Environmentally safe technology with the conversion of used cooking oil into soap

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Abstract. Cooking oil consumption in Indonesia is very high and tends to rise every year, reaching 500,000 tons/year. Waste of used cooking oil pollute water and reduces the biota. Therefore, the conversion of used cooking oil will help to reduce environmental damage. One of the conversions done is making the bulk cooking oil into soap. This study aims to determine the effect of NaOH concentration on the quality of soap made from purified used cooking oil. Activated charcoal from sugarcane bagasse was used in the conversion of soap to diminish odor and brown color. This study was designed using an experimental method with descriptive analysis. The treatment in this study was the difference in NaOH concentrations of 10%, 30%, and 50% with each concentration repeated three times. The results obtained showed that the most optimal NaOH concentration is 50% since it has a dense soap consistency. In contrast, the 30% NaOH concentration has a semi-solid soap consistency. At 10% NaOH concentration the consistency of soap is still liquid. It can be concluded that the concentration of NaOH affects the quality of the soap.

1. Introduction
Cooking oil is categorized as a basic need for Indonesian people and the use of cooking oil in Indonesia is quite high. Cooking oil is mostly obtained from plants such as palm oil, cotton seeds, corn, olives, and nyamplung. Usually the use of cooking oil is used up to three to five times the frying pan. Even though oil has changed color due to repeated use many people still use it. When frying is done, the double bonds found in unsaturated fatty acids will break up to form saturated fatty acids [1]. Repeated frying has made the fatty acids contained in the oil will become more saturated. Meanwhile, good oil is an oil that contains more unsaturated fatty acids compared to saturated fatty acid content. Thus, the oil can be said to have been damaged or can be called used cooking oil [2]. Population growth as well as changes in consumption patterns and lifestyle, have been the main drives of an increased waste production which causes several impacts on the environment and public health [3].

Soap is a surfactant that is used with water to clean or wash something available in solid and liquid form. Soap can be useful as a cleaning tool because this soap molecule contains polar groups (bound to water) and non-polar (bound to oil) so that it can clean fat or dirt that cannot be removed by water. Soap is the major product of the chemical reaction between triglyceride (fixed oil from seed) and lye solution
Chemically, soap is a salt of fatty acids. Whereas soap is traditionally made by reacting between fats or oils and bases (NaOH or KOH). The reaction that occurs is called saponification [6]. The process of soap formation is known as the saponification reaction, which is the reaction between fat/triglyceride with NaOH and KOH. Fat or oil is heated with a little excess alkali. When soaping is complete, salt is added to precipitate the soap as a solid. A layer of water containing salt, glycerol, and excess alkali is separated, and glycerol is recovered by distillation [7]. Initially the lathering reaction is slow because oil and an alkaline solution are immiscible. After the soap is formed, the reaction speed will increase, wherein the end the reaction speed will decrease again due to the reduced amount of oil 2020/3/30. Lathering is an exothermic reaction, so it must be considered when adding oil and alkali to avoid excessive heat. In the saponification process, the addition of an alkaline solution (KOH or NaOH) is carried out little by a little while stirring and heated to produce soap. To make the process more perfect and equitable, stirring must be done better.

Sodium hydroxide (NaOH) is also known as caustic soda. Sodium hydroxide is used in various fields of industry, mostly used as bases in the process of producing wood pulp and paper, textiles, drinking water, soap, and detergents. Pure sodium hydroxide is solid white and is available in the form of pellets, flakes, granules, or 50% saturated solution. Sodium hydroxide is hygroscopic and spontaneously absorbs CO₂ from free air, forming Na₂CO₃ [8]. Sodium hydroxide is very soluble in water and will release heat when dissolved. Sodium hydroxide is also soluble in ethanol and methanol, insoluble in diethyl ether, and other non-polar solvents. Sodium hydroxide solution will leave yellow stains on cloth and paper [9].

A lot of research on used cooking oil is reused into biodiesel and a lot of it is processed into soap. But there is still little research on used cooking oil which is reused into new, more economical products such as soaps. Used cooking oil adsorption processes using activated carbon based on sugarcane bagasse to improve the quality of used cooking oil in the main ingredients of solid soap. Research on this environmentally friendly bar soap, used cooking oil used as a raw material in the manufacture of solid soap reacted with NaOH and an adsorption process was carried out to improve the quality of used cooking oil with activated carbon based on sugarcane bagasse.

2. Material and methods

2.1. Place and time
The research was conducted at the Biochemical Laboratory Biology Faculty of Mathematics and Natural Sciences, Universitas Negeri Jakarta on January - March 2020.

2.2. Material and reagents
The recycled waste products used as major raw materials in the soap formulations were used to cook oil and activated charcoal of sugarcane bagasse. In formulations, commercial materials were used, such as coffee and vitamin E. Reagents were also used, namely: sodium hydroxide (NaOH).

2.3. Activated carbon of sugarcane bagasse
Bagasse was cleaned and heated at 400°C for 60 minutes. The carbon form was then activated with 0.1 N KMnO₄ for 72 hours. Activated carbon was then washed with distilled water and dried at 115°C for 1 hour. After that it was filtered with 225 μm mesh.

2.4. Cooking oil preparation
Cooking oil used is cooking oil was used four times to fry chicken. Consumable cooking oil is put into a closed jar.

2.5. Adsorption process
Activated carbon (5 g) was immersed in 100 ml of cooking oil. It could settle for a while before mixing with a magnetic stirrer for 3 x 24 h. Oil was then filtered with filter paper.
2.6. Soap preparation

In this research, we used three-level of NaOH concentration, which are 10%, 30%, and 50%. In the first treatment used 10% NaOH. As much as 15 ml of 10% NaOH was put into the stainless bowl, then added with 225 ml of purified cooking oil which has been heated to 60°C. After that, mixed with mixer until set. Then added 22.5 gr of coffee as coloring and deodorizing. Mixed again used a mixer until well blended. Put it in a soap mold. The treatment was repeated 3 times. The same process was carried out in the second treatment used 30% NaOH and the third treatment used 50% NaOH. All the prepared soaps were characterized by their pH, foaming ability, solubility, and hardness whilst comparing their values with commercial soap samples using a standard procedure [10]. Treatment of used cooking oil involves three phases: filtration, for the removal of particulate matter; washing, for the extraction of non-visible particles in suspension; and deodorization, for the removal of molecules that give the oil some odor [11].

3. Results and discussion

In this study the physical condition of cooking oil was first observed. Production of soaps with unique properties needs a careful selection of oil type. The criteria for the selection of oil for industrial or domestic application in soap making includes the presences of natural characteristic aroma, clarity, natural color, low moisture content and absence of flat and rancid (unpleasant) odor [12,13]. Furthermore, the oil is used for frying up to 4 times the frying pan, the oil obtained smells slightly rancid and turbid yellow. The purification process is carried out with bagasse as an adsorbent.

![Figure 1. Comparison of cooking oil (a). Before frying, (b). After four times frying.](image)

This used cooking oil cannot be directly used as raw material for making bath soap because the results are not good. This bath soap from used cooking oil has an unattractive color because it is dirty and dark and from the side of the scent it might be the aroma of the fried material that will still be attached to the soap product. Therefore, to produce physically attractive soap products and in terms of fragrant aroma, the used cooking oil must be purified first.

This research uses sugarcane bagasse as a basic ingredient to make activated charcoal for the purification of used cooking oil. Activated charcoal is a form of charcoal that has been activated using CO₂ gas, water vapor, or chemicals so that its pores are open and thus the adsorption power is higher for dyes and odors. To activate bagasse charcoal, we use a chemical KMnO₄ with soaking charcoal for 72 hours. Kaur (2008) explained that sugarcane bagasse can also be used as heavy metal adsorbents such as Zn²⁺ (90%), Cd²⁺ (70%), Pb²⁺ (80%), and Cu²⁺ (55%) [14]. The high carbon content in sugarcane bagasse is the basis for making active charcoal in the purification of used oil.

Activated charcoal is used to purify used cooking oil for 72 hours to remove odor and color from used cooking oil. After that, it goes into making soap by mixing alkali with purified oil. The alkali used
in this experiment is NaOH which can make soap solid. Soap is produced from the saponification process, which is the hydrolysis of fats into fatty acids and glycerol in NaOH (oil heated with NaOH) until it is fully hydrolyzed. These esters are the major constituents of vegetable oils and animal fats; they can react with a strong mineral base like sodium hydroxide, in an aqueous medium, to produce the sodium salts of the hydrolyzed free fatty acids (the opaque soap) and glycerol [15-17].

When mixing oil with NaOH, the oil is first heated to 60 °C. Because in the temperature range of 55-65 °C, an increase in temperature will accelerate the reaction, which means increasing the results in a faster time. But if the temperature rise has exceeded its optimum temperature it will cause a reduction in yield. This happens because saponification is an exothermic reaction. Because the temperature is too high it will oxidize the oil resulting in oil damage where the oil becomes brownish. Besides, temperatures that are too high will accelerate the hardening where when the alkali is mixed the soap hardening reaction arises in the reactor.

After reaching 60 °C, the oil is mixed with NaOH using a high-speed mixer. Stirring is done to increase the probability of collisions of reactive molecules. If the collision between reactant molecules is greater, then the likelihood of the reaction will be even greater. After mixing thoroughly and trace, we add coffee to add aroma. Stir again until evenly mixed and put into soap molds. After two weeks, we observed differences in the quality of soap in each NaOH concentration.

Quality parameters to be considered are general appearance (including soap density, luminous, abrasive), good solubility, good foaming and stable, high cleaning power, foaming, resistant to rancidity, good in soft water, good stability (related to color). Based on the literature, differences in oil and fat produce a soap with different qualities, for example color, foaming consistency, and cleaning power. Table 1. shows the characterization of soap produced from several important oils and fats.

Table 1. Characteristics of soap made from different oils and fats [18].

| No. | Oil and fat         | Color and result of the soap | Soap consistency | Foaming power            | Cleaning properties | Effect on the skin |
|-----|---------------------|------------------------------|-------------------|--------------------------|---------------------|--------------------|
| 1   | Palm kernel oil     | White to pale yellow         | Very hard         | Fast, but the foam       | Very good           | Little             |
|     | Coconut oil         | White to pale yellow         | Very hard         | Fast, but the foam doesn’t last long | Very good           | Little             |
| 3   | Palm stearine       | Pale yellow                  | Hard enough       | Slow, but durable foam   | Good                | Nothing            |
| 4   | Tallow              | Yellowish brass              | Hard enough       | Slow, but durable foam   | Good                | Nothing            |
| 5   | Peanut oil          | Yellowish brass              | Rather soft       | Fast, somewhat foamy    | Good                | Nothing            |

In this study, it was observed the appearance of soap from a mixture of used cooking oil that had been purified with activated charcoal and NaOH with 3 different concentrations and the addition of coffee as a coloring and deodorizing agent. The following are the results of the appearance of soap with a concentration of NaOH 10%, 30%, and 50% after settling for 2 weeks.

Table 2. Differences in the appearance of soap after settling for 2 weeks.

| NaOH concentration | 10% NaOH | 30% NaOH | 50% NaOH |
|--------------------|----------|----------|----------|
| Soap density       | Liquid   | Soft     | Very hard|
| Color              | Black    | Black    | Pale white|
There is an influence of NaOH concentration on soap density. According to Dalimunthe, the use of 50% NaOH in the manufacture of solid soap from used cooking oil [19].

NaOH is one type of alkali. Alkaline compounds are dissolved salts of alkali metals such as potassium and sodium. Alkali is used as a chemical that is alkaline and will react and neutralize acids. The physicochemical characteristic of soap which includes moisture content, total fat matter (TFM), pH, free caustic alkalinity depends largely on several factors such as the strength and purity of alkali, the type of oil used, degree of saponification, a constituent of the oil and many others [20,21]. NaOH is widely used in the manufacture of solid soap because it is not soluble in water [22].

The use of the amount of NaOH that is lacking in the saponification reaction will cause the formation of residues / residual fatty acids (oil) after the reaction. This will cause the soap to appear slippery, softer, and moisturized. Conversely, the use of excessive amounts of NaOH in the saponification reaction results in the absence of residues / fatty acids (oils) after the reaction. This causes the soap to be hard. Free fatty acids in the soap can interfere with the emulsion of soap and impurities when soap is used [23].

NaOH concentration affects the quality of the soap made because it can affect the pH of the soap, free fatty acids, free alcalins, levels of non-soapy fractions, soap fatty acids, and water content. High or low concentration of NaOH will affect the perfection of the saponification process in soap so that it will indirectly also affect the quality of the soap produced. The use of soap with high pH value causes an increase in skin pH, which increases dehydration, irritation, and destruction of the bacterial flora [24].

Refer to table 1. The color of the soap that matches the crystalline is 50% NaOH concentration, which is yellowish-white. That is because at the concentration of NaOH 10% and 30%, the use of excess oil or fat so that the effect on the soap becomes turbid and vice versa. The chemical nature of the lipophilic part of soap plays the largest role in determining the performance of finished soap [25].

4. Conclusion
The results obtained indicate that the most optimal NaOH concentration is 50% because it has a dense soap consistency. While the 30% NaOH concentration has a semi-solid soap consistency. At a concentration of 10%, NaOH has a consistency of soap that is still runny. It can be concluded that the concentration of NaOH affects the quality of the soap.

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