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The decision of soap formula selection using analytical hierarchy process

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ABSTRACT

Waste cooking oil is one of household waste. Waste cooking oil is usually disposed to the sewers or gardens. Utilization of waste cooking oil is by recycling it into a solid soap product. The production of solid soap from waste cooking oil is a solution to reduce waste. There are various formulas for making soap products from waste cooking oil. In order to utilize waste cooking oil becomes maximal dan useful, it is necessary to select the best formula for further development. The research begins by identifying the soap formula with a simple process. The identification results obtained six soap formulas that can be produced on a household scale. The six soap formulas were then produced and tested according to Indonesia's national standards (SNI). The method used to select the best formula was Analytical Hierarchy Process (AHP), which involved four partisipants as experts. The result of the decision of the best soap formula is Soap 6. Meanwhile, the three priority attributes for decision-making are soap standard (SNI), cleaning power, and the ability to hold bacteria.

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1. INTRODUCTION

Indonesia is a rich country with many ethnic groups, so there are also many variations on the culinary menu. Most variations of the cooking menu involve the frying process, so they require a lot of cooking oil [1]. That is why cooking oil is the primary need of Indonesian people. Based Food Consumption Bulletin [2] per capita cooking oil consumption per year is 0.8 kg. Yogyakarta has a population of 3,882,288 people in 2021 [3] requires 3,105 tons of cooking oil and will produce 621.2 tonnes of used cooking oil. This is a significant condition for Yogyakarta, whose area reaches 3,186 km^2.

People (households) still often throw used cooking oil into the drain or the yard. This fact was reported in several reports [4]. This behavior will impact the quality of clean water and the environment. An unpleasant odor is produced due to the decomposition of used cooking oil into other chemical compounds. The decay process can increase the oxygen levels absorbed by microorganisms, thereby reducing clean water quality. Used cooking oil, which is not easily decomposed, can also cover plant biota from sunlight, disrupting plant growth [5].

One effort that can be made to overcome environmental pollution caused by used cooking oil is to produce solid soap. This effort has been carried out in almost all regions of Indonesia, such as in Lampung [6] and [7], Pekanbaru [8], Pontianak [9], Tegal [10], Mataram [11], Surakarta [1], Palembang [12], Ambon [13], and Banjarbaru [14]. The large number of implementations of processing used cooking oil into laundry soap that has been carried out in several cities shows that this processing is much more feasible and can be done with equipment on a household scale. This will also help the household economy by reducing expenses for buying washing soap. It can even be sold to significantly reduce used cooking oil waste and ultimately protect the environment.

Researchers provide varying formulas. Several researchers [15]–[22] completed the organoleptic assessment of the samples produced. The organoleptic attributes used by each researcher also vary. Organoleptic assessment is critical because efforts to produce used cooking oil to make soap can also have economic value. Therefore, ensuring that the soap produced meets user expectations needs to be done. Apart from that, it would help to ensure the product is safe. Several researchers mostly use the 2016 SNI standards [15]–[21] to show the soap is safe for human use.

This article describes the process of selecting several formulas that have the potential to be implemented to reduce environmental impacts and provide added economic value to society. The criteria for soap are that it is safe (according to standards - technical aspects) and that users like it. Technical aspects based on SNI 3532-2016 concerning solid soap [23]. Meanwhile, user preferences are carried out by considering several organoleptic attributes. Meanwhile, the number of recipes or formulas to be decided is six. According to Apip [24], when deciding with many criteria and many alternative decisions can be approached using the Analysis Hierarchy Process (AHP). The application of AHP is broad, such as determining supplier selection [25], vendor assessment [26], choosing water traffic protection [27], choosing a house to live in [28], even for determining the position of attackers in football teams [29].

2. MATERIALS AND METHODS

The object of this research is the formula for making used cooking oil soap in solid form. The used cooking oil soap formula that will be tested can be produced on a household scale. In this article, we will evaluate six solid soap formulas. Soap production from the six formulas is carried out in a chemical laboratory. The materials needed for the experiment are adjusted to the needs of each formula that is the object of research. Each soap formula has its ingredient composition levels.

The research was carried out in four stages. The first stage is to identify formulas that have the potential to be applied in households. The second stage, the soap-making process, uses six formulas. The third stage is the testing process according to SNI soap and antibacterial. Antibacterial testing was carried out to determine the effectiveness of the soap in fighting staphylococcus aureus and escherichia coli bacteria. The fourth stage is the process of selecting the best formula. This fourth stage involved four expert respondents who understand the soap-making process.

The fourth stage begins with developing a hierarchical structure of decisions to be assessed, assessing the attributes/parameters to arrive at an alternative formula for each participant, and then validating with a consistency ratio of less than 0.1.

3. RESULTS

The results of the soap identification stage obtained six formulas from six researchers [30], [31], [32], [33], [22] and [34]. These six soaps are called Soap 1, Soap 2, Soap 3, Soap 4, Soap 5, and Soap 6. Each formula uses different ingredients, but the process is almost the same and easy.

3.1 Material and tools

The ingredients used to make soap are used cooking oil, NaOH, water, activated carbon, lemongrass extract, perfume, dyes, stearic acid, citric acid, NaCl, castor oil, olive oil, and sucrose. Meanwhile, the tools used are a magnetic stirrer hot plate, beaker, thermometer, digital scale, measuring cup, dropper pipette, silicone mold, mixer, glass funnel, and filter paper. The materials used for testing are pH indicator paper, pp indicator, and HCl.

3.2 Soap production

Making soap from used cooking oil is carried out in the laboratory, where each formula is made from 100 grams of used cooking oil in the same mold size.

The production results of the six soap formulations can be seen in Figure 1. Each formula contains natural (lemongrass) and artificial (rose and apple) ingredients. This fragrance aims to ensure that the smell of used cooking oil is manageable. The next stage is the SNI standard test of soap samples from each formula. The average amount of soap from 100 grams of used cooking oil is 12-14 units. The amount of soap varies because the density of the mixture for each formula is different.

Figure 1. Soap Samples

3.3 Soap Quality Standar Test

To ensure this soap is safe for consumers, each sample must be tested to meet specified quality requirements. The test uses the test method in SNI 3532-2016 concerning solid soap. The quality requirements are water content, free alkali or free fatty acids, pH level, and foam stability. All tests are carried out in the laboratory. The results of each quality requirements test are listed in **Table 1**. The results of the decision to meet the quality requirements or not can be seen in **Table 2**.

Table 1. SNI Test Result

Soap	% Water rate	% Alkali free	pH	% Foam stability	Anti-Bacterial Test
1	4%	4.43	13	80%	0.74
2	4%	0.98	12	90%	0.96
3	5%	0.06	9	87%	0.96
4	2%	0.56	9	87%	0.82
5	2%	5.00	13	84%	1.27
6	4%	0.24	10	85%	0.74

Table 2. Summary of Laboratory Test Result

Soap	Water rate test	Free alkali test	pH test	Foam stability test
1	standard	no	no	no
2	standard	standard	no	standard
3	standard	standard	standard	no
4	standard	standard	standard	standard
5	standard	no	no	standard
6	standard	standard	standard	standard

3.3.1 Water rate test

The principle of testing the water content of solid bath soap preparations is to measure the weight after drying for a certain time. Based on SNI 3532-2016, the water content in solid soap preparations is a maximum of 15%. Testing the water content of solid bath soap needs to be done because the air content will affect the quality of the soap. The amount of water content can affect the solubility of soap in water when used. If the air content in the soap is too high, it will cause the soap to shrink easily and be uncomfortable when used. Based on the water content data in Table 1, it can be stated that all formulas produce water content that follows the SNI standard for solid soap.

3.3.2 Free Alkali Test (NaOH)

Free alkali is the alkali in soap that is not bound as a compound. Excess-free alkali that does not meet standards can cause skin irritation. The addition of excess alkali in the soap production process can cause excess alkali. The maximum free alkali content in soap is 0.1%. Based on the observations made on used cooking oil solid soap, the free alkali value for each soap can be seen in Table 1.

Based on the free alkali values in Table 1, it can be seen that Soap 2, Soap 3, Soap 4, and Soap 6 have an alkaline value according to the SNI standard for soap, namely less then1%. Soap 2, Soap 3, Soap 4, and Soap 6 are safe or do not cause irritation.

3.3.3 Foam Height Test (castor oil)

The aim of measuring the height of the foam is to see how much foam is produced. Soap with excessive foam can cause skin irritation. The requirements for foam height according to SNI according to the requirements for the height of solid soap foam are 1.3 - 22 cm [33]. Based on the measurements that have been carried out, it can be seen that only Soap 1 and Soap 3 have a foam height that does not meet the standards for soap foam height.

The results of the four standard solid soap tests can be seen in Table 2. Participants also used these results to assess the best formula for the attributes.

3.3.4 Anti-Bacterial Test

The anti-bacterial test was carried out using staphylococcus aureus and escherichia coli bacteria. This soap is said to resist staphylococcus aureus bacteria when the value is more than 7-8 and is said to resist escherichia coli bacteria when the value is more than 6-7.

Tests for the formulas for the six soaps could not resist these two bacteria. However, of the six soap formulas, Soap 6 has the highest resistance among the other soap formulas.

3.3.5 Organoleptic Tests and Formula Selection

The fourth stage begins by determining the attributes expected by the user. The fourth stage is the stage of selecting the best soap formula. Determination of criteria or attributes apart from being based on references is also obtained through the distribution of open numbers. The attributes used are color, aroma, shape, texture, and cleaning power. The seven attributes are then included in the decision hierarchy structure, which can be seen in Figure 2.

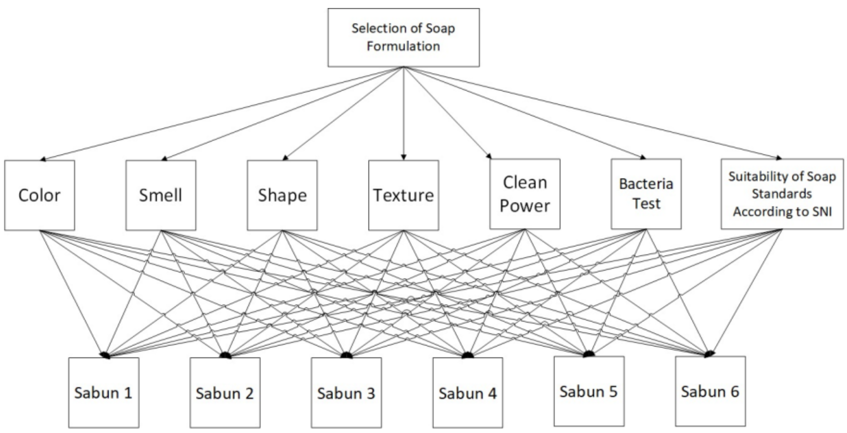


Figure 2. Hierarchical structure

4. DISCUSSION

Organoleptic tests are carried out to measure the level of liking or hedonics for solid soap from used cooking oil that has been made and taking into account the results of bacterial tests and soap standards. This research used four expert participants. Participants were asked to rate five favorite attributes: color, aroma, shape, texture, and cleaning power, as well as bacterial test attributes and soap standards in **Table 2**. Each participant will receive six samples and Table 2 to compare based on seven attributes.

Assessment and processing of organoleptic tests using expert choice 11.0. Each expert participant was asked to provide an assessment of six samples as well as data on bacterial test results and standard soap test results at different times. Data from the four participants was then processed in expert choice software.

This software is very helpful in processing assessment results. The weakness of assessment with many attributes is the inconsistent grouping of each object and the time each expert provides the assessment. This is done to ensure the inconsistency of the results by calculating the eigenvalue to give weight to each criterion, then calculating the consistency index and consistency ratio. The processing results can be analyzed if the CR value is less than 0.01.

Figure 3. Expert Choice Hierarchy Structure

Figure 3 is a display of the expert choice hierarchy. Each participant will first determine the weight value for each attribute, as shown in Figure 4. where one participant weighs the shape and texture attributes. The results of one participant's eigenvector values for the weights on the seven attributes can be seen in Figure 5, where the three priority weights of the participant are SNI standards, clean power, and ability to resist bacteria. This assessment has an inconsistent value of 0.06, meaning that participants assess it consistently. Next, participants weighted the soap formula (Figure 6 and Figure 7). This participant's assessment shows that the three priority weights for the soap formula are Soap 5, Soap 6, and Soap 2.

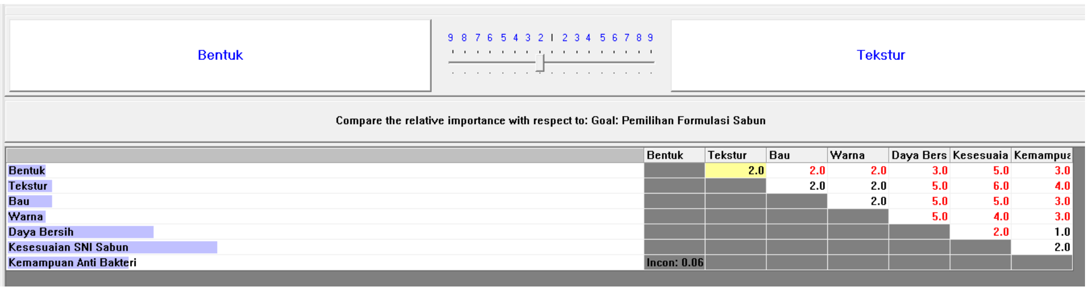


Figure 4. Determination of weight values for shape and texture attributes

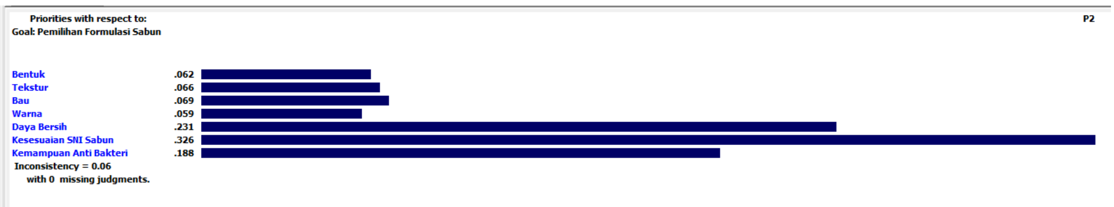


Figure 5. Vector eigenvalues and inconsistency between attributes from one participant

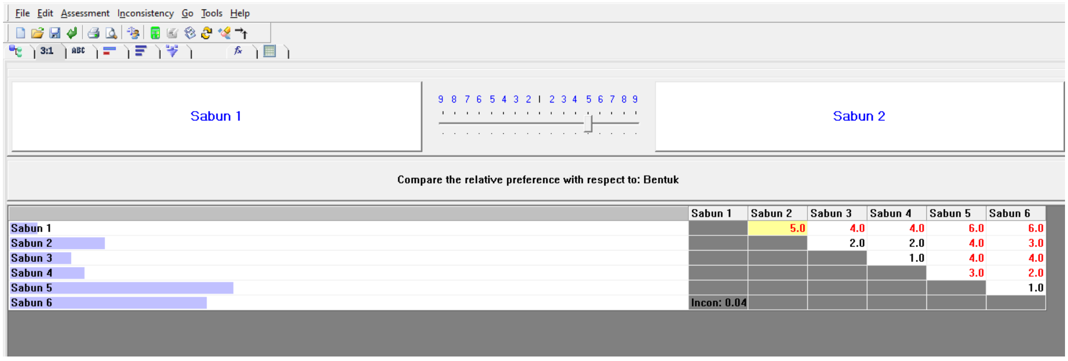


Figure 6. Determination of weight for each soap formula by one participant

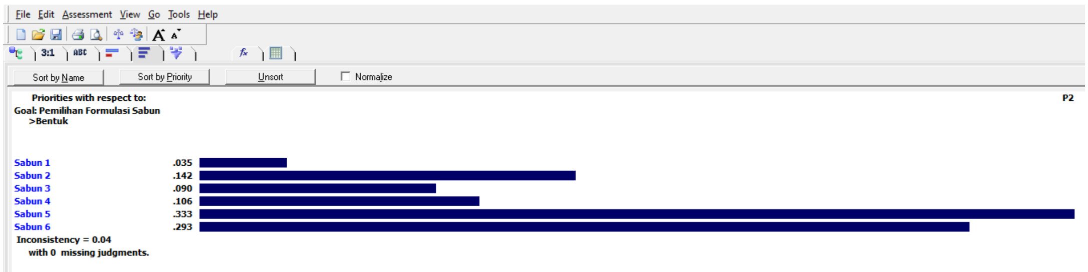


Figure 7. Vector eigenvalues and inconsistencies between soap formulas from one participant

Based on Figure 8, we can see the sequence of soaps that were selected based on the parameters set for one of the participants who had an inconsistency value < 0.1 so that this participant could become a candidate for inclusion. The order of soap selected is based on its shape starting from the highest to the lowest, namely soap formulations 5, 6, 3, 2, 4 and 1, based on texture, namely soap formulations 6, 5, 4, 3, 1 and 2, then based on aroma or odor namely soap formulations 6, 4, 3, 5, 2 and 1, based on color namely soap formulations 3, 2, 4, 6, 1 and 5, based on clean power namely soap formulations 3, 2, 4, 5, 6 and 1, based on SNI conformity, namely soap formulations 3, 6, 4, 2, 5 and 1. Then based on the ability to resist bacteria, namely soap formulations 5, 6, 1, 2, 3 and 4.

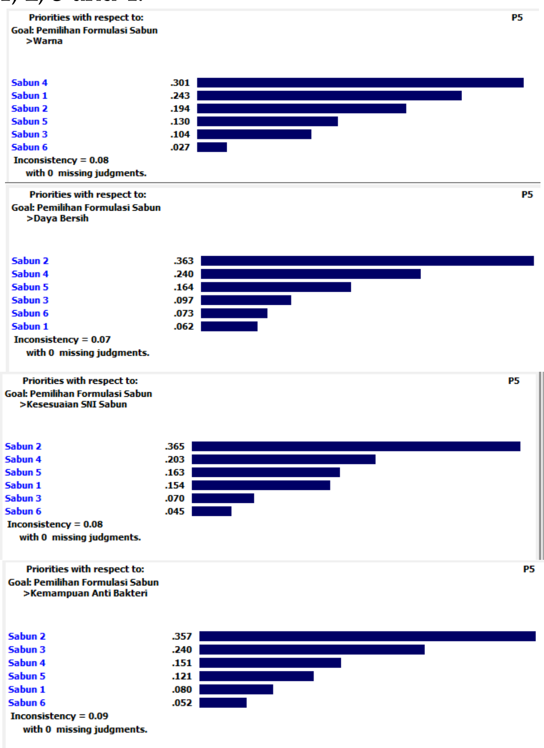


Figure 8. Graph of Priority Selection of Soap Formulation for Each Attribute from one of the participants

The differences in order or value for the four participants are caused by several factors that cannot be controlled. For example, people's opinions differ, and soap conditions can change due to unintentional treatment by participants and the participants' background knowledge. The global priority order for selecting soap formulations for the four participants can be seen in the Figure 9.

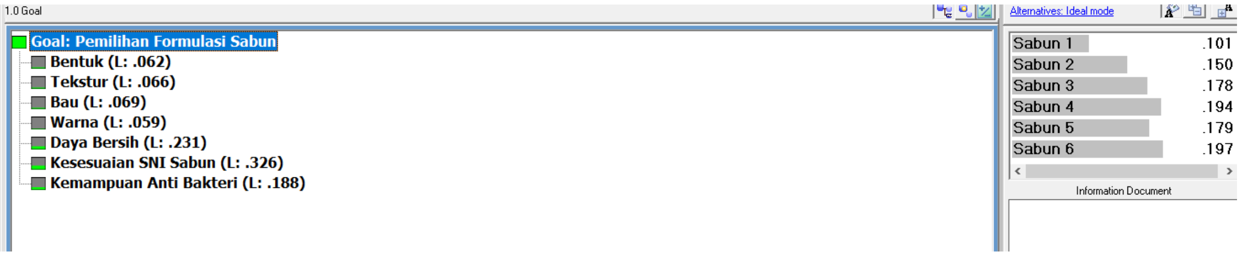
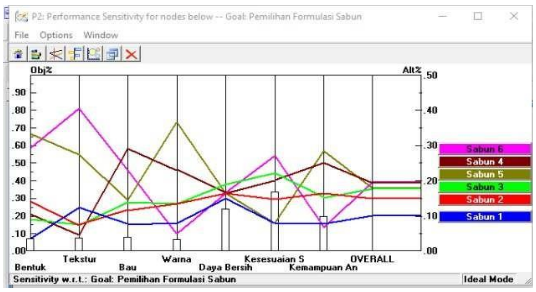
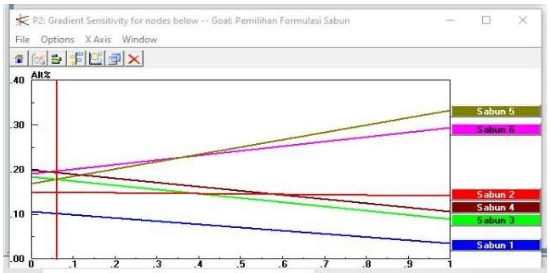


Figure 9. Graph of Priority Selection of Soap Formulation for Each Attribute from one of the participants

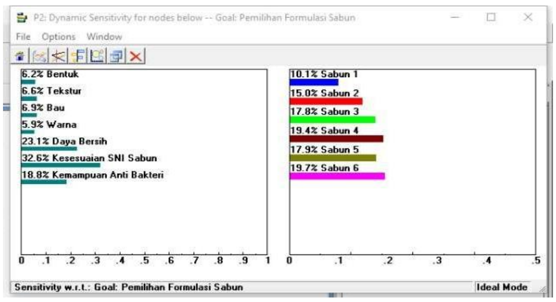
Participant 1 indicated that soap formulation 6 was the best formulation. In contrast, Participant 2 indicated that soap formulation 1 was the best. Participant 3 indicated that soap formulation 6 was the best formulation, and Participant 4 indicated that soap formulation 4 was the best formulation. Based on the global priority of soap formulations, it can be concluded that soap formulation six can be said to be the best formulation, judging from the results of the global priority of soap formulation 6, it is the soap formulation chosen by two participants out of four participants. The best decision-making is not taken from the highest average value of all the attributes given, but rather the priority assessment of the combination of all parameters assessed as a whole.



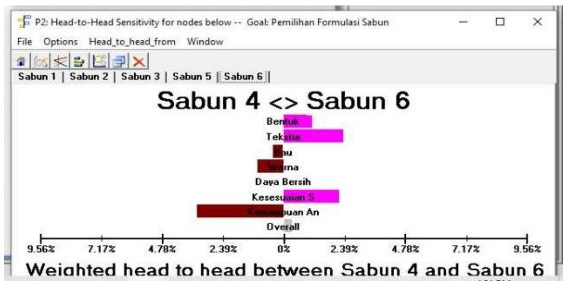
(a) Performance Sensitivity



(b) Gradient Sensitivity



(c) Dynamic Sensitivity



(d) Head-to-Head Sensitivity

Figure 10. Sensitivity Analysis of Selection of Six Soap Formulations based on Calculation from Expert Choice: (a) Performance Sensitivity; (b) Gradient Sensitivity; (c) Dynamic Sensitivity; (d) Head-to-Head Sensitivity

5. CONCLUSION

The decision on the best soap formula, according to the four expert participants, respectively, was Soap 6, Soap 4, Soap 5, Soap 3, Soap 2 and Soap 1. Decision-making with the help of expert choice was beneficial because the assessment process was faster.

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