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Evaluation of the Stability of a Biodetergent for Industrial Use

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In the industrial setting, it is common to use toxic oils and petroderivates, which are difficult to remove. For the cleaning of machines, equipment, and other surfaces impregnated with these oils, industries use products with high cost and that, many times, are also toxic and harmful to the health of workers and the environment. In this context, natural detergents/degreasers, formulated from renewable/sustainable sources, have been developed. Therefore, this work aimed to optimize the visual and stability characteristics of a non-toxic biodetergent in the face of large-scale production. In this sense, was avaluated the variation in the concentration of the stabilizing gum (0.7, 0.8, and 1.0 1.5%), one of the main components of the formulation and the agitation times (10, 15, 20 and 25 minutes). The volume of batchs was 250 liters in an industrial homogenizer tank with agitation of 3500 rpm at 80 °C. After mixing, the stability (phase formation) of the biodetergent was verified in relation to the storage time (48 hours and 8 days) and the maintenance of the product's efficiency regarding the application in the removal of OCB1 fuel oil on metallic surface. As for the processing conditions studied, the results obtained demonstrated the interaction of the concentrations of solid component and the physical parameter (stirring time) that directly influenced the final characteristics of the product. All tests showed excellent results, with emphasis on the contraction of 1.0% stabilizing gum and the stirring time of 20 minutes, reaching 100% stability. As for the evaluation of the biodetergent for the removal efficiency of OCB1, it showed satisfactory results, with 100% removal of the oil impregnated on the metallic surface. Thus, it can be concluded that the biodetergent formulation presented reliability in relation to the large-scale production process, ensuring greater quality control of the final product.

1. Introduction

The increasingly automated industrial processes use a large amount of oil to make their activities feasible, as in the case of the thermoelectric plants that they use of fuel oil (OCB1). Thus, the generation of oily waste arising from the operation, maintenance and cleaning of parts, floors and equipment arouses the concern of companies with the environment and the health of workers (Rocha e Silva et al., 2019; Farias et al., 2021a). The detergents that have been commonly used by industries powered by fuel oil in the main stages of the washing process of parts, equipment, floors and machines, are synthetic derivatives of petroleum, and therefore have a high degree of toxicity, which can generate secondary hazardous waste such as BTEX and HAP's, which can cause irreversible effects over time in different environments (Rocha e Silva et al., 2019). In addition, most of these commercial detergents / degreasers contain petroleum-based solvents, many of which are not biodegradable and persist in the environment (Selva Filho et al., 2023). In this context, the advancement of sustainable technologies has increasingly driven the search for natural and biodegradable surfactant compounds, which reduce impacts on the environment and guarantee the health of workers (Durval et al., 2019; Sarubbo et al., 2022). Therefore, this work aimed to improve the visual characteristics and stability of a non-toxic biodetergent, formulated from natural components such as organic vegetable solvent, natural surfactant and stabilizing gum front large-scale production.

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2. Material and Methods

2.1 Material

The biodetergent formulated consists in organic vegetable solvent (fatty acid ester), natural surfactant, stabilizing gum and water. All compounds were purchased from local stores (Recife-PE/Brazil).

2.2 Evaluation of the interaction between stabilizing gum concentration/stirring time parameters of the biodetergent

To study the interaction between the components of the formulation and a greater dispersion between the phases of the mixture, the variation in the concentration of the stabilizing gum (0.7, 0.8, 1.0 and 1.5%) was evaluated, one of the components responsible for the stability and efficiency of the product and different dispersion times. The natural surfactant classified as a fatty alcohol (2.0%) and the liquid components of the formulation, such as the vegetable organic solvent and water, had their concentrations maintained according to previous studies, 20.0% and q.s.p to complete 100%, respectively (Farias et al., 2022). In the present study, the batch volume was 250 liters in an industrial homogenizer tank (Figure 1), with agitation at 3500 rpm at 80 °C, with samples taken at different agitation times (10, 15, 20 and 25 minutes). At the end of the mixing process, the samples (1 liter) were stored in glass graduated cylinder and kept at room temperature (28 - 30 ºC) for 48 hours. Then, the stability and efficiency of removing OCB1 oil in metallic surface were evaluated.

Figure 1: Mixer with a capacity of 250 liters for the biodetergent production process

2.3. Determination of the stability of biodetergent

To determine the stability of the biodetergent, the samples were analyzed according to the emulsification index, evaluating the level of phase separation of the formulation. The readings of the formulation's stable phase and the total formulation height in graduated containers were taken, and the readings expressed in centimeters. The stability index was calculated by the ratio between the height of the stable phase and the total height of the formulation, the value being multiplied by 100. The evaluation occurred after 48 hours of rest. All analyzes were performed in triplicate (Cooper and Goldenberg, 1987). The stability was calculated using the formula:

$$I_E = \frac{(H_E)}{H_T}\, x\, 100 \qquad (1)$$

Where I_E is the emulsification index, H_E which represents the height of the emulsion and H_T which represents the total height of the emulsion.

2.4. Metal surface wash

The process was carried out with metallic pieces (nuts) uniformly impregnated by immersion in OBC1 oil. The impregnated parts were subsequently immersed in the test samples (biodetergent) for 30 min, then the parts were immersed in distilled water, removing excess test solution and destabilized residues from the surface. The removal efficiency was visually qualified (Farias et al., 2021b).

3. Results and discussion

It is common for small adjustments to occur in the concentrations of components in commercial formulations due to changes in the characteristics of the inputs, depending on the supplier and, mainly, changes related to scaling of production. Even with the most economical definition of the biodetergent formulation (Farias et al., 2022), an attempt was made to further reduce the discrete phase separation of the formulation, just to better understand possible modifications on a larger scale. In this sense, the evaluation of the variation in the concentration of the stabilizing gum showed an improvement at a concentration of 1.0%, based on the absence of phase separation after 48 hours and going further most, after a week of rest (Figure 2).

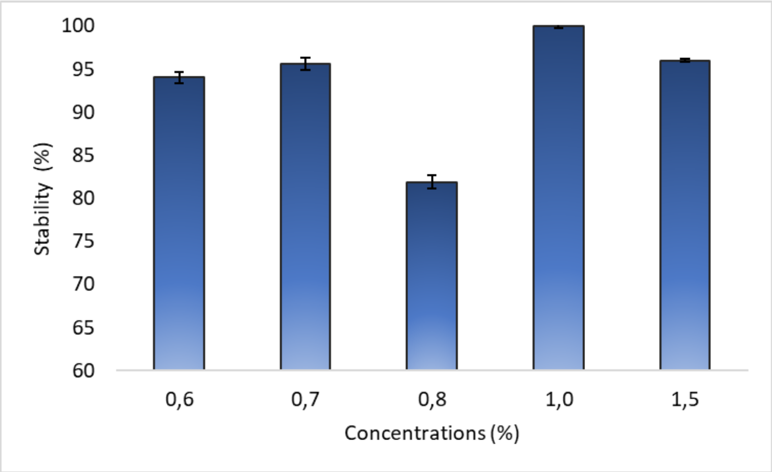

Figure 2: Percentages of stability for the concentrations of stabilizing gum in the biodetergent production process, after 8 days of rest

Applying the methodology to the new adjustment in the percentage of stabilizing gum (1.0%), it was immediately possible to observe that, regardless of the various agitation times employed (10 – 25 minutes) to the volume of 240 liters in the mixer of the production plant, at a speed of 3500 rpm at a temperature of 80 °C, the original physical characteristics of the formulation, such as creamy appearance, mild odor, uniformity and good fluidity, were maintained in all tests (Figure 3).

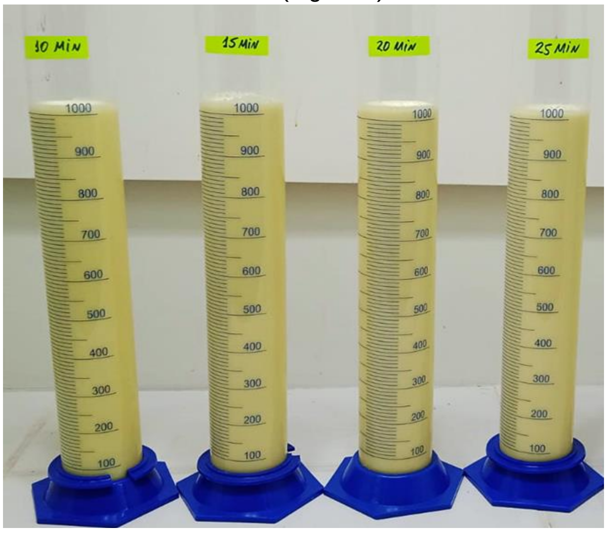

Figure 3: Illustration of the biodetergent production tests right after production to evaluated the agitation times (10, 15, 20 and 25 minutes)

In addition to these aspects right after production, it is also necessary to consider the maintenance of the product's characteristics in terms of resting time at room temperature. The evaluated processing condition (agitation times) depending on the volume of the mixing vessel can directly influence the final characteristics of the product after hours of rest. According to the National Health Surveillance Agency (ANVISA, 2004), this study is important because the physical characteristics of a product impact on market acceptance.
The stability of a product after a certain period of storage and its level of fluidity are important, since the physical characteristics of the product are decisive for choosing the most appropriate way of applying, such as, for example, blasting, immersion or even through manual application. The results presented below clearly demonstrate the interaction between the physical processing conditions, which directly influence the final characteristics of the product after 48 hours of rest. As can be seen in Figure 4, there was a slight phase formation in the lower area of the container, referring to the hydrophilic (polar) portion of the formulation, which easily returns to its stability after minimal manual agitation. There was also a slight increase in the emulsion pouring point, but without interference in the ways of applying the product.

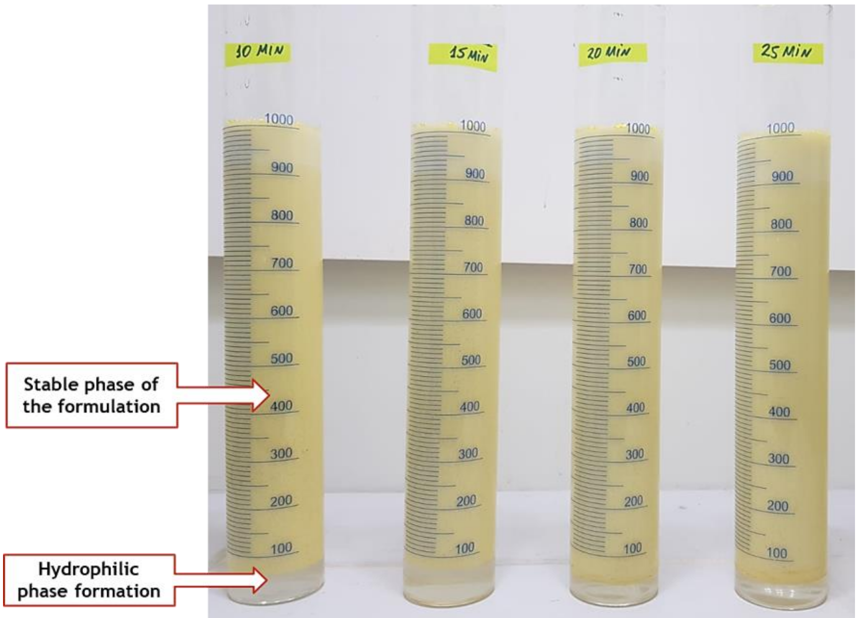

Figure 4: Illustration of biodetergent production tests after 48 hours of production to assess stability for stirring times (10, 15, 20 and 25 minutes)

These events were expressed with greater accuracy after determining the percentage of stability. We present in a summarized way all the production tests which presented excellent results. According to the graph (Figure 5), an excellent result of 98.0% stability was achieved for the 20 minutes of agitation, this time being selected as the most suitable for the production process in larger scale.

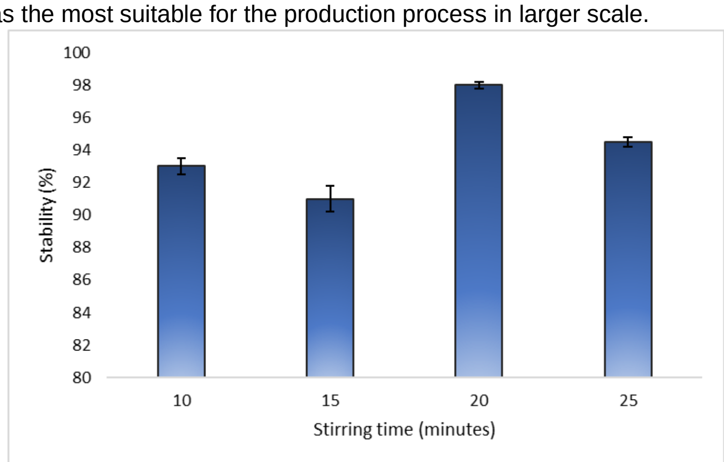

Figure 5: Percentages of stability for the agitation times investigated in the biodetergent production process, after 48 hours of rest

The evaluation of the biodetergent in terms of OCB1 oil removal efficiency showed excellent results in all scale-up tests, with 100% removal of oil impregnated on a metallic surface (Figure 6). Thus, it is understood that the effectiveness of the product has not changed in relation to physical and compositional factors in the large-scale production process of the biodetergent.

Figure 6: Illustration of the removal of OCB1 oil by the biodetergent on a metallic surface. Metal part impregnated with OCB1 oil (A). Removal of OCB1 after immersion in formulation (B). Oil removal from finished metal surface (C)

The presented results confirm the influence of agitation time and concentrations of the stabilizing component on the visual properties of the final, product produced at a volume of 240 liters in the biodetergent production plant. Thus, the best large-scale processing conditions indicated in this study were 20 minutes of agitation at 3500 rpm, 80°C for a volume of 240 liters, which will be maintained to ensure greater quality control of the final product.Similar results are found in the literature. In a work related to the present study, some parameters were evaluated on a bench scale, such as agitation time (5-10 minutes) and increase in volume of batches (4, 5 and 6 liters), regarding the stability of a biodetergent produced from from non-toxic components. The variation between processing conditions showed some influence on the final characteristics of the product after 96 hours of storage. All tests showed good results, with emphasis on 7 minutes of agitation for all volumes tested, reaching almost 100% stability and maintenance of efficiency, with 100% removal of OCB1 oil impregnated on a smooth and metallic surface (Farias et al., 2021b). Almeida et al. (2020), evaluated the ability of a surfactant to remove oil in steel parts. The results showed that the surfactant of vegetable origin promoted an efficient oil removal between 82.6 ± 0.5 to 78.4 ± 0.6%, and can be considered with potential for commercialization and replacement of chemical surfactants. A formulation developed similarly to the biodetergent, from biodegradable components, also showed satisfactory results in the removal of heavy oil, demonstrating the potential to be a commercially viable product (Rocha e Silva et al., 2020).

3. Conclusion

The presented results confirm the direct influence of the investigated physical parameters on the visual properties of the final product. From this study, the factors linked to the composition of a stabilizing ingredient and of the formulation agitation time demonstrated interaction in relation to the high volume of production evaluated. Thus, the percentage related to the adjustment of the stabilizing gum (1.0%) was considered the most promising and the best processing condition (agitation time) selected was 20 minutes of agitation, at 3500 rpm at 80 °C for the process in stirring vessel of 240 liter, suitable for industrial scale, ensuring greater quality control of the final product.

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