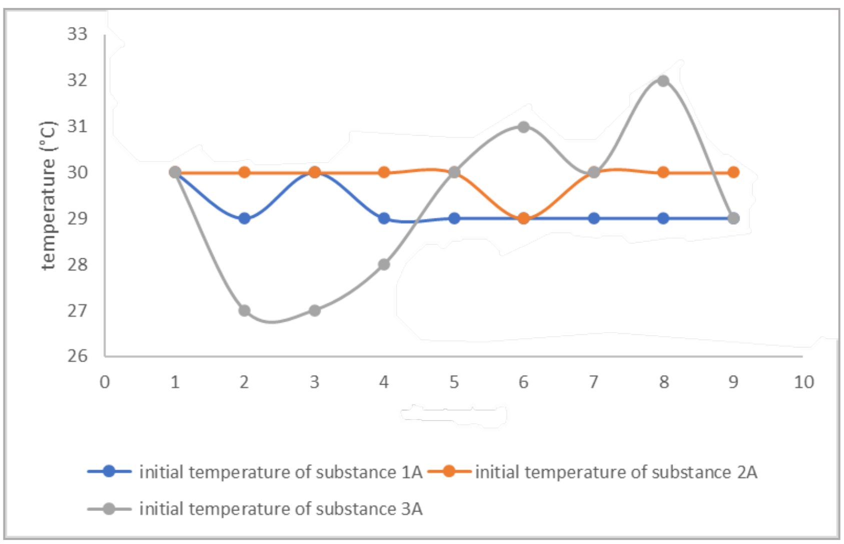

Figure 1. Initial temperature in 3 types of mixtures

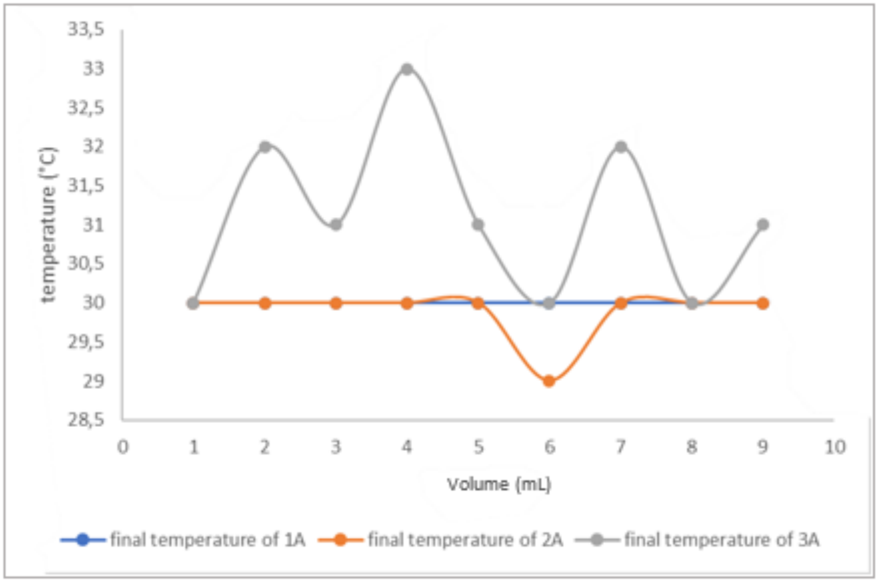

Figure 2. Final temperature on 3 types of mixtures

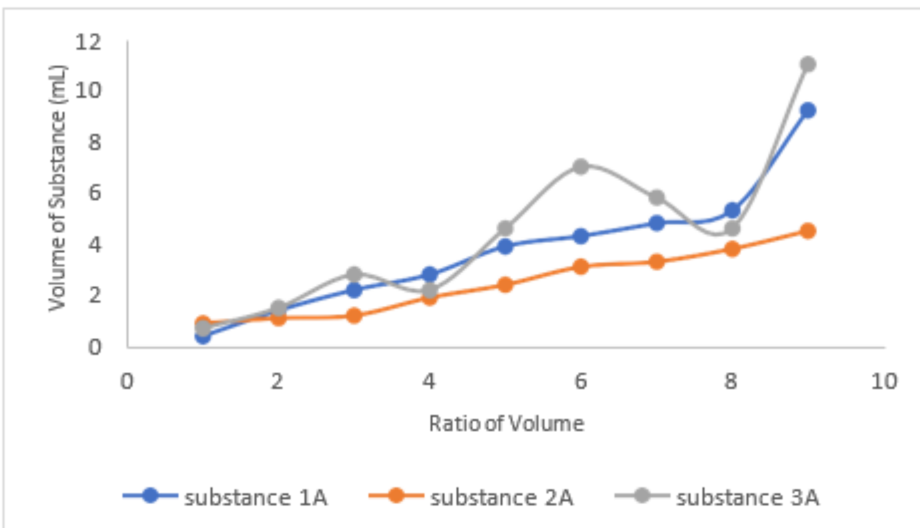

Figure 3. Ratio of volume to water required

The three ternary diagrams illustrate how the composition of oil, sodium hypochlorite solution, and distilled water determines the cloud-point boundary for each type of oil. In the coconut oil diagram, the plotted points shift toward regions requiring a larger volume of water as the oil fraction increases, indicating strong immiscibility and rapid phase separation between the nonpolar oil and the aqueous phase. In contrast, the olive oil diagram shows a more scattered distribution of points, reflecting the tendency of olive oil to form temporary dispersions before clear separation occurs. The baby oil diagram exhibits a pattern similar to olive oil but is accompanied by slight variations in the final temperature at certain composition ratios, suggesting that, in addition to mechanical dispersion, slow chemical interaction with hypochlorite may influence the observed

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behavior. Overall, these diagrams demonstrate that the position of the cloud-point region in the ternary system is strongly governed by the physicochemical properties of the oil, with each oil displaying a distinct dispersion–separation characteristic.

a. Coconut Oil

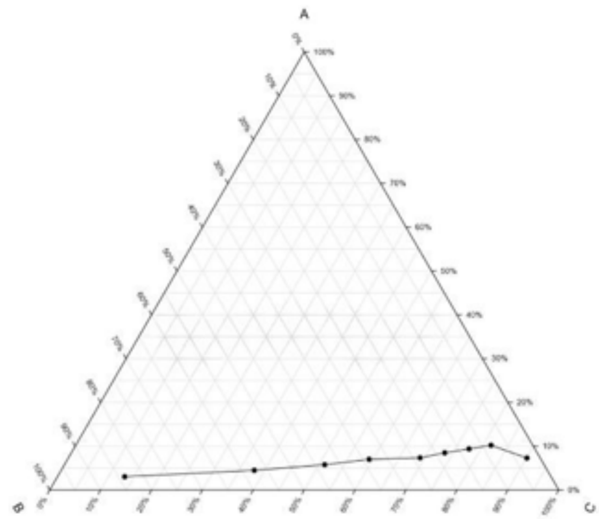

Figure 4. Ternary diagram of substance A1 coconut oil + bleach solution + distilled water

Coconut oil From the data obtained based on a ternary system experiment using coconut oil as substance A, bleach solution as substance B, and water as substance C, changes in the volume of each component greatly affect the stability of the mixture. It can be seen that the higher the amount of coconut oil and the lower the amount of bleach solution, the greater the volume of water used will be. This is related to the solubility properties of each substance, where coconut oil (substance A) is included in a nonpolar compound consisting of triglycerides and cannot dissolve in water (substance C) which has polar properties. The bleach solution (substance B), which generally contains compounds such as sodium hypochlorite ($NaClO$) in water, is polar and can mix with water but cannot mix with coconut oil.8 According to the ternary system phase diagram, this condition is described as a shift in composition towards the two more dominant phases. In addition, the mole fraction in the table shows that increasing coconut oil as substance A causes the mole fraction of water to increase.9 this provides an indication that naturally, the system compensates for the decrease in bleach solution by increasing the amount of water so that the mixture of these substances remains in one phase or at least approaches maximum emulsification stability.

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b. Olive Oil

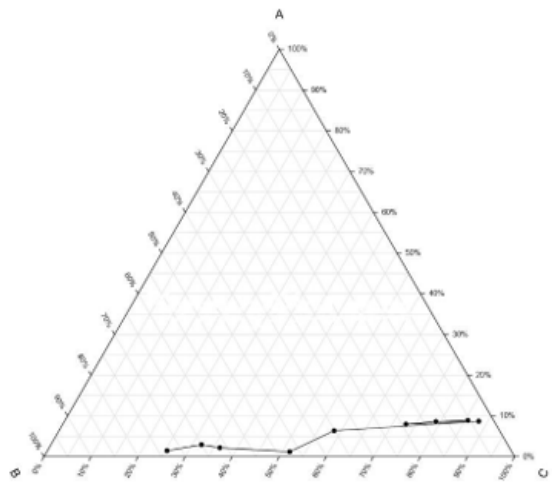

Figure 5. Ternary diagram of substance A2 olive oil + bleach solution + distilled water

Based on the results of the practicum, the volume of water used in the three-component system consisting of olive oil (substance A), bleach solution (substance B), and water (substance C) fluctuates and does not follow a stable pattern. This instability occurs because the bleach solution acts as a surfactant that allows olive oil to mix with water through the emulsification process. When the amount of bleach solution is high, the mixture is more stable, and the volume of water needed tends to be less, as seen in the ratios of 1:9 and 2:8, where the volume of water used is only 0.7 mL and 1.5 mL. However, when the bleach solution decreases, the system's ability to maintain the emulsion decreases, so that water is needed in varying amounts to adjust the stability of the phase in the system. As a result, there is irregularity in the volume of water used, depending on how well the oil can still be dispersed in the mixture.

This fluctuation shows that the relationship between the three components is not linear, but is influenced by complex molecular interactions. At some ratios, the amount of water required increases sharply as the system approaches the emulsification stability limit, such as at ratios 8:2 and 9:1, where the water volume jumps from 4.6 mL to 11 mL. In contrast, at other ratios, less water is added because the composition of oil and bleach is still sufficient to maintain the emulsion. If the bleach solution is too small compared to the oil, the oil and water phases tend to separate, causing the volume of water used to increase significantly to overcome the separation.10 Thus, the stability of the mixture in this three-component system is greatly influenced by the ratio of oil, bleach, and water, where there is an optimal equilibrium point that prevents phase separation and maintains a stable dispersion.

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c. Baby Oil

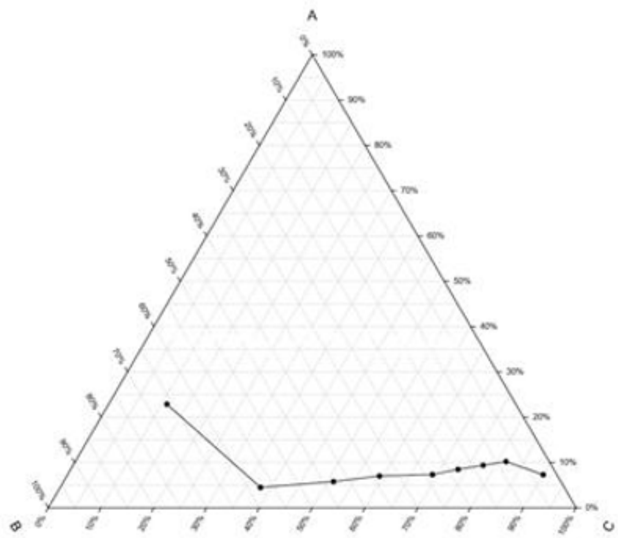

Figure 6. Ternary diagram of substance A3 baby oil + bleach solution + distilled water

From the table obtained, we can see that the type of oil used (baby oil) affects the final temperature of the mixture. In experiments with baby oil (Substances A1 and A4), the final temperature of the mixture tended to remain the same as the initial temperature, namely around 30°C. This shows that the addition of bleach and distilled water solution does not produce significant temperature changes in the baby oil mixture.11 However, in experiments with baby oil (Substances A2 and A3), there was a greater variation in final temperature. Some mixtures experienced temperature increases of up to 33°C, indicating an exothermic reaction that produces heat. Effect of Mixture Ratio on Final Temperature Apart from the type of oil, the mixture ratio between the oil and the bleach solution also affects the final temperature.

3.2 Effect of Mixture Ratio on Final Temperature

In addition to the type of oil, the ratio of oil to bleach solution also affects the final temperature. However, in experiments with baby oil (Substance A3), it was observed that certain mixture ratios (e.g., 4:6) resulted in a higher temperature increase. This suggests that the mixture ratio can influence the reaction rate and the amount of heat produced.

4. CONCLUSION

This study shows that the observable phase behavior of oil–water–sodium hypochlorite ternary mixtures is strongly affected by oil type and composition ratio, as identified using a turbidity (cloud-point) observation method to mark the boundary between temporary dispersion and clear phase separation. Coconut oil exhibited rapid separation with minimal dispersion, olive oil formed more persistent cloudy mixtures before separating, and baby oil showed similar dispersion behavior with slight temperature increases in some compositions. The

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increasing volume of water required to reach turbidity at higher oil fractions reflects the strong immiscibility between the nonpolar oil phase and the aqueous ionic phase, while the turbidity observed represents only temporary droplet dispersion due to mixing rather than stable emulsion formation. Overall, the cloud-point approach provides a simple and practical way to describe the phase characteristics of oil–water–NaOCl systems and highlights the important role of oil physicochemical properties in determining visible phase behavior.

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