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# Production Process of Hand Sanitizer from Vietnamese Coconut Oil

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Currently, hand sanitizers are seen as an indispensable household product, which not only cleanses and protects the skin from bacteria but also confers skin-softening function. With the objective of research and development the process for producing hand-sanitizer from coconut oil, this study aimed to optimize the production conditions to provide a natural-derived and low-cost hygienic product. The two factors that characterized the standard for product evaluation are the level of foaming and durability of the emulsion, which reflects the cleansing ability of the product from the saponification reaction. Upon analysis, the coconut oil/NaOH ratio of 5.5:1, the alkaline solution concentration of 10 %, 3 h reaction, 80 ºC, stirring speed of 300 rpm, pH 8 and 1:2 dilution rate were found to be the optimal reaction conditions for the highest cleaning ability. In addition, other substances are used for finalizing the product such as moisturizing glycerol, dipropylene glycol, softener skin coca amidopropyl betaine, preservatives dimethylol dimethyl hydantoin, thickener hydroxyethyl cellulose, colour and essential oils.

**Keywords: Hand sanitizer, Vietnamese coconut oil, Saponification, Health care products, Cleaning ability.**

## INTRODUCTION

Hand sanitizer is of increasing demands, along with other healthcare products to improve personal hygiene. It has been shown that handwashing is an efficient method to reduce the rate of infection and handwashing products also provide a cosmetic effect of softening the skin [1,2]. There are many hand sanitizers available on the market, which vary in disinfectant strength, odour and other properties, but most of them have chemical origin. Concerning the recipe of hand sanitizers, it is usual that safe agents are listed specifically on the label, but substances such as preservatives, flavors, chemical colorants are not specified. These non-specified agents are potential causes of allergy, respiratory issues and other side effects. Almost all products with strong cleansing properties are produced from the primary surfactants as sodium laureth ether sulfate, sodium lauryl sulfate, cocamidopropyl betain, disodium lauryl sulfosuccinate or sodium cocoyl isothionate, which are known to cause skin dryness and irritation [3-6]. Therefore, a hand-sanitizer product with the main raw materials from nature is preferred by consumers. Successful production of hand-sanitizers from coconut oil could also benefit the domestic cultivation of coconut with increasing demand for the raw material and increase the value of this agricultural product.

Coconut oil is a fat extracted from copra and is widely used in food, pharmaceutical cosmetics worldwide [7]. Coconut oil is pressed from copra, with a rate of extraction of about 620-625 kg of coconut oil per ton of dry copra. Copra is largely used for the production of coconut oil, rarely for export though, as only 2 % of copra is exported annually. In term of coconut oil production, the global production volume is about 3.2 to 3.6 million tons per year [8,9]. The saturated fatty acids in coconut oil consist of lauric acid (45-52 %), myristic acid (16-21 %), and palmitic acid (7-10 %). In addition, there is a small portion of other fatty acids such as stearic acid, caprylic acid, capric acid and oleic acid. Most of fatty acids in coconut oil are fatty acids with a medium carbon chain $C_{12}$-$C_{14}$, which are compatible with the skin [10,11]. It was reported that these medium chain fatty acids of virgin coconut oil are incredible for antimicrobial properties of harmful viruses, bacteria, fungi and parasites [12]. In addition, rich polyphenol content of coconut oil provides antioxidant and anti-stress functions [12]. Oyi *et al.* [13] also pointed out that coconut oil has bactericidal activity against *Pseudomonas aeruginosa*, *Escherichia coli*, *Proteus vulgaris* and *Bacillus subtilis* owing to the presence of monolaurin. In particular, monolaurin could enhance absorption owing to the presence of active emulsifying substances, which is used to make cream from coconut oil [13]. Moreover, the antibacterial properties of lauric acid are also exploited to treat oral infections such as mouth sores or prevent tooth decay. Therefore, the combination of coconut oil and 0.05 % sodium hypochlorite was used as an antiseptic in the prevention of stomatitis [14,15]. In Vietnam, researchers have come to the conclusion that the nutritional value of fat in coconut oil for humans and the average fatty acid chain in coconut oil could facilitate digestive absorption. Because of these multifunctional effect, coconut oil has become a reliable, popular product [8,16]. In addition, the lauric acid in coconut oil is proven to be beneficial for the skin owing to its optimal distribution, solubility parameters and the formation of high adhesion, high permeability, which are properties of potential detergent product [17].

At present, the demand for cleaning products having bactericidal properties is growing as the consumers have realized the importance of personal hygiene and the high risk of infection. Foreseeing the need for hand-washing soaps and hand sanitizers have bloomed in Vietnam market. Large retailers such as Maximark and Coop Mart account for 70 % of weekly sales of Vietnamese hand-washing products. They mostly contain various surfactants, sodium lauryl sulfate or sodium laureth ether sulfate. These substances are neutralized with lauric acid, stearic acid in coconut oil, respectively. Additionally, fatty acids such as myristic acid, lauric acid, palmitic acid, and capric acid are utilized to produce soap [18]. These fatty acid are produced from vegetable oils, by hydrolysis and distillation and thus are usually expensive. As a result, liquid detergent products (hand cleansers, lotions, *etc*.) produced directly from coconut oil are not yet popular and there are not many publications in this field.

With the objective of research and development production processes of cleaning products, namely hand sanitizer from the main raw material of coconut oil, the project has investigated the factors that influence and optimize the saponification reaction, devised the product formula and evaluated the quality of the product. Resulting products are comprised of natural ingredients, safe, biodegradable and environmentally friendly.

## EXPERIMENTAL

The research utilized crude coconut oil, produced by the method of conventional heat from coconut scraps provided by Ben Tre coconut jam producer. Purchased oil will be preserved in normal conditions. Other chemicals such as sodium hydroxide, glycerol, citric acid and additives (foam, lotion, *etc*.) are stored in a dry place. Food colorants, essential oil fragrance of mint and equipment used for research as analytical balance, magnetic stirrer, overhead stirrer, pH meter are provided and supported by the NTT Hi-tech Institute, Ho Chi Minh city, Vietnam.

**Production process of hand washing lotion from coconut oil:** Firstly, the saponification reaction was performed by mixing and stirring heated coconut oil at 80 ºC with an alkaline agent. The reaction was then optimized in experimental parameters to achieve the highest cleaning efficiency. Then, the product of the optimized saponification reaction was neutralized to adjust its pH value ensuring efficiency and safety for consumers. The substrate was then diluted and mixed with additives such as foaming agents, moisturizer to increase the effectiveness of the product. In addition, flavor and colour are also added to increase the sensory value, as well as diversify the nature of the product. The finished product is stored in a plastic bottle and in a dry cool place.

**Factors affecting the saponification reaction:** Saponification reaction is the reaction between vegetable oil (coconut oil) and alkaline NaOH solution to form glycerol and salts of fatty acids (soap). In this study, saponification reaction occurs when coconut oil reacts with NaOH solution. This is the critical stage to determine the effectiveness of cleansing and the level of foaming. In the optimization, the mass ratio between coconut oil and alkaline varied from 4:1 to 8.5:1 ratio; alkaline agent concentration ranged from 5 to 20 %; reaction temperature ranged from 60 to 90 ºC; time of saponification reaction is conducted for about 1 to 4 h; stirring speed from 100 to 700 rpm.

**Factors affecting the neutralization and dilution ratio:** When the saponification process ends, the pH of the mixture is alkalized (pH 10-11). This causes the skin to dry and cause burns or irritation to the hands. Therefore, the pH of mixture was also investigated and adjusted. Saponification products are tested for pH. Then, citric acid solution was added to neutralize the alkaline to pH 6-9. Subsequently, the solution is diluted with water at a ratio of 1 to 0.5-4.0. The assessment results are based on foaming, as well as on the skin reaction to select the appropriate pH and dilution ratio.

**Finalizing the product:** Personal cleansing products are products used primarily for the purpose of cleaning stains on the body. When using the product, besides the ability to cleanse, organoleptic evaluation such as the level of foaming, ability to wash away the skin, sensation after washing, irritation, dryness, colour and scent is also concerned. In this study, the mixture was added with a number of additives to complete the formula for hand washing lotion. Additional agents for moisturizing the skin such as glycerol and dipropylene glycol, coca amidopropyl betaine (CAB) are added to soften the skin. Dimethylol dimethyl hydantoin (DMDM), which reduces the growth of microorganisms in the product environment is also included. To finalize, the mixture is added with hydroxyethylcellulose (HEC) thickener, colour and peppermint essential oil.

**Evaluation conditions:** To evaluate the results of analysis, sensory use and cleaning ability are two typical criteria for product evaluation. The standard use is shown by the foaming ability of the product (level of foaming) - the ratio between the foaming height and the height of the initial product solution.

The mixture after the reaction was diluted 100-fold. Then, 2 mL of solution was put into a centrifuge tube with a cap, shaken with a moderate force until the foam volume was maximized (foam volume was not changed) as shown in Fig. 1a. The level of foaming is calculated by eqn. 1. Accordingly, the foaming is equal to the difference between the initial volume and the volume after shaking divided by the volume after shaking.

$$\varepsilon_f = \frac{V_{foam} - V_{liquid}}{V_{foam}}$$

where $\varepsilon_f$ = level of foaming; $V_{foam}$ = volume of foam after shaking; $V_{liquid}$ = initial liquid volume

The cleaning ability was demonstrated by the duration of the emulsion against a selected paraffin oil (a substitution for dirt). Firstly, 2 mL of diluted solution was added to 2 g of paraffin oil, then was shaken to create the emulsion. A stopwatch, which was stopped when 1 mL oil volume was separated into distinct layers was used to determine the durability of system.

## RESULTS AND DISCUSSION

### Saponification reaction

**Effect of ratio between coconut oil and alkaline solution:** The effect of the ratio between coconut oil and alkaline solution is shown in Fig. 2. Based on Fig. 2, the level of foaming and durability of the emulsion increase when the ratio of coconut oil to alkaline is within the range of 4.0 to 5.5. However, additional coconut oil content in the solution further caused foaming to decrease and formed oil scum on the surface of the solution. This is because excess oil content saponification reaction could have reduced foaming ability. When the oil/alkaline ratio is low (about 4.0-5.5), the coconut oil is almost completely reactive, increasing the amount of soap produced and making the post-reaction system more homogeneous. The level of foaming is also increased. Consequently, the 5.5:1 ratio was chosen and used in further experiments.

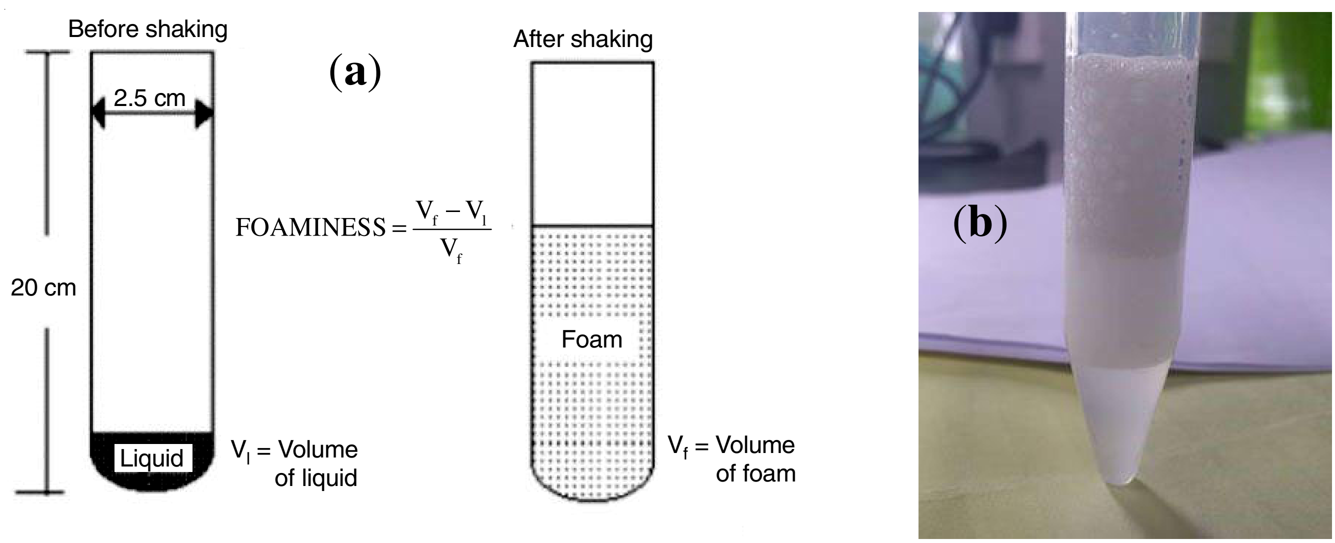


Fig. 1. Evaluation of the saponification reaction. (a) The shaking test; (b) Emulsifying method

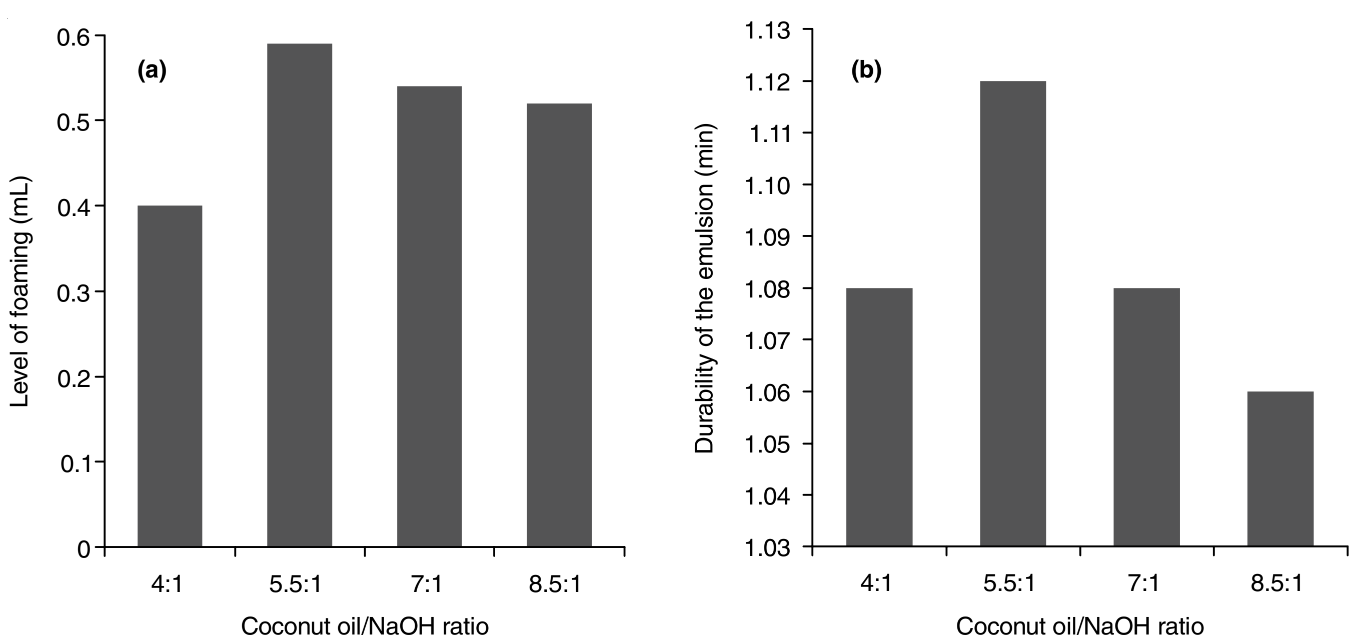


Fig. 2. Effect of coconut oil to NaOH ratio on the (a) level of foaming and (b) the durability of the foam

**Influence of concentration of alkaline agents:** The results reflecting the influence of alkaline agent are shown in Fig. 3. In general, when NaOH concentration (% weight) increases, the level of foaming and durability of emulsion of the system also increase. However, when the optimum value is reached, these two conditions of the product start to decrease afterward. In particular, the level of foaming and durability of emulsion increase when the alkalinity increases from 5 to 10 %. At the low alkaline concentration of 5 %, the product obtained after the reaction was separated and oil scums were observed floating on the surface. This demonstrated that the reaction is inefficient and the oil is not fully saturated, resulting in low foaming level and weak durability of the emulsion. When increasing concentrations of alkaline agent to 10 %, the reaction occurs more rapidly and completely, producing more soap and foam. However, at the range of alkaline concentration of 15-20 %, the reaction occured more strongly and the post-reaction system tends to be solidified adversely, disrupting the reaction. That resulted in the trapping of the unreacted oil and, thus, is difficult to assess (Fig. 4). It is concluded that 10 % of alkaline agent in the reaction is sufficient to form soap.

**Effect of reaction temperature:** The evaluation of foaming level and the durability of the emulsion at various temperature is displayed in Fig. 5. As the reaction temperature increases, these concerned properties of the product are also improved significantly. It shows that the temperature has a great influence on the foam formation and the durability of emulsion. Specifically, when the temperature increases from 60 ºC to 90 ºC, the level of foaming increases by 0.2 to 0.37 and the durability of emulsion increases by 0.52 to 1.17. However, when the temperature is within 80 to 90 ºC, the difference in the level of foaming and durability of the emulsion is marginal.

This temperature-dependent result can be explained simply as the result of thermodynamics. The high temperature increase the speed of the reaction, promoting the foam formation and durability. Even though the temperature level beyond 80 ºC still showed some improvement of saponification characteristics, extreme reaction temperature would be dangerous as it may damage the reactor and pose economic issues regarding energy provision for heating. Therefore, the reaction at 80 ºC is suitable for saponification reaction.

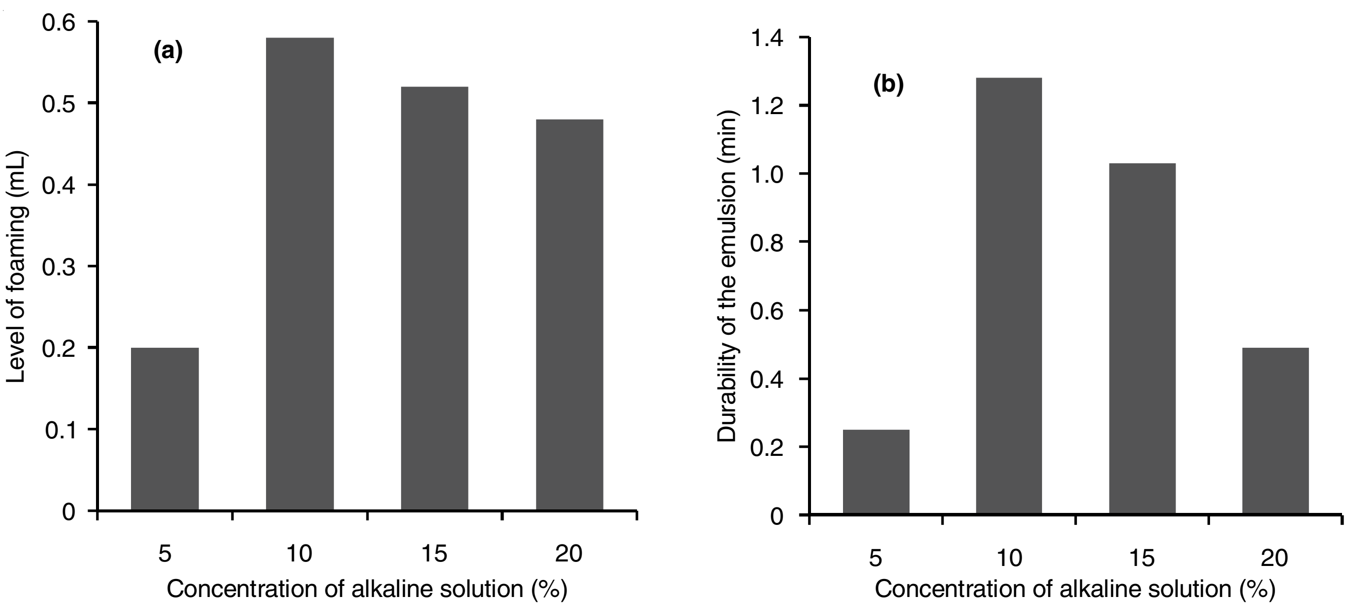


Fig. 3. Effect of alkaline concentration on the (a) foam formation and (b) the durability of the foam

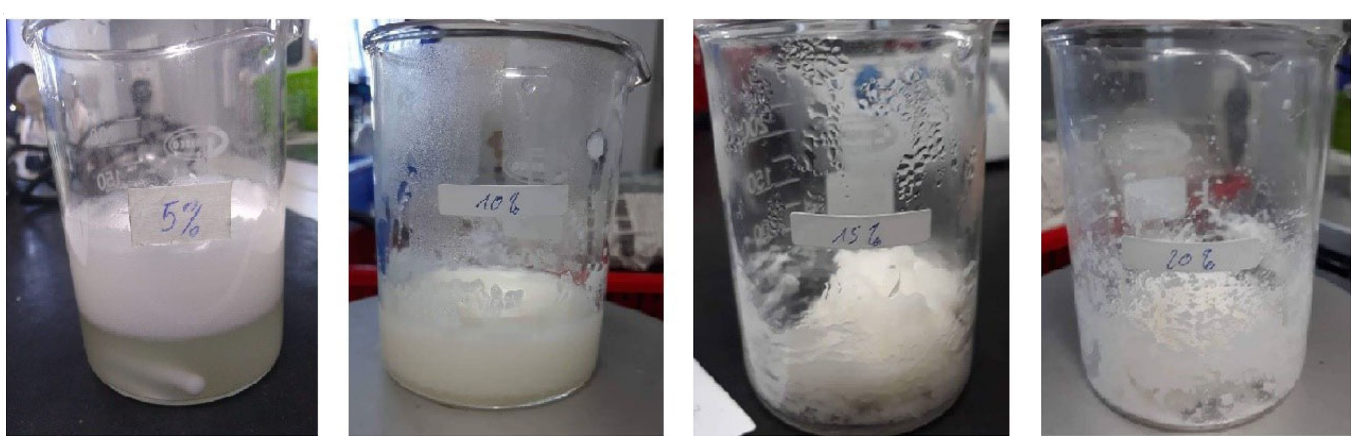


Fig. 4. Emulsion performed observed in a glass jar at different alkaline concentrations (5 %, 10 %, 15 %, 20 %). The percentage of the alkaline agent is indicated on the jar

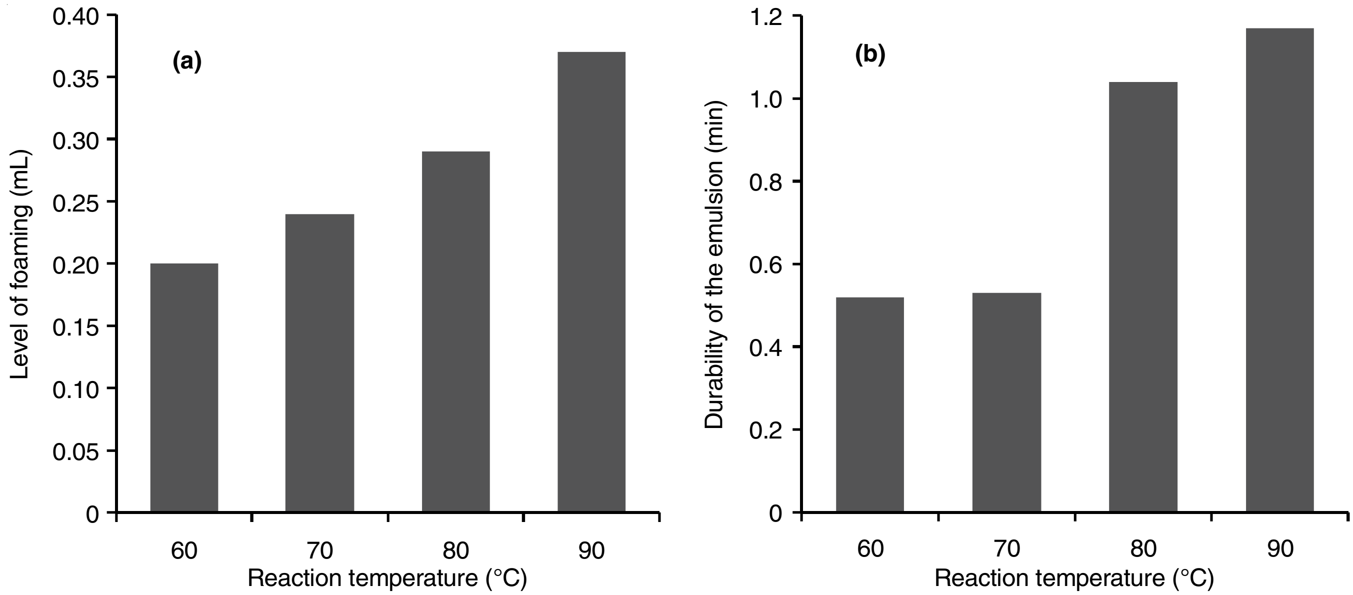


Fig. 5. Effect of reaction temperature on the (a) foam formation and (b) the durability of the foam

**Effect of stirring effect:** Experimental results obtained are shown in Fig. 6. When the stirring speed increased from 100 to 300 rpm, the level of foaming increased from 0.42 to 0.45 mL. However, as the stirring speed increased from 300 to 700 rpm, the foaming decreased from 0.45 (300 rpm) to 0.39 (500 rpm) and finally 0.29 mL (700 rpm). The level of foaming reached the optimum at the stirring speed of 300 rpm. Similarly, for the durability of the emulsion results, the foam tended to last longer as the stirring speed increased from 100 rpm to 300 rpm. In particular, the lasting time for the efficient emulsion expanded from 0.45 min to as long as 0.65 min. As the stirring speed accelerated to 500 rpm, the shear time also reached 0.36 min, followed by a sharp decrease to 0.26 min at 700 rpm.

The stirring speed promotes the rate of reaction of the system, generating more soap, foam and increasing the durability of the emulsification after the reaction. However, if the stirring speed is too high, the gas pockets in the foam are easily damaged and the reaction will be short-lasting. It is noteworthy that at fast stirring speed, the system will clot and float on the surface during the reaction, impairing the visual presentation of the product. Thus, a stirring speed of 300 rpm is appropriate for the implementation of saponification reaction and is used for the further analysis. From the analysis results, the obtained saponification recipe is listed in Table-1.

TABLE-1
BASIC CONDITIONS TO PRODUCE THE HAND SANITIZER, BASED ON THE ANALYSIS RESULT

| Tested parameter | Optimal value |
|---|---|
| Concentration of NaOH alkaline agent (%) | 10 |
| Ratio of coconut oil and NaOH | 5.5:1 |
| Reaction temperature (°C) | 80 |
| Reaction time (h) | 3 |
| Stirring speed (rpm) | 300 |

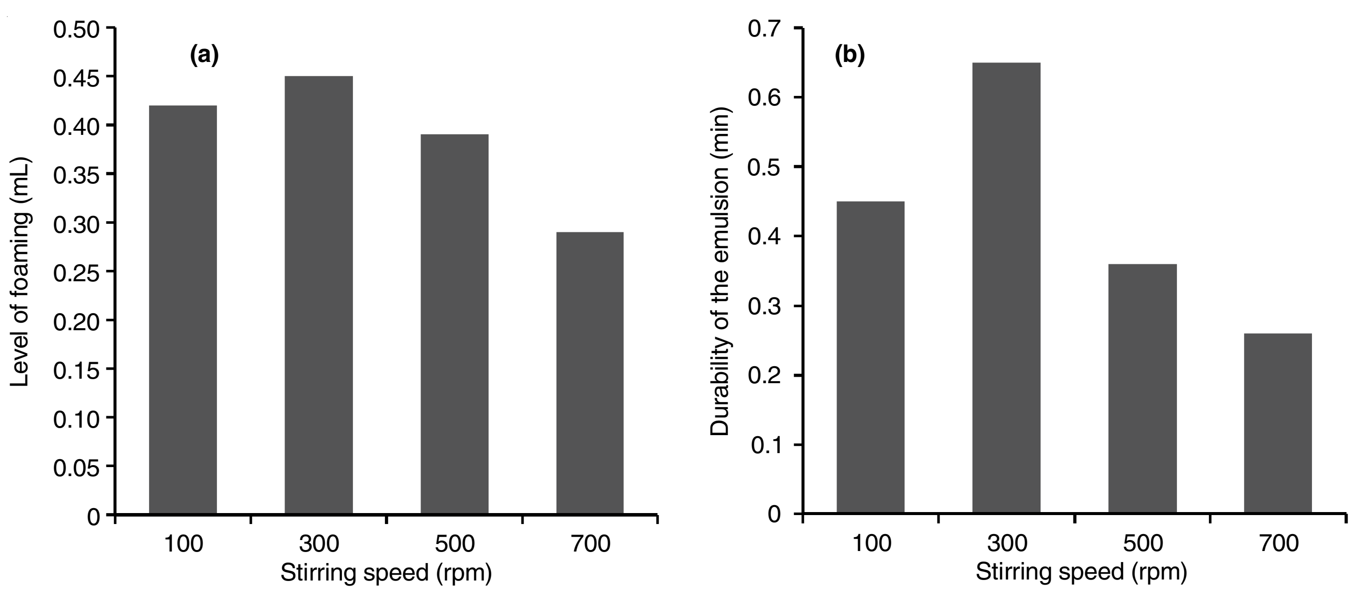


Fig. 6. Effect of the stirring speed on the (a) foam formation and (b) the durability of the foam

## Building basic products

**Effect of pH:** The result represented in Fig. 7 showed that within the pH range of 8 to 9, there was no difference in the foam formation. Interestingly, when the pH dropped to 7 and 6, thickness of the foam layer suddenly dropped from 0.48 (pH 8) to 0.2 (pH 7) and disappeared at pH 6. The foam durability reached the maximum at pH 8 though. When the pH dropped to pH 6, the foam durability decreased rapidly from 0.39 min (pH 8) to 0.05 min (pH 6). The foaming ability, as well as the cleaning ability of the soap detergent product, get improved as the environment become more alkaline. It is obvious that the acidic environment has negative impact on the functionality of saponification reaction. On the other hand, high pH value could adversely irritate sensitive skin. Therefore, pH 8 is chosen as the appropriate value for the hand sanitizer formula.

**Effect of dilution ratio:** In order to reduce the production cost, we proposed the dilution of substrate after the saponification process. The results shown in Fig. 8 indicated that when diluting the substrate with water with the ratio exceeding 1:2 (substrate volume:water volume), even though substantial amount of foam was generated, the foaming levels were in distinguishable. The durability of emulsion decreases as the dilution rate increases. At 1:0.5 dilution ratio, the durability of emulsion achieved the longest lasting time of 1.88 min. Afterward, the durability of substrate significantly reduced to 1.09 min at 1:1 dilution rate and to the minimum of 0.48 min at 1:4 rate. Diluting the substrate with water will enhance the foaming formation but the effectiveness of emulsion also reduces, as the durability of foam is strongly affected.

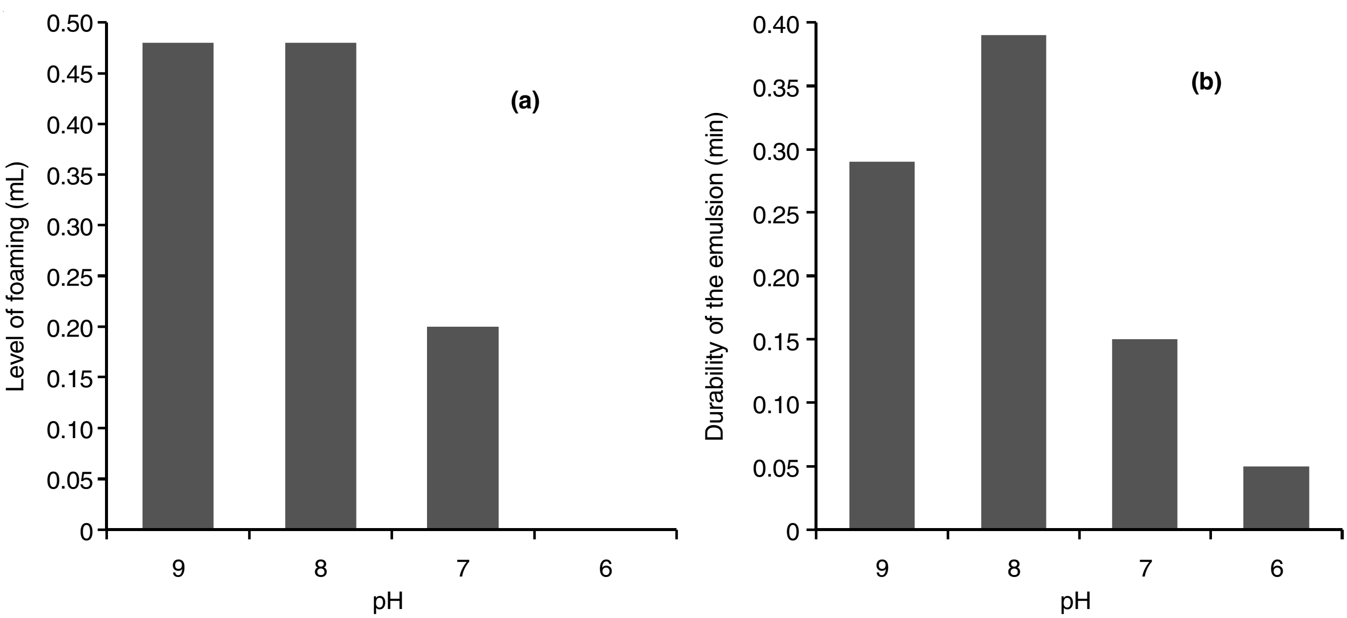


Fig. 7. Effect of pH on the (a) foam formation and (b) the durability of the foam

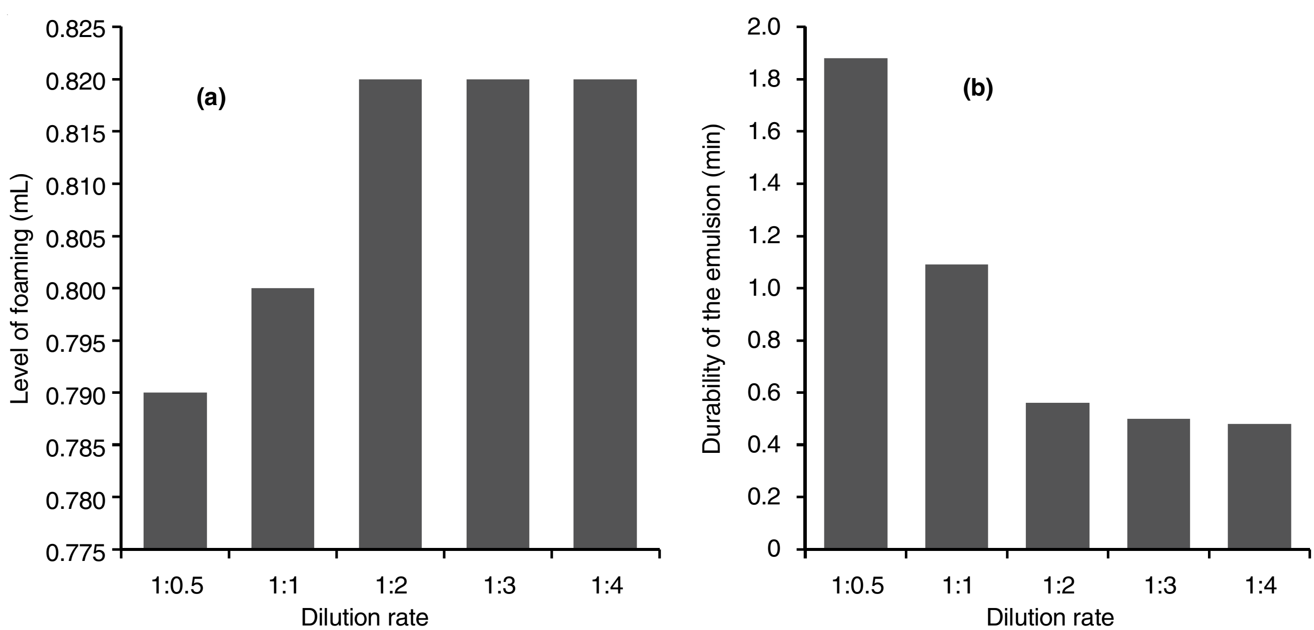


Fig. 8. Effect of water dilution on the (a) foam formation and (b) the durability of the foam

**Product finalization:** The product after the saponification is adjusted to pH 8 and the substrate and water dilution ratio is chosen as 1:2. After comparing some hand sanitizer products available on the market, we added several supplemented ingredients to complete basic hand sanitizer from coconut oil. The proposed additives are shown in Table-2.

TABLE-2
LIST OF PROPOSED ADDITIVES TO ACHIEVE THE MAXIMUM HAND-WASHING EFFECTIVENESS

| STT | Substance name | Content (%) |
|---|---|---|
| 1 | Glycerine | 2-3 |
| 2 | CAB | 1-2 |
| 3 | Dipropylene glycol | 2-3 |
| 4 | DMDM | 0.4-0.5 |
| 5 | HEC | 0.5-1.0 |
| 6 | Color | Just enough |
| 7 | Smell | Just enough |

## Conclusion

The research has developed and optimized the production process of hand sanitizer from coconut oil. Two factors that characterized the standard for product evaluation are identified as the level of foaming and cleaning ability, demonstrated through durability of the emulsion of product from the saponification reaction. The results are summarized as:

- The ratio of coconut oil and NaOH is chosen as 5.5:1.
- The concentration of alkaline agent (NaOH) is used at 10 %.
- The reaction temperature is chosen at 80 ºC for 3 h and stirring speed of 300 rpm.

pH value at 8 and dilution ratio between base product and water is 1:2. In addition, additional substances for finishing products include moisturizing glycerol, dipropylene glycol, softener skin coca amidopropyl betaine, preservatives dimethylol dimethyl hydantoin, thickener, colour and oil.

## ACKNOWLEDGEMENTS

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## CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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