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Development of Soap Formulation from Agarwood and Waste Oil using Taguchi Method

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DECLARATION

I declare that this thesis entitled "title of the thesis" is the results of my own research except as cited in the references.

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ABSTRAK

Kajian ini menyelami isu-isu kritikal berkaitan penggunaan sabun, dengan tumpuan pada menangani cabaran yang berkaitan dengan kesihatan kulit, kelestarian alam sekitar, dan kesejahteraan individu. Selain itu, pengeluaran dan pelupusan sabun boleh menyumbang kepada masalah alam sekitar termasuk penebangan hutan dan pencemaran air. Kemunculan patogen menekankan kepentingan formulasi sabun yang efektif. Selain itu, meneroka manfaat kewangan dan peribadi pembuatan sabun mendedahkan cabaran potensial akibat kos yang berubah-ubah. Untuk mengatasi kebimbangan ini, kajian menggunakan kaedah reka bentuk eksperimen Taguchi (DOE) untuk mengoptimumkan formulasi sabun. Ini melibatkan analisis komprehensif terhadap sifat mekanikal seperti pH, kandungan kelembapan, pembuatan buih, dan ciri antimikrob, bersama dengan pemeriksaan kos pengeluaran. Kepuasan pengguna dinilai melalui soal selidik Ujian Hedonik. Proses pembangunan sabun termasuk merumus sabun dengan esen gaharu dan serbuk gergaji, melakukan ujian untuk ketahanan kelembapan, pH, pembuatan buih, dan mengaplikasikan Kaedah Taguchi untuk pengoptimuman. Aktiviti antibakteria dinilai melalui ujian pertumbuhan mikrob, dan kepuasan pengguna dinilai melalui Ujian Hedonik. Pendekatan sistematis ini bertujuan untuk meningkatkan formulasi sabun dengan mempertimbangkan aspek teknikal dan preferensi pengguna, mempromosikan peningkatan kualiti dan penerimaan. Hasil yang diperolehi dari kajian ini merangkumi pelbagai analisis. Kajian ini menggunakan analisis pelbagai untuk penilaian sabun. Penilaian Hedonik menilai preferensi pengguna berdasarkan aspek sensorinya. Analisis psikokimia meneroka bagaimana sifat kimia mempengaruhi tekstur dan keberkesanan sabun. Analisis buih dan pH menilai kualiti pembuatan buih dan keselamatan kulit, masing-masing. Analisis mikrob mengesahkan potensi antibakteria. Analisis kos memastikan kemampuan, sementara analisis kandungan kelembapan memberi kesan kepada tekstur dan jangka hayat. Analisis Taguchi mengoptimumkan formula, dan analisis regresi menjelaskan kesan faktor terhadap kualiti. Analisis gabungan ini bertujuan untuk mengembangkan sabun yang menyenangkan, berkesan, dan berpatutan. Hasil menyeluruh ini menyumbang kepada pemahaman holistik tentang sifat sensori, kimia, fungsional, dan ekonomi sabun. Seterusnya, mereka memudahkan keputusan yang

tepat untuk peningkatan lanjut, akhirnya mempromosikan kesejahteraan pengguna dan alam sekitar secara keseluruhan.

Kata Kunci: Kaedah Taguchi, ujian hedonik, analisis sifat, regresi, analisis kos

ABSTRACT

This research delves into the critical issues surrounding soap usage, with a focus on addressing challenges related to skin health, environmental sustainability, and individual well-being. Furthermore, the production and disposal of soap can contribute to environmental problems, including deforestation and water contamination. The emergence of pathogens underscores the importance of effective soap formulations. Additionally, exploring the financial and personal benefits of soap-making reveals potential challenges due to variable costs. To address these concerns, the study employs the Taguchi design of experiment (DOE) method to optimize soap formulation. This involves a comprehensive analysis of mechanical properties such as pH, moisture content, foaming, and antimicrobial features, along with an examination of production costs. User satisfaction is assessed through a Hedonic Test questionnaire. The soap development process includes formulating soap with agarwood essence and sawdust, conducting tests for moisture resistance, pH, foaming, and applying the Taguchi Method for optimization. Antibacterial activity is evaluated through microbial growth tests, and user satisfaction is assessed through the Hedonic Test. This systematic approach aims to enhance soap formulation by considering both technical aspects and user preferences, promoting improved quality and acceptance. The results obtained from this research encompass a broad spectrum of analyses. This study uses diverse analyses for soap evaluation. Hedonic evaluations gauge user preferences on its sensory aspects. Psychochemical analysis explores how chemical properties affect soap's texture and efficiency. Foam and pH analyses assess lathering quality and skin safety, respectively. Microbial analysis confirms antibacterial potency. Cost analysis ensures affordability, while moisture analysis impacts texture and shelf-life. Taguchi analysis optimizes the formula, and regression analysis elucidates factor effects on quality. These combined analyses aim to develop a soap that's enjoyable, effective, and cost-effective. These thorough results contribute to a holistic understanding of the soap's sensory, chemical, functional, and economic attributes. In turn, they facilitate informed decisions for further improvements, ultimately promoting the overall well-being of users and the environment.

Keywords: Taguchi method, hedonic test, properties analysis, regression, cost analysis

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Ancient civilizations employed a variety of components, including animal fat, plant oils, and ash, to make cleaning agents, including soap. A mixture of ash and oil was used to clean wool in ancient Babylon about 2800 BC, and this is the oldest known instance of soap manufacture (Jafar, 2021). With the introduction of new components and production techniques, soap's composition and formulation changed over time. New kinds of soap were created in the 19th century as a result of chemistry advancements and the discovery of new raw ingredients like palm and coconut oils.

If not handled appropriately, waste oil can have a huge negative influence on the environment. One of them is land contamination. Remaining oil can cause the soil to become less healthy and inappropriate for plant growth when it seeps into the ground (Gavrilescu, 2021). Waste oil contains toxic substances including heavy metals and polycyclic aromatic hydrocarbons (PAHs), which can linger in the soil for a very long time and endanger the stability of the environment. Next, waste oil that gets into rivers, lakes, or oceans can contaminate the water (Zhang et al., 2022). Oil builds up as a coating on the water's surface, obstructing sunlight and lowering oxygen exchange, both of which are bad for aquatic life. Lastly, air pollution. When waste oil is burned improperly, dangerous particles are released into the atmosphere, which adds to air pollution. Burning waste oil has been shown to release harmful chemicals that have been linked to respiratory issues, smog production, and climate change (Rajmohan et al., 2019). These emissions include sulphur dioxide, nitrogen oxides, and volatile organic compounds (VOCs).

Today, soap is used for many different things, including cleaning the house, maintaining personal cleanliness, and even industrial uses. In order to attain desired features like lather, scent, and moisturising benefits, different components and additions are employed in soap depending on the intended application. The effectiveness of soap in removing dirt and germs, as well as its effects on the environment and the health of the skin, have all been the subject of research. According to studies, using soap to wash your hands properly might greatly slow the spread of contagious diseases (Wu, 2020). Additionally, using some soaps, such as those containing harsh chemicals, can be harmful to the environment and the health of your skin. New, sustainable soap formulas that balance effectiveness, safety, and environmental impact are the subject of ongoing study.

Aquilaria's tree species produce agarwood, also known as oud, aloeswood, or agarwood, which is a rare and extremely precious resinous wood. Wood is used to make incense, traditional remedies, ornamental carvings, and other items because of its distinctive aroma, which is highly prized in the perfume industry (Adhikari et al., 2021). A form of fungus infection or human intervention, such as drilling or putting metal rods into the trunk, can cause trees to produce agarwood. As a result, the centre of the tree begins to generate resin deposits that eventually turn into agarwood.

The creation of soap from waste cooking oil can help to support environmental sustainability, increase economic effectiveness, and produce social advantages. The ecology and the industry both benefit from this.

In this study, the Taguchi method was used to visualize the result of optimized the soap from agarwood formulation. The Taguchi method is also known as Taguchi robust design or Taguchi parameter design (Freddi et al., 2019). By methodically detecting and minimizing the effects of variation on the result, it seeks to enhance the quality and performance of products and processes. Several industries, including manufacturing, engineering, and product development, frequently use the Taguchi approach. System design, parameter design, and tolerance design are its three primary principles. The "quality loss function," which calculates the cost or loss resulting from departure from the desired target value, is a key concept in the Taguchi technique. Engineers can produce strong designs that are less impacted by variation by minimizing the quality loss function, which boosts customer satisfaction and lowers costs. Overall, the Taguchi technique offers a structured, methodical strategy for optimizing product and process designs, taking into consideration both controllable and uncontrollable aspects (TUR, 2023). It is especially helpful when there is system noise or inherent variability.

1.2 Problem Statement

Depending on the precise environment and research topic, the issue statement for soap may change. However, some possible soap-related problem statements which have unfavorable effects on skin health: Some soaps can dry out the skin by removing its natural oils, which can cause irritation, dryness, and other skin issues (Mijaljica et al., 2022). Next, Environmental concern. The manufacture and disposal of some soaps can have detrimental effects on the environment, including deforestation and water contamination. Lastly, effectiveness against emerging pathogens. With the rise of novel infectious diseases and antibiotic-resistant bacteria, it is critical to assess how well various types of soaps work to stop the spread of these infections. The demand for soaps made from agarwood is rising in an effort to alleviate this issue for the human body. Agarwood soap has the benefit of being created from abundant and renewable natural resources, which can lower production costs (Syazwan et al., 2019). This study will use waste cooking oil. Waste cooking oil is mostly used because, although produced on a small scale, it is easy to obtain. The use of soap made from agarwood is safer and more effective when added to agarwood.

Significant environmental issues like sewer and drain blockages, as well as water and soil pollution, can be brought on by using cooking oil. Waste cooking oil can be catalytically cracked to produce hydrogen gas because it has a high ratio of hydrogen atoms to carbon and oxygen atoms. Transesterification has historically been used to create waste cooking oil-based biodiesel, which is intended to replace petroleum-based diesel, which has non-degradable and non-renewable qualities. Therefore, due to its appealing psychochemical qualities and economic viability, the potential of hazardous waste cooking oil as a green alternative energy source for electricity generation, hydrogen gas as well as the manufacturing of biofuels (e.g., biodiesel, biogas, and bio jet fuel) is critically discussed.

One of the simplest actions can do to live frugally and give our family a more natural and healthier atmosphere is to make your own soap at home. the three advantages of producing your own soap. Let's start by discussing the unfavourable components of commercially made soap. Next, talk about the best components for making our own soap. Third, we'll examine the financial savings and personal fulfilment of producing one's own goods, such as soap. The process of creating bar soap can be expensive dependent on a number of variables, such as the volume of manufacturing and the components utilised, which include distilled water, sodium hydroxide, waste coconut oil, waste palm oil, essence, and agarwood dust. The Taguchi approach can reduce material and testing costs more than the typical factorial method because conducting tests requires the utilisation of resources and materials. The Taguchi method's capacity to provide significant outcomes with fewer trial runs translates into lower expenses for testing and materials. This is especially helpful for businesses where resources could be expensive or hard to get it.

1.3 Objectives

Three main objectives in this study as following:

1. To design the formulation of bar soap with addition of agarwood using the Taguchi design of experiment (DOE) method.

2. To analyze the mechanical properties such pH, moisture content, foaming and antimicrobial and cost.

3. To study the user satisfaction toward the developed product using a Hedonic Test questionnaire.

1.4 Scope of Study

Normally, waste oil is disposed of by running it through the washbasin, drainage system and sewage system. Pollution from used cooking oil happens when it interacts with plants and animals. Cooking oil waste has a detrimental effect on the environment, especially aquatic life (Chirani et al., 2021). Water supplies, soil structures, and drainage systems are all polluted. Consequently, a large amount of leftover or spent cooking oil can be converted into something useful (Foo et al., 2022). For instance, from November 2020, the people of Belo Horizonte, Brazil, have been making scented soap bars from used cooking oil for cleaning and disinfecting (Noronha, 2022). Since no waste products are created during this process, manufacturing soap from used cooking oil is both environmentally and economically sustainable. The saponification process uses little energy, and the soap itself is biodegradable (Félix et al., 2017).

Agarwood (Aquilaria crassna) (ACW) waste is a common by-product of the manufacture of agarwood essential oil.(Mahathaninwong et al., 2021). Against all of the studied microbial strains, the essential oil showed no anti-microbial action. According to the study, agarwood essential oil may soon be utilized in the development of antioxidants, anti-diabetic, skin-whitening, and anti-inflammatory medications. Essential oils are widely used in a variety of items today, including air fresheners, cosmetics, fragrance, household cleaning products, and pharmaceutical formulations (Osimani et al., 2022).

One of the best experimental approaches for determining the bare minimum of experiments to run within the permitted range of variables and levels is the Taguchi technique. The research demonstrated the Taguchi method as a valid technique for identifying the ideal manufacturing parameters for the enhanced attributes.

This study explains how to make soap from agarwood. The use of waste cooking oil will be varied in order to compare the mixture in the end result. Finally, this study investigates soap properties using moisture content, foam, antimicrobial, pH. In the sample, the Taguchi method is used to determine the relationship between the amount of agarwood used, the waste cooking oil used, NaOH and water used in the study.

1.5 Significances of Study

As an alternative to fossil fuels, bioproducts. Bioproducts used in the production of biomass can either supplement or replace components derived from fossil fuels. In essence, they offer an alternative to reliance on fossil fuels, which can result in negative environmental effects. And in order to achieve our Sustainable Development Goals, we must promote a decrease in this dependence by establishing a viable bio-based economy that creates alternative renewable end products. For example, in the environment, bioproducts use biomass resources to make products, making them an enhanced version of traditional goods. biodegradable, biocompatible, and environmentally responsible potential products. Bioproducts lower the number of hazardous emissions and waste by utilising sustainable and renewable biomass resources. The United States may shift away from finite fossil fuel resources and achieve more efficient production of bio-based products by reducing energy usage throughout the supply chain.

Eco-friendly products have a decreased environmental impact across their whole life cycle, from the raw materials used in their production through their design, transportation to the end user, usage period, and recycling ability.

Pollution of the earth and water can come from improper handling of used cooking oil from the catering business. Soap is created by reusing leftover frying oil. This will conserve resources and cut down on the expense of waste treatment and disposal. The utilization of leftover cooking oil as a raw source makes the soap-making process environmentally beneficial. Used cooking oil can be converted into liquid soap to clean floors and wash dishes.

The amount of waste cooking oil used in the experiment will be determined using the Taguchi approach, and agarwood soap will also be manufactured using different waste cooking oils which are palm oil, coconut oil and canola oil. The characteristics and structure of the soap can be determined by the Taguchi methods to discover the optimal composition. Additionally, the amount of waste cooking oil used in the experiment will be determined using the Taguchi approach, and gaharu soap will also be produced using different waste cooking oils, namely palm oil, coconut oil and canola oil. The characteristics and structure of the soap can be determined by the Taguchi method to find the optimal composition. In addition, the soap will be checked through psychochemical sensory. At the end of this study, the material selected according to the options chosen by the volunteers.

CHAPTER 2

LITERATURE REVIEW

2.1 Bio-product development

There is widespread worry that the earth's atmosphere will eventually change due to rising levels of carbon dioxide and other greenhouse gases. It is natural to wonder if there are ways to power the global economy that might have less of an impact on the environment because they emit less carbon dioxide, given the significant role that fossil fuels play in the economies and lifestyles of people throughout the world. The bio development of biowaste as a substitute and sustainable energy source may be one method to handle this delicate situation. Popular methods for dealing with biowaste include incineration and landfilling, however both have detrimental environmental implications, including the usage of priceless land and the creation of hazardous gases. The structural elements of cells, cellulose and hemicellulose, make biowaste particularly amenable to the generation of bioproducts, and biowaste presents a chance for biotechnology to help preserve environmental quality (Ochieng et al., 2022).

The market for bio products is expanding, and more businesses are choosing organic goods for a variety of factors. According to common consensus, the level of pollution and the pressure-level working circumstances are getting worse and worse for the state of people's health, so they still have the most to maintain. Utilizing environmentally friendly items and the public's belief that doing so will enhance health status will lessen negative consequences. With all of this in mind, we might ask whether those who opt to consume organic products have done their research and are aware of the positive scientific consequences on which they have or are depending. The goal is to ascertain the factors that influence people's decisions to consume particular foods, and objectives are identified to identify the source of the information used to make those decisions, the allocation of funds used to purchase environmentally friendly goods, and the benefits that users have come to appreciate. It served as one of the questionnaire study methods in a quantitative study that was undertaken. The majority of individuals pick bio goods because they believe they are the most advantageous to the processed product (Chivu, 2019).

Bioproducts, commonly referred to as bio-based products, come from biological resources that are renewable, such as plants, animals, and microbes. Compared to more conventional petroleum-based or synthetic alternatives, these goods have a number of advantages. The following are some of the key benefits of using bio products such as renewable resources and biodegradable materials, economic opportunities, improved health and safety, decreased reliance on petrochemicals, versatility and performance (Asgher et al., 2020).

2.2 Bio-soap development history

In the contemporary era, there has been a considerable increase in the diversity of specialised companies in the food industry as well as a massive development in the production of diverse materials. Any kitchen now relies heavily on cooking oil, so the waste that results from using too much of it is a major issue space opening up so that more space can be used for planting palm oil is one of the key reasons why greenhouse gases have increased in the nation. This necessitates the creation of new procedures in this nation that will lower CO2 emissions using what is known as "life cycle assessment." In actuality, the most effective initiatives gathered and converted leftover cooking oil into bio diesel oil. Waste oil can be recycled and reused in a number of ways, but regeneration is the most efficient. This means that we will produce biodiesel energy by recycling used cooking oil from restaurants or household garbage. We receive additional components as waste, such as glycerin or glycerol, after converting household cooking oil into biodiesel oil that is suitable for consumption. A productive and efficient technique to reuse glycerol/glycerin is to create new items that are prepared for sale in academic or other marketplaces. Additionally, using recycled cardboard and eco-friendly packaging (Chivu, 2019).

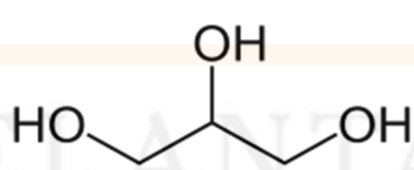

Figure 2.1: Glycerol

(Source: Wikipedia, 2019)

2.2.1 Advantages of bio-soap

Making use of used vegetable oil from the cafeteria's deep fryer to create replacing petroleum-based fuel with biodiesel. It is a waste-to-energy innovation that reduces waste, greenhouse gas emissions, and fossil fuel usage in measurable ways. Glycerin, a byproduct of biodiesel synthesis, starts to build up. A chemistry professor then ordered the glycerin to be added to the soap (Tuchman, 2016).

The oldest product manufactured specifically as a surfactant is unquestionably soap, which is still used extensively today in a variety of forms. In this fiercely competitive market, soap is offered in a wide variety of solid and liquid forms. The goal of this chapter is to outline the many ways that soap has changed over history to become a common item that we most likely take for granted today (Siqueira de Azevedo Sá et al., 2022).

2.2.2 Bio-soap formulation

Penicillium spiculisporum efficiently converts glucose to 4,5-dicarboxy-4-pentadecanolide (spiculisporic acid, S-acid). S-acid sodium salts of three different types were created. Potentiometric titration, infrared spectroscopy, and 13C NMR were used to determine that the monosodium salt of sulfuric acid (S-1Na) mainly consisted of the neutralising product of the carboxylic group attached to the 4-positioned carbon of S-acid, the disodium salt of sulfuric acid (S-2Na) corresponded to the neutralising product of the carboxylic group attached to the 4- and 5-positioned carbons, and the Surface tension and electrical conductance measurements were used to determine how these three types of S-acid salts formed micelles in water. Additionally, the CMC values for S-1Na, S-2Na, and S-3Na were 3.9, 6.1, and 1.7 moles/liter, respectively. S-2Na had the highest foaming property out of the three salts, but all three showed low foaming properties. Additionally, these demonstrated a dispersion effect for hydrophilic pigments as well as acts to buffer and sequester calcium ions. Studying the relationship between S-acid's biological function from the perspective of a biosurfactant will be a future research focus (Ishigami et al., 1983).

Cooking fats and oils undergo hydrolysis, oxidation, and polymerization when heated, which alters their physical characteristics. Remaining fats and oils can be used to create bio-based softeners, such as soaps. The gel formulation makes it easier to dispense and store products, does not leak, and lets you adjust the phase of the gel with shear and heat. Cooked soybean oil and bacon fat were saponified and made into soaps and gels in order to test lipid residues as potential replacements for edible soap source materials. Viscometry and spectroscopy describe how waste items can be categorised based on their material characteristics, which helps us comprehend how fats and cooking oils and their origins affect soap solutions. In this case, the soap mixture made with used lipids creates a shear-thickening mixture as opposed to the soap mixture made with new oil, which creates a shear-thinning mixture. In order to determine if gel formulations made from renewable sources are compatible with soap solutions, infrared and melting point spectroscopy are used to screen the gels for this purpose. There are several soap gel formulations that use gelatin, water, glycerol, and saponified oil or fat (Gambardella et al., 2023).

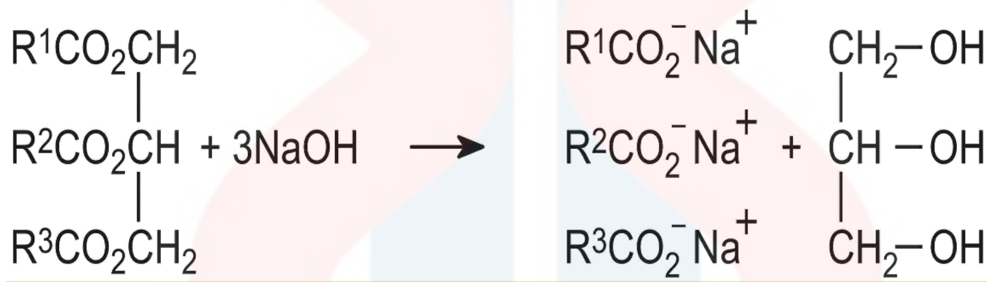

Figure 2.2: Soap formulation

(Source: Anon, 2021)

200 cm^3 of palm oil was measured, melted, combined with 100 cm^3 of 4.5 M sodium hydroxide, and then agitated continuously for 15 minutes at room temperature to create a viscous mixture. After that, ingredients like 1 g of a pink colourant and 10 cm^3 of water are added of colognes. To create the so-called lid soap, the mixture was allowed to solidify for a week (Jimoh 2021) (Muhammed et al., 2022a). A viscous mixture was produced after stirring 100 cm^3 of palm kernel oil (PKO) and 100 cm^3 of 4.1M sodium hydroxide in one direction at room temperature for 15 minutes. additives such as 1g of colourant (light green and dark green, etc.) and 5 cm^3 of fragrances are added next. To make solid soap, the mixture was allowed to set for a week. (Jimoh, 2021)

2.2.3 Bio-soap analysis (texture, aromatic level, pH, moisture)

A variety of triglyceride sources, including local restaurant grill waste and Vietnamese garlic oil, have been saponified to create a variety of unusual soaps. The degree of unsaturation in the initial triglyceride seems to be correlated with the texture of the soap. However, it is possible that blocking impurities could cause textural alterations. In general, saturated fats and oils (like butter) produce hard, thick, waxy soap, whereas unsaturated fats and oils (like olive, maize, peanut, and sunflower oils) produce soap that flakes and crumbles readily. The level of triglyceride unsaturation during the period of the study did not match the colour of the soap. The substantial shift in smell is explained by a change in chemical structure. (i.e., conversion from ester to carboxylate salt) (Phanstiel IV et al., 1998).

The saponification reaction results in soaps, which are sodium or potassium salts of fatty acids. The physicochemical characteristics of soap define its quality, which in turn affects how well and how effectively it cleans. According to established analytical procedures, eight commercial washing soaps were examined for alcohol insoluble matter, moisture content, total fatty matter, free caustic alkalinity, percent chloride, pH, and total alkali. Alcohol's value for insoluble matter ranges from 6.22% to 61.80%, its moisture content is between 10.91% and 22.69%, its total fat content is between 22.64% and 70.51%, its free caustic alkali is between 0.00% and 0.06%, its pH is between 10.63 and 11.71, and its total alkalinity is between 0.00% and 0.99%. This study demonstrated that there was no harmful impact on fabric or skin due to the free caustic alkalinity of all the soap samples examined falling below the KEBS limit, and that the pH values of all the soaps examined were under the KEBS limit (Vivian et al., 2014).

2.3 The usage of agarwood essence

Aromatics made from wood infected with resin and belonging to the genera Aquilaria and Gyrinops have a distinctive and priceless scent. In the trunk of the agarwood tree, resin is produced in reaction to internal injury and/or infection. Many cultures have long prized and employed agarwood-based incense and perfumes for its spiritual, opulent, and aphrodisiac properties. The Chinese were aware of the human-caused production of agarwood (Freund et al., 2021).

The first factor is the physical characteristics of the traded agarwood itself, which can be found in a variety of items ranging from raw chips, blocks, and flakes to finished oils, incense, perfume, accessories, and carvings (Mohamed, 2016).

2.4 Taguchi method

Key ideas in Dr. Taguchi's work include robust product design and parameter design, which are techniques for creating goods that perform well despite changes in unpredictable environmental conditions or that are insensitive to component variation. Engineers in design and manufacturing should be encouraged to use these smart concepts. However, more efficient and straightforward techniques exist for planning experiments and analysing data, two crucial components of the practical application, and these oughts to be used instead of Taguchi's convoluted and illogical procedures. Taguchi's orthogonal array-based experimental design is efficient in that it enables the execution of a small number of tests while capturing the effects of numerous process parameters and their interactions. This method for process optimisation greatly minimises the time, effort, and resources needed for experimenting, making it effective and economical (Bisgaard, 1990).

Genichi Taguchi created the Taguchi methods, which are statistical techniques, to enhance the quality of Applied to marketing and advertising, engineering, biotechnology, and manufactured goods more recently. Experts in statistics have embraced the objectives and advancements made possible by Taguchi methods, particularly his creation of designs for analysing variance. With extremely few resources available after World War II, Japanese industries struggled to survive. Without Taguchi's innovations, the nation might not have survived, let alone flourished as it has. Through cost reductions, Taguchi revolutionised the manufacturing process in Japan. Like many other engineers, he recognised that noise from outside sources affects all production operations. But Taguchi discovered ways to recognise the noise sources that have the most impact on product variability. Successful manufacturers all over the world have adopted his concepts because they produce better production processes at considerably cheaper costs (Karna, 2012).

An experimental approximation to minimising the predicted value of target variance for particular kinds of problems is the Taguchi technique of product design. The Taguchi approach is expanded to include designs with variables that each have a range of values that must all be satisfied (necessity) and designs with variables that each have a range of values that may all be employed (possibility). The Taguchi approach also shows how to tune parameters as part of the design process. By utilising the techniques of constrained optimisation, the method is additionally expanded to address design issues with restrictions. The Taguchi technique, which has a limited definition of an optimal solution, uses a factorial method to search the design space. This is contrasted with other ways of searching the design space and their ideas of what constitutes an ideal response (Otto, 1993).

This article discusses a method for turning operations with various performance characteristics that is based on the Taguchi method and uses grey relational analysis. The turning operations with different performance criteria are solved using a grey relational grade generated from the grey relational analysis. The Taguchi method can then be used to determine the best cutting parameters using the grey relational grade as the performance index. The life of the tool, the cutting force, and the surface roughness are crucial factors in turning. These features are used in the study to optimise the cutting parameters, such as cutting speed, feed rate, and depth of cut. This method has led to better experimental outcomes (Lin, 2004).

2.5 Feeling of scrub effect in soap.

To cleansing your skin, our Relaxing Oud Soap gently nourishes it with waste coconut oil and waste palm oil. Instead of removing the natural moisture from your skin, it gives it an extra boost of nutrients. Woodsy scent of agarwood oud that lingers on your skin for hours. Additionally, the scent has aromatherapy properties that relax and soothe you from head to toe (Mensing, 2023).

2.7 Hedonic test

When determining target product quality, two issues must be taken into consideration: the essential sensory qualities that influence liking and the sensory standards that must be adjusted to accommodate various customer groups within a market sector. After determining which product(s) are the most popular, it is necessary to specify the allowable range of variation from this target. This method bases its range-setting on the amount of sensory quality fluctuation that consumers will endure before accepting the product and deciding whether or not to remain loyal to it. The deviation or tolerance range has always been the most difficult and contentious part of a sensory specification. Setting the stage for the conversion of information into product specifications is made easier by using the notion of a sensory acceptance range during product development. Grading is a very practical way for routine sensory quality assessment, be it daily QC (quality control) inspections or longer-term monitoring (Everitt, 2009).

In order to collect information on liking, hedonic scales have been thoroughly evaluated in consumer research (Stone, 1985).

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Figure 2.3: Nine-point hedonic scale with verbal anchors.

2.8 Antibacterial and antifungal activity of antimicrobial soaps

The soap has both a bactericidal action and purges pollutants from the human body, it is essential for both cleanliness and health. to assess the efficacy of antimicrobial soaps from several commercial brands. Diffusion in agar was used to investigate the antimicrobial efficacy of several soap compositions against Escherichia coli bacteria (Santos Junior et al., 2022).

CHAPTER 3

MATERIALS AND METHODS

3.1 Materials

3.1.1 Materials agarwood essence

Agarwood chips, drying rack, tap water, Hydrodistillation apparatus, collection vials or bottles.

3.1.2 Material preparation of soap

The products used as major raw materials in the soap production were 450 ml waste palm oil, 450 ml waste coconut oil, 36 ml agarwood essential oil, 306 g sodium hydroxide (NaOH), 1440 ml water, hot plate, stainless steel bowl 500mL, spatula, measure cylinder, thermometer, pH paper, 500mL and 100 mL beaker, silicone mold, safety glove, balance and lab coat.

3.2 Methods

3.2.1 Design of Experiment

The formulation to produce the formulated soap is a represent below according to Taguchi Method

Table 3.1: Shows the soap formulation that has been changed using the Taguchi Method through experiment design the Taguchi technique seeks to minimize variation in a process.

Sample	Dust (g)	Waste Oil	Water (mL)	NaOH (g)
1	No	Palm	70	15
2	No	Palm	80	17
3	No	Palm	90	19
4	No	Coconut	70	15
5	No	Coconut	80	17
6	No	Coconut	90	19
7	No	Palm and Coconut	70	17
8	No	Palm and Coconut	80	19
9	No	Palm and Coconut	90	15
10	2	Palm	70	19
11	2	Palm	80	15
12	2	Palm	90	17
13	2	Coconut	70	17
14	2	Coconut	80	19
15	2	Coconut	90	15
16	2	Palm and Coconut	70	19
17	2	Palm and Coconut	80	15
18	2	Palm and Coconut	90	17

3.2.2 Preparation of agarwood essence

First, the agarwood chips were soaked in tap water for 7 days (1st batch), 14 days (2nd batch), and 21 days (3rd batch). Before beginning the hydrodistillation process, the agarwood chips must be dried using solar (sun). The agarwood chips are then totally immersed in water for the hydrodistillation process. The essential oils of agarwood were collected once after the oils were extracted using a three-day hydrodistillation procedure. Agarwood's essential oil samples have been produced (Nurhaslina, 2018).

3.2.3 Preparation of agarwood sawdust

Methods used for Aquilaria trees included wounding, requiring the making of incisions, punctures, or drilling holes into the trunk of the tree. Subsequently, agarwood dust was collected during agarwood processing, involving the cutting and grinding of woo d. The sieve was used to measure the fractional composition of sawdust using laboratory sieves measuring 0.5 mm to obtain agarwood dust (Sippel et al., 2021). The obtained agarwood dust was dried in an oven and processed by grinding pieces of agarwood using a milling machine. Finally, agarwood dust was stored properly to preserve its fragrance and quality before being added to the soap.

3.2.4 Preparation of soap

200 cm^3 of palm oil was measured, melted, combined with 100 cm^3 of 4.5 M sodium hydroxide, and then agitated continuously for 15 minutes at room temperature to create a viscous mixture. After that, ingredients 10 cm^3 of water are added of colognes. To create the so-called lid soap, the mixture was allowed to solidify for a week (Jimoh & Jimoh, 2021). (Muhammed et al., 2022a). In this experiment, 60 ml of waste cooking palm oil was measured. 19 g NaOH was weight and 70 ml of water was mixed using a hot plate. The temperature was measured and cooled down to 60 °C. NaOH was added into the oil and mixed with constant stirring. Next, 2 g of agarwood dust was added, and the 2 ml essential oil was put together. The soap solution was poured into the silicone mold. Left for dried for 24 until 48 hours. This step was repeated with waste palm oil, coconut oil with 15 g and 17 g NaOH, 80 ml and 90 ml water, with dust and no dust of agarwood.

3.3 Method evaluation of soap

3.3.1 Moisture resistance test

The moisture analyzer is one piece of equipment that is mostly used to determine how much water is in various items. This complex device works on the premise of a halogen radiator drying the sample while a balance registers and records the weight loss. Once the process has been examined, the sample's weight loss can be attributed to the sample's unique moisture content. This little equipment can complete tasks quickly and efficiently, enabling quick data collecting that leads to sample interpretation. First, a specified percentage of soap sample is added, and it is then placed inside the device to begin the procedure. The specimen compartment opens and closes on the moisture analyzer without human involvement thanks to the fully automated machinery. To function, the halogen moisture analyzer weighs the sample initially. The sample was rapidly heated by the internal halogen dryer until the water content evaporated. A record of the moisture content is shown on the screen monitor, and the cap automatically opens after the brief drying process is complete (Rasti et al., 2020).

3.3.2 pH test

A 2 mg soap sample was combined with 10 ml of distilled water, but little lather resulted. For optimum soap dissolution, it was left undisturbed for 24 hours. The pH of each sample was then determined. The pH of the vast majority of soaps is between 9 and 10 (Tarun et al., 2014a).

3.3.3 Foaming test

A reaction tube containing 1 g of the sample dissolved in 9 ml of water was prepared. The mixture was subjected to shaking using a vortex for a duration of 30 seconds, resulting in the formation of foam. The height of the foam was then measured. The foam generated from the sample was allowed to stand for 1 hour, after which its height was measured once again (Rifkowaty, 2023).

$$\text{\% Foam stability} = \frac{Initial\ height\ of\ foam}{Final\ height\ of\ foam} \text{ X } 100\%$$

3.3.4 Taguchi methods

To assess the data collected for the experiment, the Minitab analysis tool was employed. The software was used to develop, analyse, and forecast the Taguchi experimental design. Minitab can be used to evaluate the robust Taguchi setup. the determination of the ideal concentrations of the most important elements influencing the response variable. To visually assess the data, the programme produced graphs, a general linear ANOVA, and regression analysis. In order to determine the links between the input variables and the output response, a regression analysis was built. The equation describing the link between the variables was found using this methodology (Bratten, 2023).

Firstly, in order to consider the performance of the all-bar soap sample will be taken into consideration in this study. Secondly, correlation coefficient analysis will be taken to simplify orthogonal array (OA). Thirdly, a robust Taguchi method which contains both control factors and noise factors will be established, and the signal/noise (S/N) ratio can be employed to identify the best combination of control factor values. Besides, fuzzy theory will be used to weighting multiple objectives. Finally, sequential Taguchi will be adopted for a better optimization result by reducing the range of control factors in the optimization. In the conventional Taguchi optimization, only the average value of each control level needs to be considered. However, in this study S/N Ratio is used in this study to transform the performance objectives into the optimization process. The signal represents the mean of performance objectives, and the noise represents the variance of performance objectives. Normally, the performance characteristics can be divided into three categories: the lower-the-better, the higher the- better, and the nominal-the-better. And the most appropriate combination of parameters levels can be selected. Each factor only has three levels in this study. The range between two levels will be too large, which will cause the inaccuracy of the optimization. This means that the optimized results need to be further optimized for a better performance. In order to solve this problem, sequential Taguchi method is adopted in this study (Shi et al., 2020).

3.3.5 Test of antibacterial activity of antimicrobial soaps microbial growth

In this experiment, the antimicrobial activity of commercial soaps at different concentrations was assessed using the Kirby-Bauer technique (Reynolds, 2019). For this operation, 100 mg/mL was transferred to the agar plate with disk. 200 mg/mL ampicillin solution was used as a positive control for bacteria and 200 µL sterile distilled water for negative control. All plates were incubated at 37 °C for 24 hours and all tests were performed in duplicate (Santos Junior et al., 2022).

3.3.6 Hedonic test methods

The technique for testing the properties of solid soap is manufactured in accordance with soap quality requirements such as water content, free fatty acid levels, and pH. Using a texture analyzer, test the physical qualities of soap, such as foam stability and hardness. Furthermore, to examine the physical and chemical properties, transparent solid soap was subjected to hedonic testing on appearance, aroma, amount of foam, texture, and congestion impact. The antioxidant activity of the transparent solid soap generated was also examined by determining the proportion of antioxidant activity created from soap (Sany, 2019). The hedonic test included 5 parameters, namely colour, aroma, texture, appear after using the soap (Rusdianto et al., 2021).

The hedonic test is a technique for determining how much a person likes a thing by primarily employing their senses. Tests are conducted to gauge the degree of product liking based on using an evaluation sheet, a scale with 1 (one) as the lowest value and 9 (nine) as the greatest value (Ircham et al., 2022).

Table 3.2: Hedonic Likert Scale used in the Questionnaire

Criteria	Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely
Appearance									
Aroma									
Texture									
Colour									
Foam									
Impression									

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Sensory

4.1.1 Hedonic Sensory

Figure 4.1 shows the result of Agarwood bar soap product in 18 samples of the bar soap. This test is evaluated immediately in terms of colour, texture, appearance and smell of the soap produced for 2 days, whether there is a change or not. This formulation has different doses of oil and NaOH. In addition, a combination of waste coconut oil and waste palm oil acts as a soap hardener. Different concentrations of NaOH are used for the saponification process. (Hadiyanto et al., 2023). The essential oil used as a soap fragrance is agarwood oil. The soothing aroma of agarwood oil is perfect for blending with a different type of soap. With the inclusion of agarwood powder, the physical properties of solid soap take on a light brown and thick colour or solid consistency. This agarwood soap lathers quite a lot and quite a bit smooth. This shows that agarwood can be produced as a solid soap component. After soap has been produced effectively, research-based tests are conducted. The test carried out is in the form of pH tests on soap, tests for the height of foam produced by soap, tests for moisture content and antimicrobial tests for soap.

Based on previous study, a cosmetic product's sensory profile, or how it smells, feels, looks, and feels on the skin in addition to its benefits, is crucial to the consumer's acceptance and continued use of it. When creating cosmetic products that match customer expectations and have sufficient sensory qualities to increase consumer acceptance, sensory analysis is a very relevant and helpful approach. But selecting the best approach to employ, as well as the technical specifications for its implementation and data analysis, necessitates a thorough comprehension of the goals, constraints, and potential of each approach (de Noronha et al., 2019).

The test involved 15 untrained panelists in evaluating the texture, aroma, colour, and appearance of the 18 samples of the Agarwood bar's soap. This data are used to calculate the average acceptability values for each product and determine whether there are any appreciable variations in the acceptability of the products (Gámbaro, 2020).

In Figure 4.2, the result of the hedonic test was determined based on Table 4.1. In hedonic test, we can see the result for the appearance, aroma, texture and colour. The appearance scored varied from 3.87 to 6.8 across 18 different samples. Sample 15 received the highest score, which is 6.8, indicating a strong positive perception of its visual appeal. The sample 3 received relatively lower scores, suggesting a less favourable opinion regarding their appearance. For the aroma, aroma was scored ranged from 3.4 to 4.53. Sample 13 obtained the highest aroma score, which is 4.53, indicating a distinct and pleasing aroma. While the sample 18 received the lowest aroma scores, suggesting a less desirable fragrance. For the texture, texture was scored ranged from 3.67 to 6.13. Sample 15 scored highest for texture, suggesting a favourable mouthfeel. While the sample 3 received lower texture scores, indicating potential issues with the perceived texture. For the colour, colour was scored ranged from 4 to 6.13. Sample 15 received the highest colour scores, suggesting visually appealing products. While the sample 12 had lower colour scores, indicating potential concerns with the perceived colour quality. Combining the scores for all attributes, the appears that sample 15 is the most positively evaluated overall, with highest scores in appearance, aroma, texture, and colour and the Sample 3 consistently received lower scores across attributes, indicating potential areas for improvement.

		
Palm	Palm	Palm
		
Coconut	Coconut	Coconut
		
Palm and Coconut	Palm and Coconut	Palm and Coconut
		
Palm	Palm	Palm

		
Coconut	Coconut	Coconut
		
Palm and Coconut	Palm and Coconut	Palm and Coconut

Figure 4.1: Agarwood Bar Soap Product

Table 4.1: Data for Hedonic Test Questionnaire

Sample	Appear	Aroma	Texture	Colour
1	4.6	4.53	4.53	5.67
2	4	4.13	4.2	5.47
3	3.87	4.13	3.67	5.13
4	5.2	3.93	4.8	5
5	5.6	4.27	4.8	4.67
6	4.4	4.27	4.07	4.13
7	5.07	4.2	4.4	4.4
8	5.47	3.87	4.87	4.73
9	4.47	4	4.27	4.67
10	4.73	3.93	4.6	4.4
11	5.07	3.93	4.27	4.8
12	4.13	3.8	4.13	4
13	5.53	4.53	4.67	5.8
14	6.6	4.27	5.6	6
15	6.8	4.27	6.13	6.13
16	6.33	3.73	6	5.47
17	5.8	3.6	5.2	5.13
18	6.4	3.4	5.2	5.47

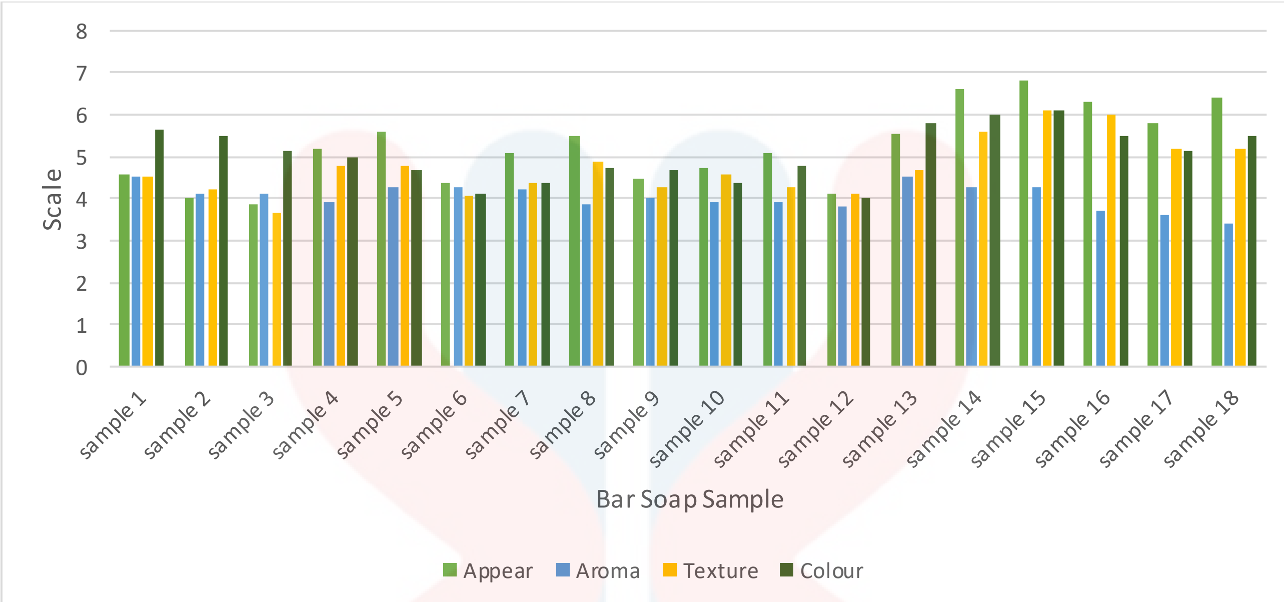

Figure 4.2: Hedonic Test Questionnaire

4.2 Psychochemical Properties Sensory

One kind of alkali is NaOH. Alkaline compounds are dissolved salts of alkali metals such as sodium. Alkali is an alkaline substance that reacts with acids to neutralize them. The physical and chemical properties of soap, such as its pH, moisture content, kind of oil utilized, level of saponification, oil component, and many other factors. NaOH is commonly utilized in the production of solid soap due to its insoluble nature in water (Rahayu et al., 2021). The psychochemical characteristics of soap, such as its pH, moisture content, microbes, cost and foam stability, have been investigated in connection with its skin-friendliness and cleaning efficacy (Ermawati et al., 2022). A neutral pH of 7 is the least harsh on skin, and it indicates how basic or acidic the soap is. Moisture content indicated how much water was in the soap, while foam stability described the soap's capacity to keep its froth over time.

4.2.1 Foaming Analysis

Based on previous study, the study discussed when choosing soap, foam is a key factor. Since it has nothing to do with cleansing the skin, the percentage of foam stability is not included in the SNI. When using soap, foam plays a part in transferring the scent to the skin and determining the user's preferred level of lather. Most customers choose soap that is stable and has a lot of foam (Sany, 2019).

In Figure 4.3, we can see the result of the foam in 18 samples of the Agarwood bar soap. The result of the foam stability, the transparent soap foam stability test was conducted in the same manner as the foam ability test (Cholifah et al., 2021).

The application of these various oils modifies the characteristics of soap, starting with its hardness, effect on the skin, and resulting foam. Surfactant soap is made of natural fats or oils. The bipolar structure of surfactants consists of hydrophilic heads and hydrophobic tails. As a result, soap may be used to clean clothing and the body of dirt, which is frequently fat. Oil and alkali are used in the saponification process to create soap, which can be either a liquid or a solid that creates foam without causing irritation to the user's skin (Hadiyanto et al., 2023).

The height test of the producing foam was conducted to determine the heigh stability of the resulting foam on soap. As a result of this test, the stability of the foam in sample 4 and sample 5 tends to be better owing to the steady drop in foam height every minute, but the stability of the foam in sample 2 is lower due to the modest fall in soap height every minute. Sample 4 and sample 5 have the highest foam stability which is 90% while sample 2 have the lowest foam stability which is 26.7%. This may occur when shaking for too long, resulting in foam that is overly thick.

The kind of fatty acids utilized is one factor that influences the high stability of soap foam. Coconut oil's lauric acid creates a gentle foam, whereas palmitic acid in palm oil stabilizes foam (Sany, 2019). Further stated that because agarwood oil has a greater surfactant characteristic, soap with a higher agarwood oil content tended to have more foam (33–80%) (Fadhlullah et al., 2022).

Foam is a highly concentrated, diffuse air-liquid system that is produced at the phase boundary by surfactants, according to colloid chemistry. The foam is stabilised by the stiff frame formed by films encircling air bubbles (Tarasov et al., 2021).

When choosing soap, foam is a key factor. Since it has nothing to do with cleansing the skin, the percentage of foam stability is not included in the SNI. When using soap, foam plays a part in transferring the scent to the skin and determining the user's preferred level of lather. Most customers choose soap that is stable and has a lot of foam (Sany, 2019)

Table 4.2: Data for Foam Analysis

Sample	Initial height of foam (cm)	Final height of foam (cm)	Foam stability (%)
1	1.2	0.9	75.00
2	3.0	0.8	26.7
3	1.2	1.0	83.3
4	1.0	0.9	90.0
5	1.0	0.9	90.0
6	1.7	1.4	82.4
7	1.7	1.3	76.5
8	1.3	0.9	69.2
9	1.5	1.0	66.7
10	1.7	1.0	58.8
11	1.5	1.2	80.0
12	2.1	1.8	85.7
13	1.1	0.4	36.4
14	1.5	1.0	66.7
15	1.3	0.7	53.8
16	1.7	0.5	29.4
17	1.0	0.3	30.0
18	1.2	0.9	75.0

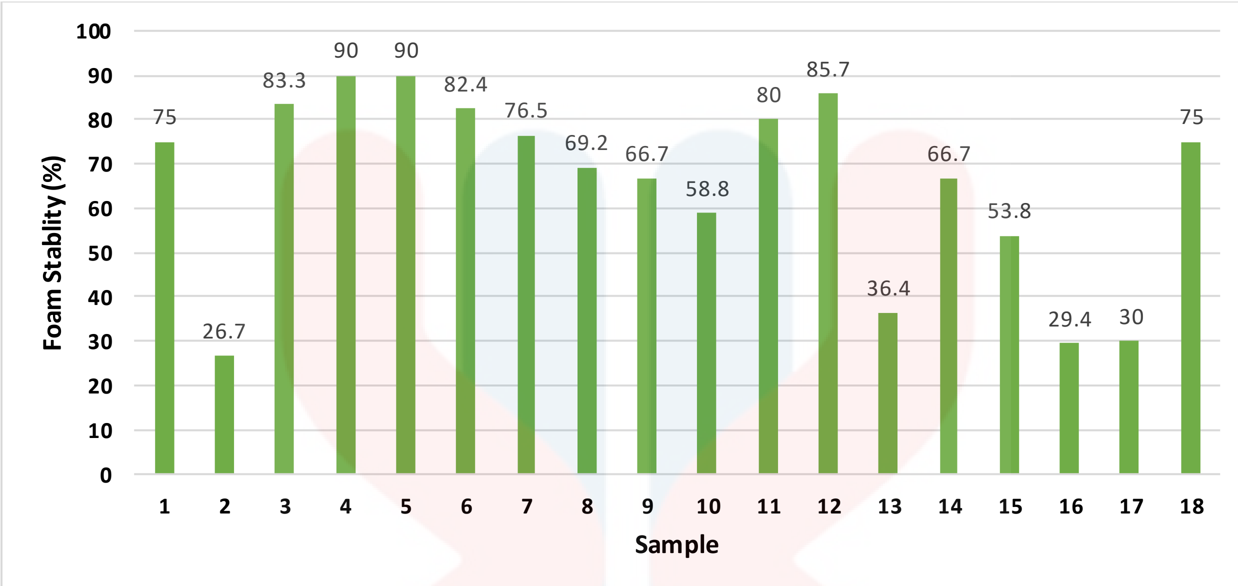

Figure 4.3: Properties Foam Analysis

4.2.2 pH Analysis

Table 4.3 shows the pH result of the 18-bar soap's sample. The chemical parameter known as pH is utilized to determine the alkalinity or acidity of the final soap. The pH level may have an impact on how irritating soap is to the skin (Amnudi et al., 2015).

The pH test is done so that the pH of the soap produced meets the pH standard of the soap in circulation. Bath soap has a pH between 8-11. In Figure 4.4, the pH value of the soap obtained in this study ranged between 9-13 which means there is a pH value between the soaps produced in this study is deep according to SNI standards. The optimal pH in this study was achieved by adding waste coconut oil because the resulting pH (9) is close to human skin. pH instability caused by heating factors due to Natrium Hydroxide NaOH, which can cause alkali to raise the pH of the soap (Cholifah et al., 2021). Because NaOH concentration can alter soap's pH, amounts of non-soapy fractions, free fatty acids, free alkalis, and water content, it has an impact on the quality of soap produced. Elevated or decreased NaOH concentrations will impact the saponification process's efficiency, which will therefore have an indirect impact on the final soap's quality. Using high-pH soap raises the pH of the skin, which exacerbates dehydration, irritation, and bacterial flora damage (Rahayu et al., 2021)

Table 4.3: Properties pH Analysis

Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
pH	12	12	12	12	12	9	12	12	13	13	13	13	12	13	12	12	13	10

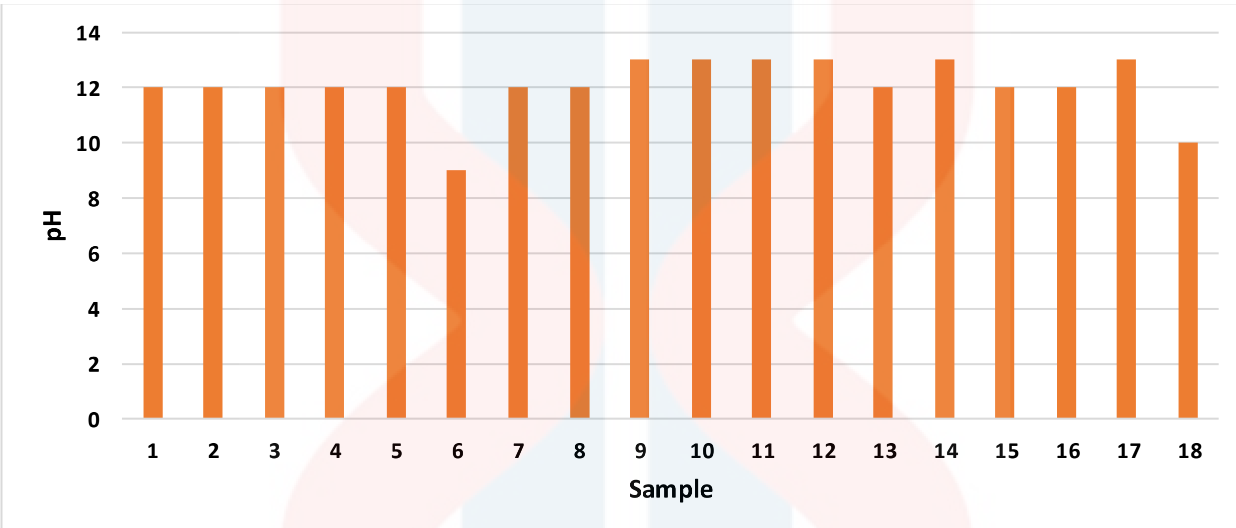

Figure 4.4: Properties pH Analysis

4.2.3 Microbial Analysis

Based on Figure 4.5, the microbial growth sizes vary from 1 mm to 9 mm. The microbial growth sizes range from 1 mm to 9 mm. Most of the samples which are sample 1, 2, 3, 4, 5, 6, 7, 11, 12, 14, 15, and 16 show the minimal microbial growth with sizes around 1 mm. The samples 8, 9, 10, 13, 17 and 18 exhibit larger microbial growth sizes, particularly with values of 7 mm, 8 mm, and 9 mm. Sample 17 exhibits the largest microbial growth at 9 mm, suggesting potential concerns regarding microbial stability.

Table 4.4: Properties Microbe Analysis

Sample	Microbe (mm)
1	0.01
2	0.01
3	0.01
4	0.01
5	0.01
6	0.01
7	0.01
8	7
9	8
10	8
11	0.01
12	0.01
13	8
14	0.01
15	0.01
16	0.01
17	9
18	8

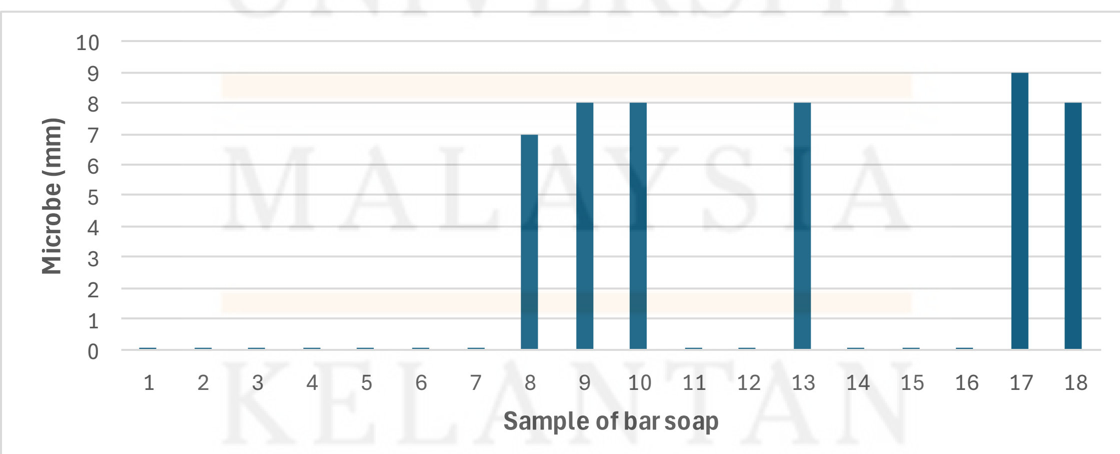

Figure 4.5: Properties Microbe Analysis

4.2.4 Cost analysis

Based on Figure 4.6, costs range from RM 5.48 to RM 6.98. Sample 1 is the most cost-effective, while the sample 17 is the most expensive. The provided cost breakdown for the production ingredients includes NaOH at RM 30, palm oil at RM 18, coconut oil at RM 17.50, dust at RM 30, essence at RM 79.50, and water at RM 12. Analyzing the sample costs ranging from RM 5.48 to RM 6.98, it is evident that there are variations in the final product costs. Upon reviewing the cost of individual ingredients, it's apparent that essence is the most expensive component, followed by NaOH, dust, palm oil, coconut oil, and water in descending order. The fluctuation in sample costs may be attributed to differences in the quantities of these ingredients used in each sample, as well as potential variations in the production process.

For a more detailed understanding, it would be beneficial to assess the specific quantities of each ingredient in the samples and their respective impact on the overall cost. Additionally, any qualitative differences in the final product, potentially influenced by variations in ingredient proportions, should be considered.

Table 4.5: Properties Cost Analysis.

Sample	Cost (RM)
1	5.48
2	5.72
3	5.96
4	6.32
5	6.20
6	6.44
7	5.87
8	6.11
9	5.99
10	6.59
11	6.47
12	6.71
13	6.02
14	6.26
15	6.50
16	6.74
17	6.98
18	6.86

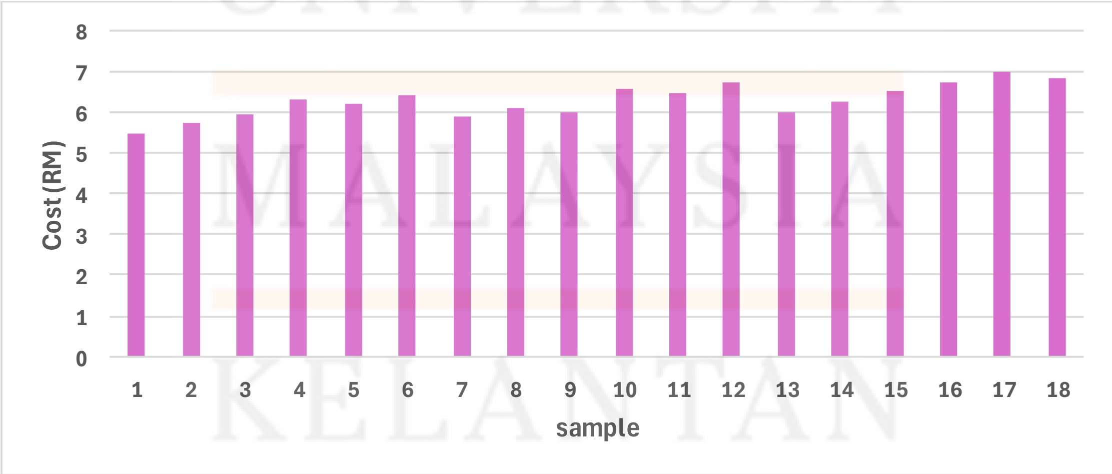

Figure 4.6: Properties Cost Analysis

4.2.5 Moisture content analysis

The result of the moisture content analysis was determined based on Table 4.6. Moisture content ranges from 5.54% to 49.31%. Samples 6 has the lowest moisture content, indicating a drier product. While sample 18 has the highest moisture content, suggesting a relatively more moist or wet product. For the time taken for moisture measurement: Time taken for moisture measurement ranges from 2.47 minutes to 21.49 minutes. Sample 1 had the shortest time taken for measurement, while sample 16 took the longest.

High moisture content can cause hydrolysis of the soap during storage, which reduces the shelf life of the product. This can be achieved by using a lower part of the water from the alkali during the cold process of soap production (Rasyidi, 2023). The 1994 SNI for soap states that a soap's maximum water content is 15%. One criterion for determining a product's shelf life is its moisture content. High water content in soap will cause surplus water reaction with unsaponified fat to create free fatty acids and glycerol in a process called hydrolysis during storage. When using soap, its shrinkage will be easier the more water it contains (Sukeksi, 2020). This explains why water plays such a significant role. This formulation contained certain water sources, including the caustic soda solution and the water generated during the neutralization process. The finished product is also impacted by the addition of free water. Less than 5% of total water addition either naturally occurring or from other ingredients usually results in soap that is excessively hard and has a tendency to crystallize, which is linked to the loss of clarity. Over 15% of free water addition results in soap that is excessively soft. When the moisture content was more than 17% but not more than roughly 21%, transparency was maintained. Increased moisture content will cause an excess of water to hydrolyze into unsaponified fat. Glycerol and free fatty acid are the end products of this process (Hayati et al., 2020).

Table 4.6: Moisture Content Analysis

Sample	Moisture content (%)	Time taken (minute)
1	15.69	2.47
2	25.89	7.24
3	36.03	9.40
4	35.12	14.18
5	32.85	13.24
6	5.54	3.58
7	17.09	17.09
8	22.08	9.39
9	39.08	13.11
10	25.36	9.36
11	42.68	16.34
12	41.51	13.50
13	33.21	19.54
14	45.79	17.51
15	31.50	19.46
16	33.03	21.49
17	25.79	13.35
18	49.31	19.21

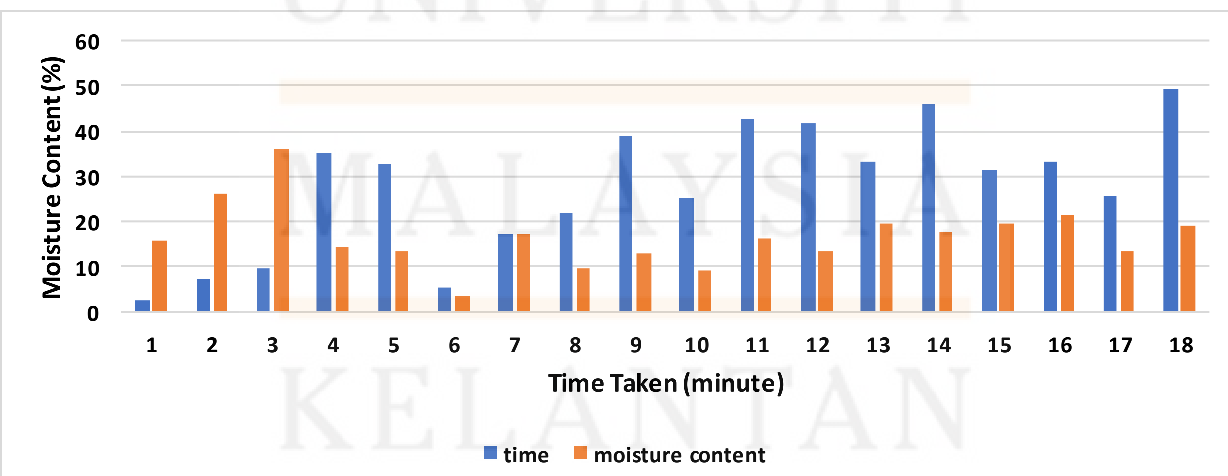

Figure 4.7: Properties Moisture Content Analysis

4.3 Taguchi Analysis

4.3.1 Hedonic versus dust, waste oil, aqua and NaOH

Table 4.7: Response Table for Signal to Noise Ratios for Hedonic Analysis

Level	Dust	Waste Oil	Aqua	NaOH
1	13.01	12.74	13.48	13.49
2	13.59	13.83	13.45	13.15
3		13.33	12.98	13.26
Delta	0.59	1.09	0.50	0.33
Rank	2	1	3	4

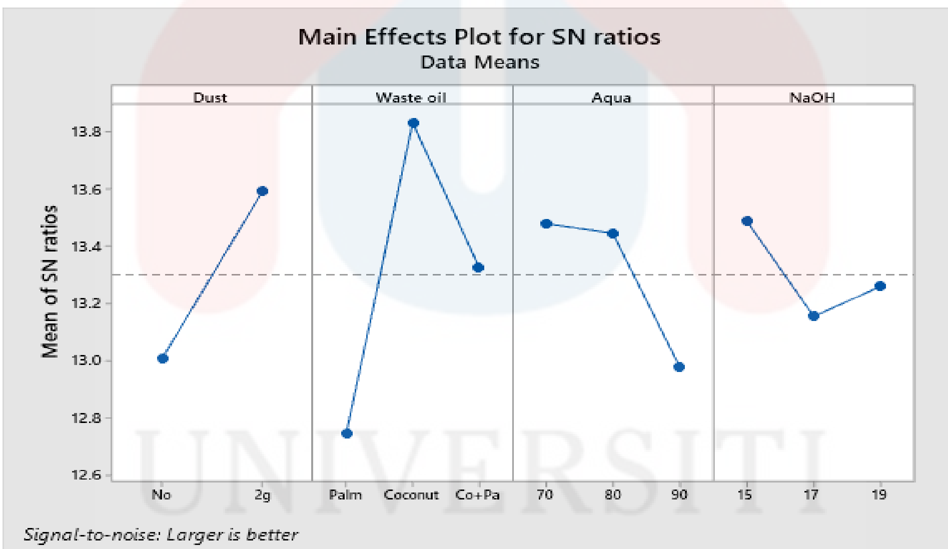

Figure 4.8: Signal to Noise Ratios for Hedonic Analysis

Interpretation of SNR Values was determined based on Table 4.7. SNR values provide insights into the signal (desired effect) to noise (undesired variation) ratio for each factor at different levels. The higher SNR values indicate a more favorable signal-to-noise ratio. The factor rankings were shown based on Table 4.7. Waste coconut oil is level 2 with the highest SNR 1.09, it is ranked first. This suggests that waste coconut oil at level 2 has the most favourable impact on hedonic analysis, contributing the most to the desired effect. Based on Figure 4.8, the presence of 2 grams of dust proves to be crucial, as it results in a notably higher mean of SN ratios at 13.6. The waste coconut oil demonstrates superiority with a mean of SN ratios at 13.83. This highlights the importance of selecting waste coconut oil for achieving higher mean SN ratios in the experiment. The volume of aqua is also a significant factor, with 70 ml yielding a higher mean of SN ratios at 13.48. This indicates that 70 ml of aqua is more favorable for obtaining higher Signal-to-Noise ratios. In terms of NaOH quantity, 15 grams stands out with a mean of SN ratios at 13.49, this suggests that a lower quantity, specifically 15 grams of NaOH, contributes to better outcomes in terms of Signal-to-Noise ratios.

4.3.2 Properties versus dust, waste oil, aqua and NaOH

Table 4.8: Response Table for Signal to Noise Ratios for Properties Analysis

Level	Dust	Waste Oil	Aqua	NaOH
1	-11.149	1.607	-17.683	-17.538
2	-24.228	-27.347	-17.728	-17.678
3		-27.326	-17.654	-17.850
Delta	13.078	28.954	0.074	0.312
Rank	2	1	4	3

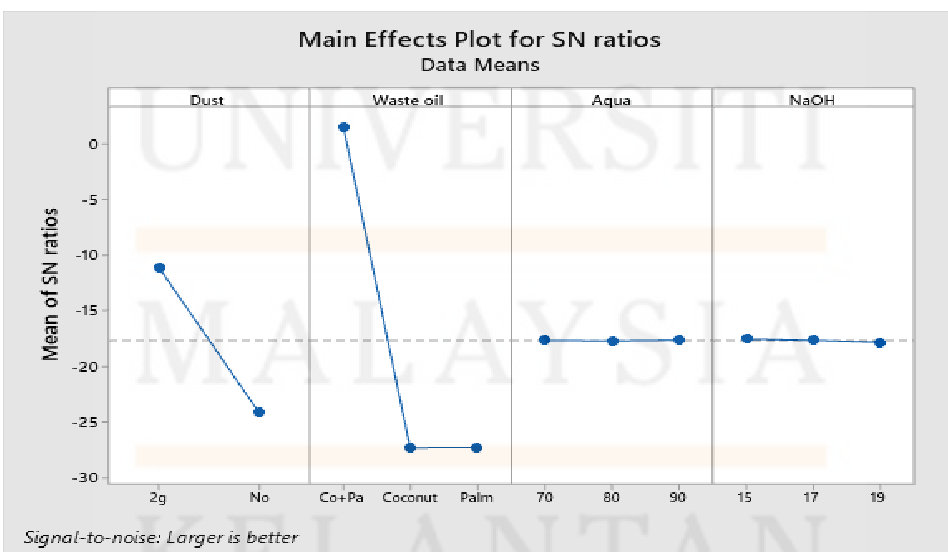

Figure 4.9: Signal to Noise Ratios for Properties Analysis

The factor rankings were shown based on Table 4.8. Coconut waste oil plus waste palm oil is level 1 with the highest SNR 28.954, it is ranked first. Based on Figure 4.9, the presence of 2 grams of dust proves to be crucial, as it results in a notably higher mean of SN ratios at -11.149. The waste coconut oil plus waste palm oil demonstrates superiority with a mean of SN ratios at 1.607. This highlights the importance of selecting waste coconut oil plus waste palm oil for achieving higher mean SN ratios in the experiment. The volume of aqua is also a significant factor, with 70 ml yielding a higher mean of SN ratios at -17.683. This indicates that 70 ml of aqua is more favorable for obtaining higher Signal-to-Noise ratios. In terms of NaOH quantity, 15 grams stands out with a mean of SN ratios at -17.238, this suggests that a lower quantity, specifically 15 grams of NaOH, contributes to better outcomes in terms of Signal-to-Noise ratios.

4.3.3 Appear versus dust, waste oil, aqua and NaOH

Table 4.9: Response Table for Signal to Noise Ratios for Appear

Level	Dust	Waste Oil	Aqua	NaOH
1	13.45	12.83	14.34	14.43
2	15.03	15.01	14.59	14.07
3		14.88	13.79	14.22
Delta	1.57	2.18	0.80	0.37
Rank	2	1	3	4

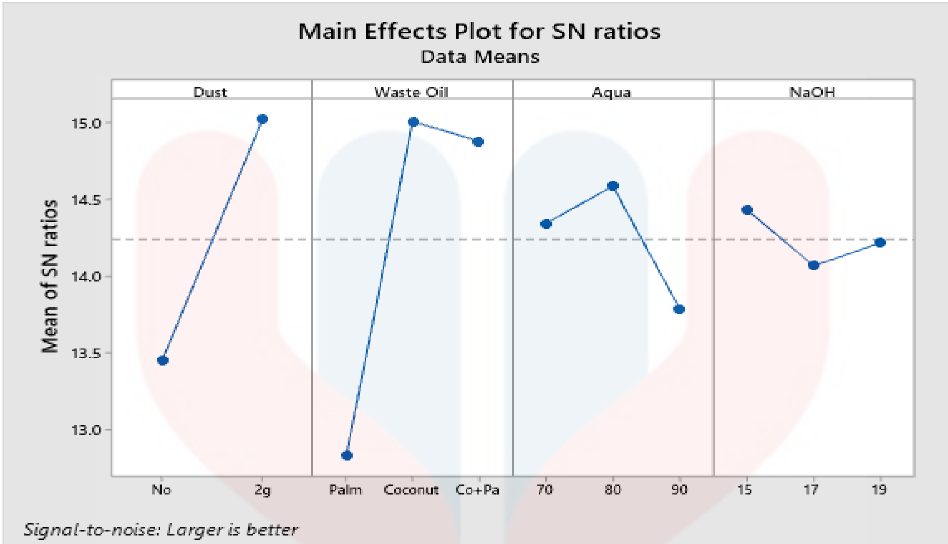

Figure 4.10: Signal to Noise Ratios for Appear

The factor rankings were shown based on Table 4.9. Waste coconut oil is level 2 with the highest SNR 2.18, it is ranked first. Based on Figure 4.10, the presence of 2 grams of dust proves to be crucial, as it results in a notably higher mean of SN ratios at 15.03. The coconut waste oil demonstrates superiority with a mean of SN ratios at 15.01. This highlights the importance of selecting waste coconut oil for achieving higher mean SN ratios in the experiment. The volume of aqua is also a significant factor, with 80ml yielding a higher mean of SN ratios at 14.59. This indicates that 80ml of aqua is more favorable for obtaining higher Signal-to-Noise ratios. In terms of NaOH quantity, 15 grams stands out with a mean of SN ratios at 14.43, this suggests that a lower quantity, specifically 15 grams of NaOH, contributes to better outcomes in terms of Signal-to-Noise ratios.

4.3.4 Aroma versus dust, waste oil, aqua and NaOH

Table 4.10: Response Table for Signal to Noise Ratios for Aroma

Level	Dust	Waste Oil	Aqua	NaOH
1	12.35	12.19	12.32	12.11
2	11.88	12.57	12.05	12.12
3		11.58	11.97	12.10
Delta	0.47	1.00	0.35	0.02
Rank	2	1	3	4

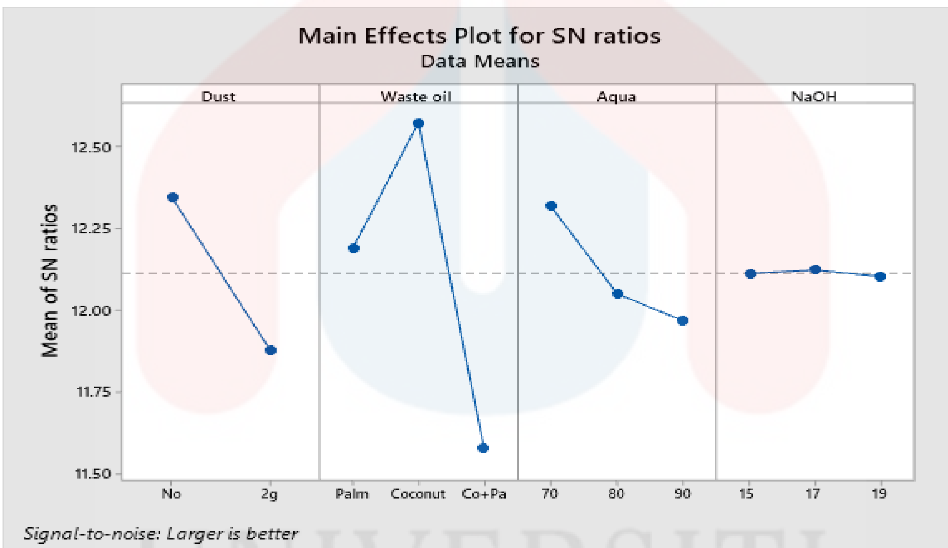

Figure 4.11: Signal to Noise Ratios for Aroma

The factor rankings were shown based on Table 4.10. Waste coconut oil is level 2 with the highest SNR 1.00, it is ranked first. Based on Figure 4.11, the presence of 0 grams of dust proves to be crucial, as it results in a notably higher mean of SN ratios at 12.35. The waste coconut oil demonstrates superiority with a mean of SN ratios at 12.57. This highlights the importance of selecting coconut waste oil for achieving higher mean SN ratios in the experiment. The volume of aqua is also a significant factor, with 70 ml yielding a higher mean of SN ratios at 12.32. This indicates that 70 ml of aqua is more favorable for obtaining higher Signal-to-Noise ratios. In terms of NaOH quantity, 17 grams stands out with a mean of SN ratios at 12.12, this suggests that a lower quantity, 17 grams of NaOH, contributes to better outcomes in terms of Signal-to-Noise ratios.

4.3.5 Texture versus dust, waste oil, aqua and NaOH

Table 4.11: Response Table for Signal to Noise Ratios for Texture

Level	Dust	Waste Oil	Aqua	NaOH
1	12.84	12.51	13.64	13.67
2	14.05	13.92	13.62	13.16
3		13.91	13.08	13.50
Delta	1.22	1.41	0.56	0.51
Rank	2	1	3	4

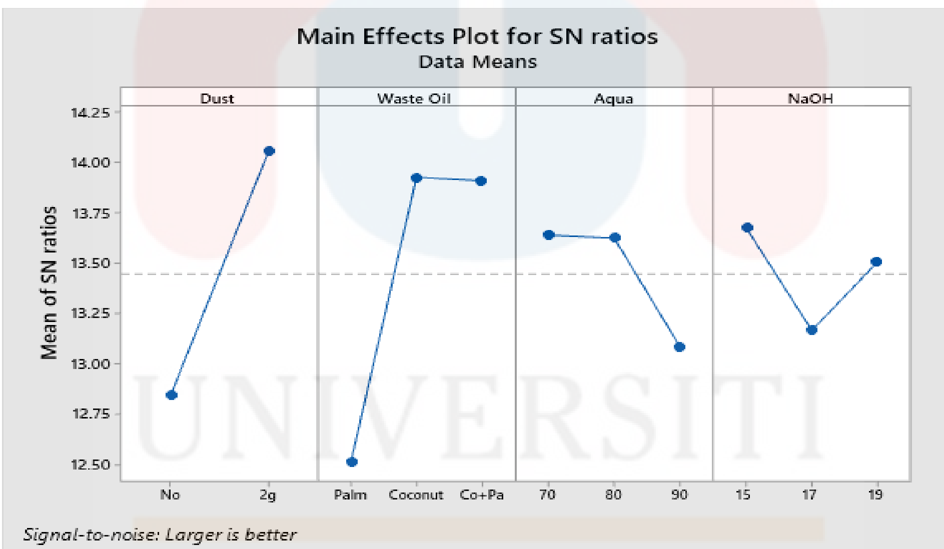

Figure 4.12: Signal to Noise Ratios for Texture

The factor rankings were shown based on Table 4.11. Waste coconut oil is level 3 with the highest SNR 1.41, it is ranked first. Based on Figure 4.12, the presence of 2 grams of dust proves to be crucial, as it results in a notably higher mean of SN ratios at 14.05. The coconut waste oil demonstrates superiority with a mean of SN ratios at 13.92. This highlights the importance of selecting waste coconut oil for achieving higher mean SN ratios in the experiment. The volume of aqua is also a significant factor, with 70 ml yielding a higher mean of SN ratios at 13.64. This indicates that 70 ml of aqua is more favorable for obtaining higher Signal-to-Noise ratios. In terms of NaOH quantity, 15 grams stands out with a mean of SN ratios at 13.67, this suggests that a lower quantity, specifically 15 grams of NaOH, contributes to better outcomes in terms of Signal-to-Noise ratios.

4.3.6 Colour versus dust, waste oil, aqua and NaOH

Table 4.12: Response Table for Signal to Noise Ratios for Colour

Level	Dust	Waste Oil	Aqua	NaOH
1	13.72	13.76	14.14	14.34
2	14.32	14.38	14.17	13.85
3		13.91	13.74	13.87
Delta	0.60	0.62	0.43	0.49
Rank	2	1	4	3

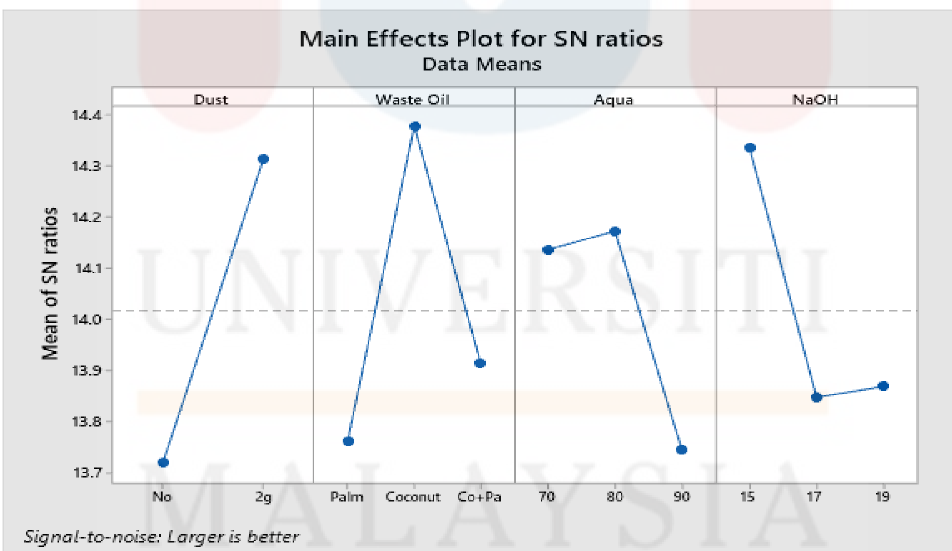

Figure 4.13: Signal to Noise Ratios for Colour

The factor rankings were shown based on Table 4.12. Coconut waste oil is level 2 with the highest SNR 0.62, it is ranked first. Based on Figure 4.13, the presence of 2 grams of dust proves to be crucial, as it results in a notably higher mean of SN ratios at 14.32. The coconut waste oil demonstrates superiority with a mean of SN ratios at 14.38. This highlights the importance of selecting coconut waste oil for achieving higher mean SN ratios in the experiment. The volume of aqua is also a significant factor, with 80 ml yielding a higher mean of SN ratios at 14.17. This indicates that 80 ml of aqua is more favorable for obtaining higher Signal-to-Noise ratios. In terms of NaOH quantity, 15 grams stands out with a mean of SN ratios at 14.34, this suggests that a lower quantity, specifically 15 grams of NaOH, contributes to better outcomes in terms of Signal-to-Noise ratios.

4.3.7 Foam versus dust, waste oil, aqua and NaOH

Table 4.13: Response Table for Signal to Noise Ratios for Foam

Level	Dust	Waste Oil	Aqua	NaOH
1	13.45	12.83	14.34	14.34
2	15.03	15.01	14.59	14.07
3		14.88	13.79	14.22
Delta	1.57	2.18	0.80	0.37
Rank	2	1	3	4

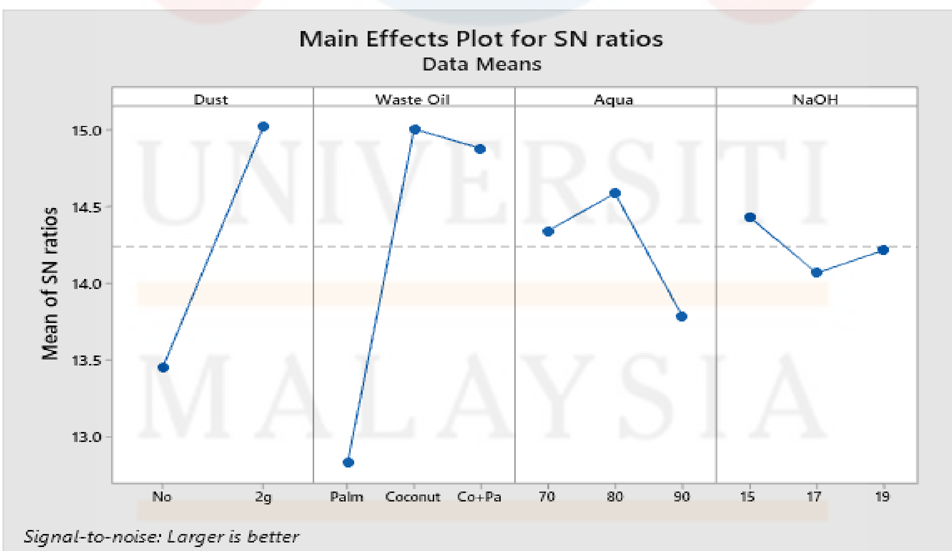

Figure 4.14: Signal to Noise Ratios for Foam

The factor rankings were shown based on Table 4.13, waste coconut oil is level 2 with the highest SNR 2.18, it is ranked first. Based on Figure 4.14, the presence of 2 grams of dust proves to be crucial, as it results in a notably higher mean of SN ratios at 15.03. The coconut waste oil demonstrates superiority with a mean of SN ratios at 15.01. This highlights the importance of selecting waste coconut oil for achieving higher mean SN ratios in the experiment. The volume of aqua is also a significant factor, with 80 ml yielding a higher mean of SN ratios at 14.59. This indicates that 80 ml of aqua is more favorable for obtaining higher Signal-to-Noise ratios. In terms of NaOH quantity, 15 grams stands out with a mean of SN ratios at 14.34, this suggests that a lower quantity, specifically 15 grams of NaOH, contributes to better outcomes in terms of Signal-to-Noise ratios.

4.3.8 Microbe versus dust, waste oil, aqua and NaOH

Table 4.14: Response Table for Signal to Noise Ratios for Microbe

Level	Dust	Waste Oil	Aqua	NaOH
1	-14.081	-1.315	-20.646	-20.476
2	-27.226	-30.323	-20.669	-20.646
3		-30.323	-20.646	-20.839
Delta	13.145	29.008	0.023	0.364
Rank	2	1	4	3

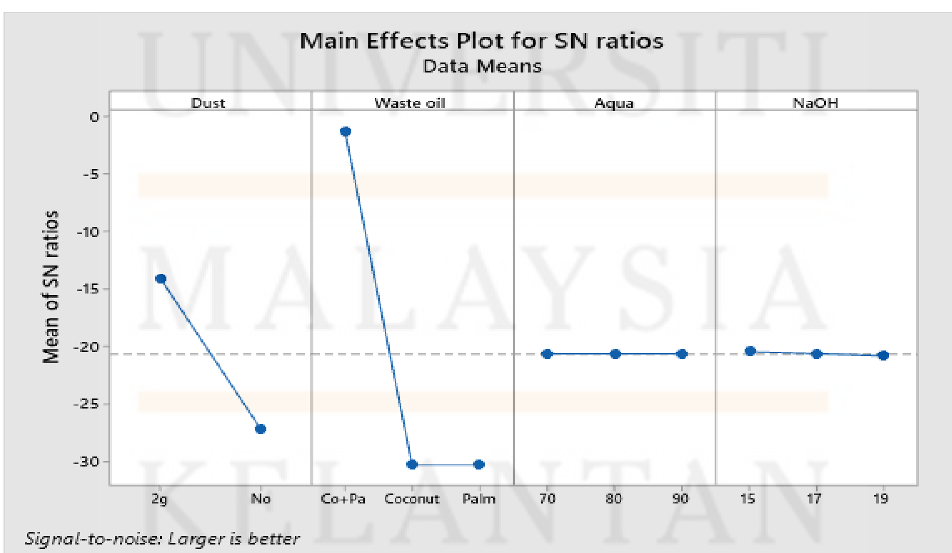

Figure 4.15: Signal to Noise Ratios for Microbe

The factor rankings were shown based on Table 4.14. Coconut waste oil plus waste palm oil is level 1 with the highest SNR 29.008, it is ranked first. Based on Figure 4.15, the presence of 2 grams of dust proves to be crucial, as it results in a notably higher mean of SN ratios at -14.081. The waste coconut oil plus waste palm oil demonstrates superiority with a mean of SN ratios at -1.315. This highlights the importance of selecting coconut waste oil plus palm waste oil for achieving higher mean SN ratios in the experiment. The volume of aqua is also a significant factor, with 70ml and 90ml yielding a higher mean of SN ratios at -20.646. This indicates that 70ml and 90ml of aqua is more favorable for obtaining higher Signal-to-Noise ratios. In terms of NaOH quantity, 15 grams stands out with a mean of SN ratios at -20.476, this suggests that a lower quantity, specifically 15 grams of NaOH, contributes to better outcomes in terms of Signal-to-Noise ratios.

4.3.9 Cost versus dust, waste oil, aqua and NaOH

Table 4.15: Response Table for Signal to Noise Ratio for Cost

Level	**Dust**	**Waste Oil**	**Aqua**	**NaOH**
1	-15.57	-15.76	-15.78	-15.95
2	-16.34	-15.97	-15.96	-15.87
3		-16.14	-16.13	-16.05
Delta	0.78	0.38	0.34	0.18
Rank	1	2	3	4

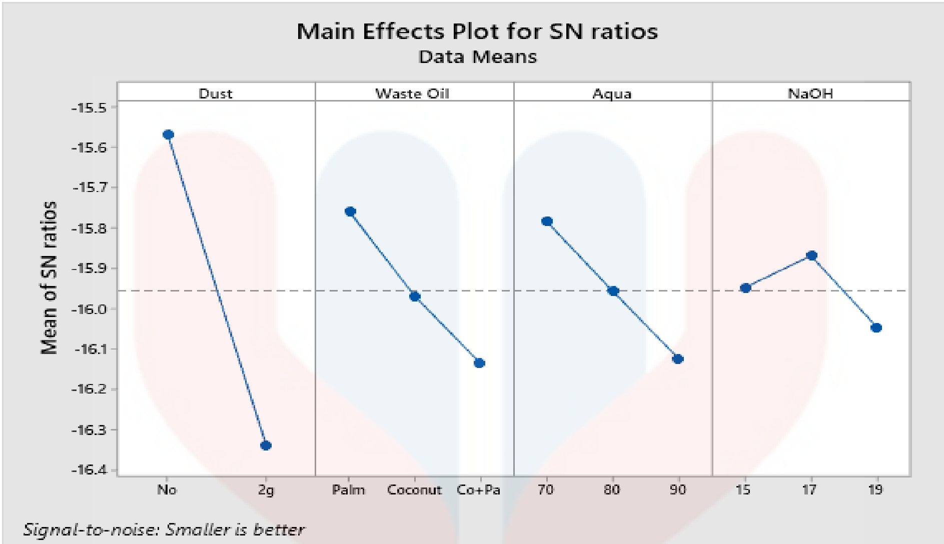

Figure 4.16: Signal to Noise Ratio for Cost

The factor rankings were shown based on Table 4.15. Dust is level 2 with the highest SNR 0.78, it is ranked first. Based on Figure 4.16, the presence of 2 grams of dust proves to be crucial, as it results in a notably lowest mean of SN ratios at -16.34. The waste coconut oil plus waste palm oil demonstrates superiority with a mean of SN ratios at -16.14. This highlights the importance of selecting waste coconut oil plus waste palm oil for achieving lowest mean SN ratios in the experiment. The volume of aqua is also a significant factor, with 90 ml yielding a higher mean of SN ratios at -16.13. This indicates that 90 ml of aqua is more favorable for obtaining higher Signal-to-Noise ratios. In terms of NaOH quantity, 19 grams stands out with a mean of SN ratios at -16.05, this suggests that a lower quantity, specifically 15 grams of NaOH, contributes to better outcomes in terms of Signal-to-Noise ratios.

SN ratio graph would likely illustrate the impact of waste oil on various attributes such as appearance, aroma, texture, colour, foam, and microbe. Higher SN ratios, indicative of a more favorable signal-to-noise ratio, would be expected for soap formulations containing waste oil (Barton, 2019). This graph serves as a visual testament to the efficacy of waste oil in enhancing the desired characteristics of the soap while minimizing undesirable variations. Each attribute would likely exhibit a distinct peak in the graph, representing the optimal conditions achieved through the inclusion of waste oil. This visual representation underscores the positive influence of waste oil on the overall quality and performance of the soap. Waste oils are mostly made up of a variety of triglycerides, which are made up of fatty acids on a glycerol backbone, and contain carbon derived from renewable resources. Depending on where the oil comes from, these triglycerides have different compositions. More saturated medium-chain fatty acids are found in coconut oils. How the oil is composed will affect the goods made from biobased feedstocks. The way that component triglycerides change after heating, saponification, and gelation can be taken into consideration when choosing feedstocks. After heating and cooking, fats and oils undergo physical and compositional changes. Although frying oil is frequently recycled, some types of oils can be successfully processed into soap through a process called saponification of fried oils. We can gain a better understanding of how waste resources can be used as feedstocks for commercial products by comparing the composition and characteristics of materials made from common and commercially accessible fresh and cooked waste oils (Gambardella et al., 2023).

4.4 Regression Equation

4.4.1 Appear versus waste oil, aqua, NaOH and dust.

Regression Equation

Appear = 6.96 – 0.0182 Waste Oil – 0.0116 Aqua – 0.022 NaOH + 0.484 Dust

Table 4.16: Coefficient's data for Appear

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	6.96	2.82	2.47	0.028	
Waste Oil	-0.0182	0.0135	-1.35	0.199	1.00
Aqua	-0.0116	0.0233	-0.50	0.628	1.00
NaOH	-0.022	0.117	-0.19	0.850	1.00
Dust	0.484	0.190	2.54	0.025	1.00

Table 4.17: Model Summary's data for Appear.

S	R-sg	R-sg(adj)	R-sg(pred)
0.807470	39.75%	21.21%	0.00%

Table 4.18: Analysis of Variance for Appear

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	4	5.5917	1.39793	2.14	0.133
Waste Oil	1	1.1917	1.19174	1.83	0.199
Aqua	1	0.1610	0.16101	0.25	0.628
NaOH	1	0.0243	0.02430	0.04	0.850
Dust	1	4.2147	4.21476	6.46	0.025
Error	13	8.4761	0.65201		
Lack-of-Fit	10	6.8757	0.68757	1.29	0.466
Pure Error	3	1.6004	0.53348		
Total	17	14.0678			

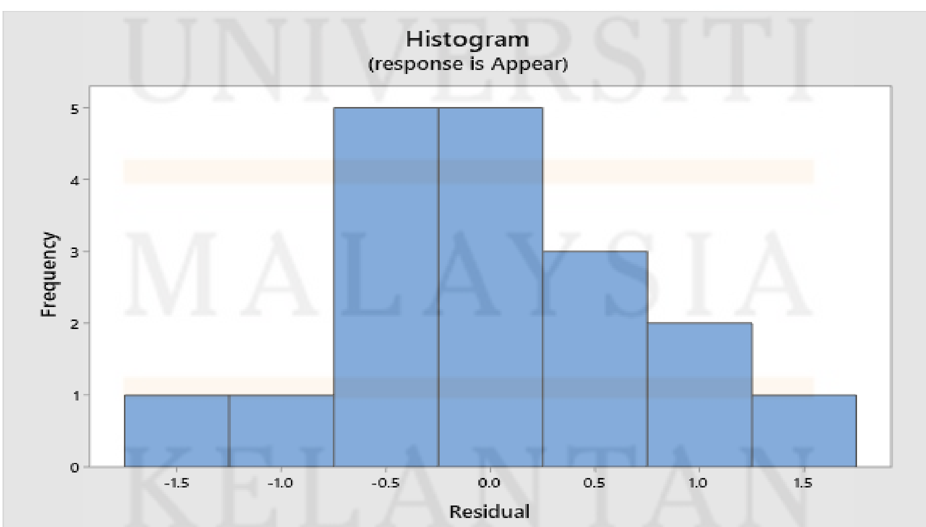

Figure 4.17: Response for Appear

Based on Table 4.16, we can see the coefficients' data based on regression equation. Factors that cause more to appear due to dust, which is as much as 0.484. For standard error coefficients, smaller standard errors usually indicate more accurate and reliable coefficient estimates, a smaller standard error usually indicates a more accurate and reliable coefficient estimate, the smallest error we found in this experiment was waste oil by 0.0135. A low standard error contributes to a high T value, resulting in a lower P value. A low p-value for a coefficient implies that the corresponding independent variable is likely to have a statistically significant effect on the dependent variable. The p-value is below the chosen significance level usually <0.05. In this regression analysis, the p value of 0.025 for the coefficient associated with dust suggests that the effect of waste dust is statistically significant at the 0.05 significance level. This means evidence to reject the null hypothesis that the true coefficient for dust is zero, and that it is possible that waste oil and dust has a meaningful effect on the dependent variable. The Variance Inflation Factor (VIF) is a measure of multicollinearity in regression analysis. A VIF value greater than 1 indicates the presence of multicollinearity, and a VIF greater than 5 is considered cause for concern. The statement shows that all VIF values are 1.00, suggesting very low multicollinearity between the independent variables in this regression model. A VIF value of 1.00 is positive, indicating that multicollinearity is not a significant concern in this regression model. This allows for a more reliable interpretation of the effects of individual variables on the dependent variable.

Based on Figure 4.17, the third bar has a frequency of 5 and a balance of -0.5. For four observations, the model predicted an appear response that was 4.5 units lower than the actual observed value. A negative sign indicates a poor prediction by the model. Residuals approaching zero, that is the fourth bar with a frequency of 6 and a residual of 0 indicate an accurate prediction where the model closely matches the actual data. In the fifth bar with a frequency of 3 and a residual of 0.5, it suggests that for three observations, the model predicted an appear response that was 3.5 units higher than the actual observed value. The positive sign indicates an overprediction by the model.

4.4.2 Aroma versus waste oil, aqua, NaOH and dust

Regression Equation

Aroma = 4.234 + 0.01219 Waste Oil – 0.00817 Aqua – 0.0025 NaOH – 0.1039 Dust

Table 4.19: Coefficient's data for Aroma

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	4.234	0.836	5.06	0.000	
Waste Oil	0.01219	0.00400	3.05	0.009	1.00
Aqua	-0.00817	0.00692	-1.18	0.259	1.00
NaOH	-0.0025	0.0346	-0.07	0.944	1.00
Dust	-0.1039	0.0565	-1.84	0.089	1.00

Table 4.20: Model Summary's data for Aroma

S	R-sg	R-sg(adj)	R-sg(pred)
0.239725	52.02%	37.25%	6.83%

Table 4.21: Analysis of Variance for Aroma

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	4	0.80994	0.202485	3.52	0.037
Waste Oil	1	0.53534	0.535336	9.32	0.009
Aqua	1	0.08003	0.080033	1.39	0.259
NaOH	1	0.00030	0.000300	0.01	0.944
Dust	1	0.19427	0.194272	3.38	0.089
Error	13	0.74709	0.057468		
Lack-of-Fit	10	0.54749	0.054749	0.82	0.646
Pure Error	3	0.19960	0.066533		
Total	17	1.55703			

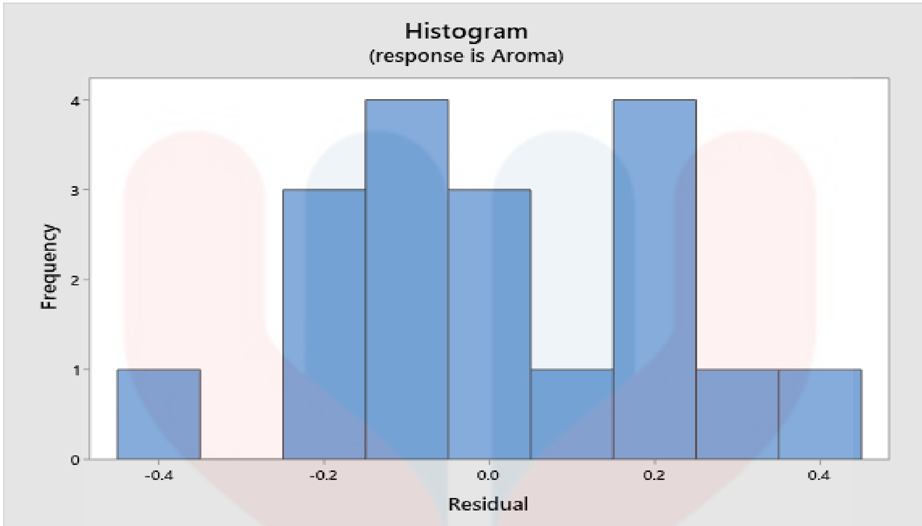

Figure 4.18: Responses for Aroma

Based on Table 4.19. we can see the coefficients' data based on regression equation. Factors that cause more aroma due to waste oil, which is as much as 0.01219. For standard error coefficients, smaller standard errors usually indicate more accurate and reliable coefficient estimates, a smaller standard error usually indicates a more accurate and reliable coefficient estimate, the smallest error we found in this experiment was waste oil by 0.00400. A low standard error contributes to a high T value, resulting in a lower P value. A low p-value for a coefficient implies that the corresponding independent variable is likely to have a statistically significant effect on the dependent variable. The p-value is below the chosen significance level usually <0.05. In this regression analysis, the p value of 0.009 for the coefficient associated with waste oil and value of dust is 0.089 suggests that the effect of waste oil is statistically significant at the 0.05 significance level. This means evidence to reject the null hypothesis that the true coefficient for waste oil and dust is zero, and that it is possible that waste oil and dust has a meaningful effect on the dependent variable. The Variance Inflation Factor (VIF) is a measure of multicollinearity in regression analysis. A VIF value greater than 1 indicates the presence of multicollinearity, and a VIF greater than 5 is considered cause for concern. The statement shows that all VIF values are 1.00, suggesting very low multicollinearity between the independent variables in this regression model. A VIF value of 1.00 is positive, indicating that multicollinearity is not a significant concern in this regression model. This allows for a more reliable interpretation of the effects of individual variables on the dependent variable.

Based on Figure 4.18, the fourth bar has a frequency of 4 and a balance of -0.3. For four observations, the model predicted an aroma response that was 3.7 units lower than the actual observed value. A negative sign indicates a poor prediction by the model. Residuals approaching zero, that is the fifth bar with a frequency of 3 and a residual of 0 indicate an accurate prediction where the model closely matches the actual data. In the sixth bar with a frequency of 4 and a residual of 0.2, it suggests that for three observations, the model predicted an aroma response that was 4.2 units higher than the actual observed value. The positive sign indicates an overprediction by the model.

4.4.3 Texture versus waste oil, aqua, NaOH and dust

Regression Equation

Texture = 6.31 - 0.0123 Waste Oil – 0.0128 Aqua – 0.0162 NaOH + 0.344 Dust

Table 4.22: Coefficient's data for Texture

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	6.31	2.10	3.01	0.010	
Waste Oil	-0.0123	0.0100	-1.22	0.244	1.00
Aqua	-0.0128	0.0174	-0.73	0.476	1.00
NaOH	-0.0162	0.0869	-0.19	0.855	1.00
Dust	0.344	0.142	2.42	0.031	1.00

Table 4.23: Model Summary's data for Texture

S	R-sg	R-sg(adj)	R-sg(pred)
0.602112	37.90%	18.80%	0.00%

Table 4.24: Analysis of Variance for Texture

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	4	2.87665	0.71916	1.98	0.157
Waste Oil	1	0.54023	0.54023	1.49	0.244
Aqua	1	0.19508	0.19508	0.54	0.476
NaOH	1	0.01267	0.01267	0.03	0.855
Dust	1	2.12867	2.12867	5.87	0.031
Error	13	4.71300	0.36254		
Lack-of-Fit	10	4.41655	0.44166	4.47	0.122
Pure Error	3	0.29645	0.09882		
Total	17	7.58965			

Table 4.25: Fits and Diagnostics for Unusual Observations for Texture

Obs	Texture	Fit	Resid	Std Resid
15	6.130	4.871	1.259	2.51 R

R Large residual

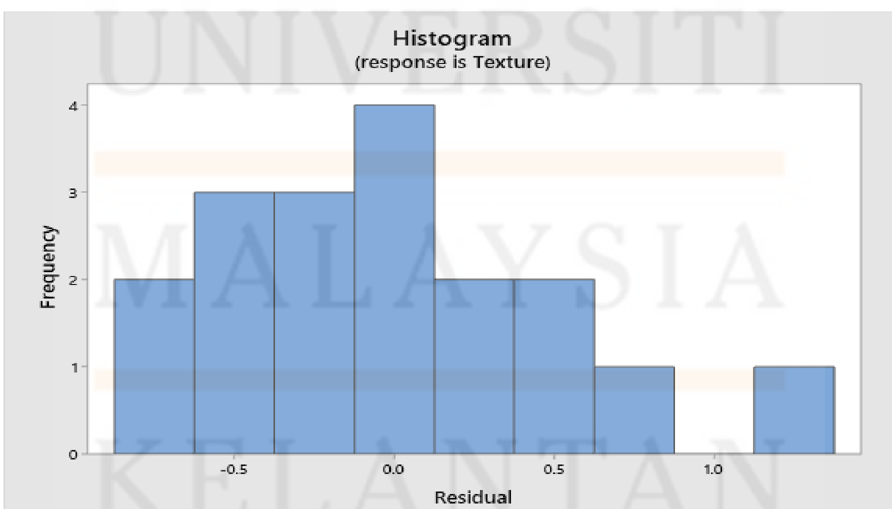

Figure 4.19: Response for Texture

Based on Table 4.22. we can see the coefficients' data based on regression equation. Factors that cause more to texture due to dust, which is as much as 0.344. For standard error coefficients, smaller standard errors usually indicate more accurate and reliable coefficient estimates, a smaller standard error usually indicates a more accurate and reliable coefficient estimate, the smallest error we found in this experiment was waste oil by 0.0100. A low standard error contributes to a high T value, resulting in a lower P value. A low p-value for a coefficient implies that the corresponding independent variable is likely to have a statistically significant effect on the dependent variable. The p-value is below the chosen significance level usually <0.05. In this regression analysis, the p value of 0.031 for the coefficient associated with dust suggests that the effect of dust is statistically significant at the 0.05 significance level. This means evidence to reject the null hypothesis that the true coefficient for dust is zero, and that it is possible that dust has a meaningful effect on the dependent variable. The Variance Inflation Factor (VIF) is a measure of multicollinearity in regression analysis. A VIF value greater than 1 indicates the presence of multicollinearity, and a VIF greater than 5 is considered cause for concern. The statement shows that all VIF values are 1.00, suggesting very low multicollinearity between the independent variables in this regression model. A VIF value of 1.00 is positive, indicating that multicollinearity is not a significant concern in this regression model. This allows for a more reliable interpretation of the effects of individual variables on the dependent variable. For fit and diagnostic was mentioned in Table 4.25, proper expectations in fitted of cost is 4.871 and the residuals is 1.259.

Based on Figure 4.19, the third bar has a frequency of 3 and a balance of -0.75. For four observations, the model predicted a texture response that was 2.25 units lower than the actual observed value. A negative sign indicates a poor prediction by the model. Residuals approaching zero, that is the fourth bar with a frequency of 4 and a residual of 0 indicate an accurate prediction where the model closely matches the actual data. In the fifth bar with a frequency of 2 and a residual of 0.75, it suggests that for three observations, the model predicted a texture response that was 2.75 units higher than the actual observed value. The positive sign indicates an overprediction by the model.

4.4.4 Colour versus waste oil, aqua, NaOH and dust

Regression Equation

Colour = 6.57 + 0.0041 Waste Oil – 0.0101 Aqua – 0.0642 NaOH + 0.185 Dust

Table 4.26: Coefficient's data for Colour

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	6.57	2.33	2.82	0.015	
Waste Oil	0.0041	0.0111	0.36	0.722	1.00
Aqua	-0.0101	0.0193	-0.52	0.610	1.00
NaOH	-0.0642	0.0965	-0.66	0.518	1.00
Dust	0.185	0.158	1.17	0.261	1.00

Table 4.27: Model Summary's data for Colour

S	R-sg	R-sg(adj)	R-sg(pred)
0.668603	14.62%	0.00%	0.00%

Table 4.28: Analysis of Variance for Colour

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	4	0.99490	0.24873	0.56	0.698
Waste Oil	1	0.05921	0.05921	0.13	0.722
Aqua	1	0.12201	0.12201	0.27	0.610
NaOH	1	0.19763	0.19763	0.44	0.518
Dust	1	0.61605	0.61605	1.38	0.261
Error	13	5.81139	0.44703		
Lack-of-Fit	10	4.76694	0.47669	1.37	0.443
Pure Error	3	1.04445	0.34815		
Total	17	6.80629			

Table 4.29: Fits and Diagnostics for Unusual Observations for Colour

Obs	Colour	Fit	Resid	Std Resid
12	4.000	5.184	-1.184	-2.01 R

R Large residual

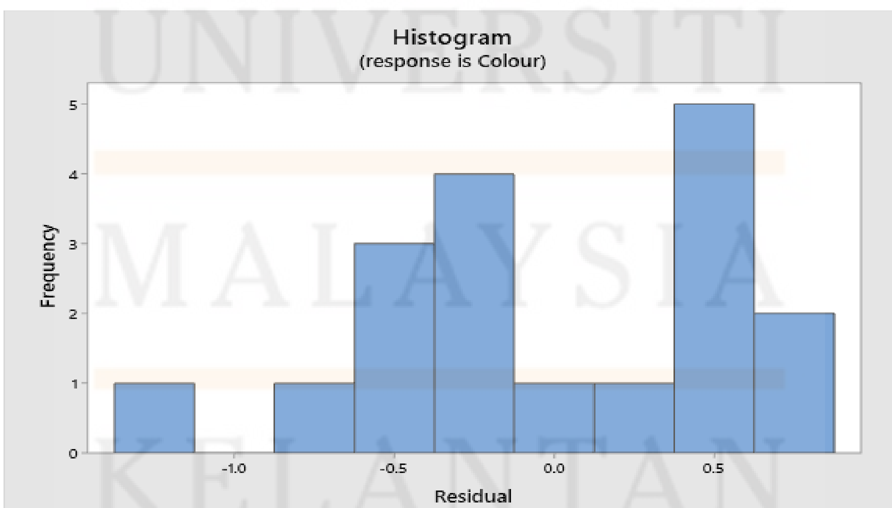

Figure 4.20: Response for Colour

Based on Table 4.26. we can see the coefficients' data based on regression equation. Factors that cause more to colour due to waste oil, which is as much as 0.041 and dust is 0.185. For standard error coefficients, smaller standard errors usually indicate more accurate and reliable coefficient estimates, a smaller standard error usually indicates a more accurate and reliable coefficient estimate, the smallest error we found in this experiment was waste oil by 0.0111. A low standard error contributes to a high T value, resulting in a lower P value. A low p-value for a coefficient implies that the corresponding independent variable is likely to have a statistically significant effect on the dependent variable. The p-value is below the chosen significance level usually <0.05. In this regression analysis, the p value of 0.015 for the coefficient associated with constant suggests that the effect of constant is statistically significant at the 0.05 significance level. This means evidence to reject the null hypothesis that the true coefficient for constant is zero, and that it is possible that waste oil and dust has a meaningful effect on the dependent variable. The Variance Inflation Factor (VIF) is a measure of multicollinearity in regression analysis. A VIF value greater than 1 indicates the presence of multicollinearity, and a VIF greater than 5 is considered cause for concern. The statement shows that all VIF values are 1.00, suggesting very low multicollinearity between the independent variables in this regression model. A VIF value of 1.00 is positive, indicating that multicollinearity is not a significant concern in this regression model. This allows for a more reliable interpretation of the effects of individual variables on the dependent variable. For fit and diagnostic was mentioned in Table 4.29, proper expectations in fitted of cost is 5.842 and the residuals is -0.842.

Based on Figure 4.20, the fifth bar has a frequency of 4 and a balance of -0.75. For four observations, the model predicted a colour response that was 3.25 units lower than the actual observed value. A negative sign indicates a poor prediction by the model. Residuals approaching zero, that is the sixth bar with a frequency of 1 and a residual of 0 indicate an accurate prediction where the model closely matches the actual data. In the eighth bar with a frequency of 5 and a residual of 0.5, it suggests that for three observations, the model predicted a colour response that was 6.0 units higher than the actual observed value. The positive sign indicates an overprediction by the model.

4.4.5 Foam versus waste oil, aqua, NaOH and dust

Regression Equation

Foam Stability = 4.7 + 0.376 Waste Oil + 0.673 Aqua – 0.24 NaOH – 8.00 Dust

Table 4.30: Coefficient's data for Foam

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	4.7	72.6	0.06	0.949	
Waste Oil	0.376	0.347	1.08	0.299	1.00
Aqua	0.673	0.601	1.12	0.283	1.00
NaOH	-0.24	3.00	-0.08	0.938	1.00
Dust	-8.00	4.90	-1.63	0.127	1.00

Table 4.31: Model Summary's data for Foam

S	R-sg	R-sg(adj)	R-sg(pred)
20.8098	28.16%	6.05%	0.00%

Table 4.32: Analysis of Variance for Foam

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	4	2206.51	551.63	1.27	0.330
Waste Oil	1	507.75	507.75	1.17	0.299
Aqua	1	544.05	544.05	1.26	0.283
NaOH	1	2.71	2.71	0.01	0.938
Dust	1	1152.00	1152.00	2.66	0.127
Error	13	5629.65	433.05		
Lack-of-Fit	10	3513.30	351.33	0.50	0.823
Pure Error	3	2116.35	705.45		
Total	17	7836.16			

Table 4.33: Fits and Diagnostics for Unusual Observations for Foam

Obs	Foam Stability	Fit	Resid	Std Resid
2	26.7	77.1	-50.4	-2.61 R

R Large residual

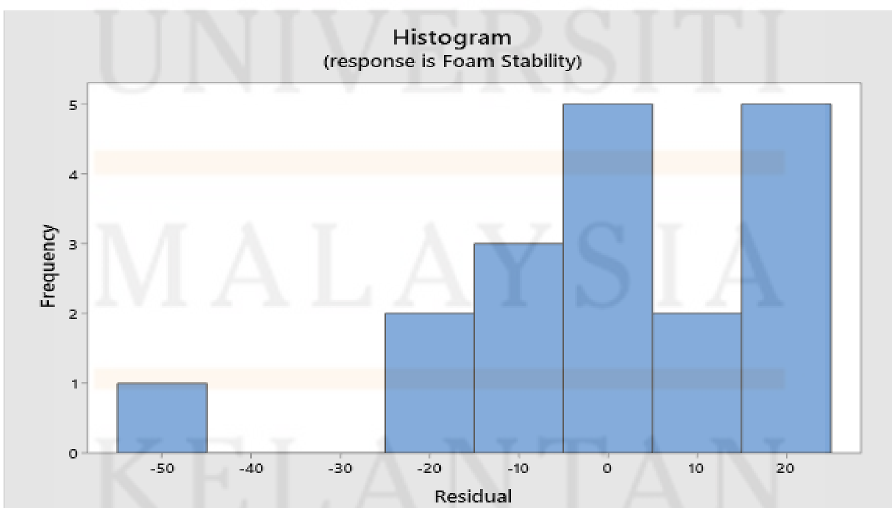

Figure 4.21: Response for Foam

Based on Table 4.30, we can see the coefficients' data based on regression equation. Factors that cause more to foam due to waste oil, which is as much as 0.376 and aqua is 0.673. For standard error coefficients, smaller standard errors usually indicate more accurate and reliable coefficient estimates, a smaller standard error usually indicates a more accurate and reliable coefficient estimate, the smallest error we found in this experiment was waste oil by 0.347. A low standard error contributes to a high T value, resulting in a lower P value. A low p-value for a coefficient implies that the corresponding independent variable is likely to have a statistically significant effect on the dependent variable. The p-value is below the chosen significance level usually <0.05. In this regression analysis, the whole p-value have 0.05>. indicates that there is insufficient evidence to reject the null hypothesis. In this regression analysis, a high p-value for the coefficient implies that the corresponding variable may not have a statistically significant effect on the dependent variable. The Variance Inflation Factor (VIF) is a measure of multicollinearity in regression analysis. A VIF value greater than 1 indicates the presence of multicollinearity, and a VIF greater than 5 is considered cause for concern. The statement shows that all VIF values are 1.00, suggesting very low multicollinearity between the independent variables in this regression model. A VIF value of 1.00 is positive, indicating that multicollinearity is not a significant concern in this regression model. This allows for a more reliable interpretation of the effects of individual variables on the dependent variable. For fit and diagnostic was mentioned in Table 4.33, proper expectations in fitted of foam stability is 77.1 and the residuals is -50.4.

Based on Figure 4.21, the fifth bar has a frequency of 3 and a balance of -10. For four observations, the model predicted a texture response that was 7 units lower than the actual observed value. A negative sign indicates a poor prediction by the model. Residuals approaching zero, that is the sixth bar with a frequency of 5 and a residual of 0 indicate an accurate prediction where the model closely matches the actual data. In the eighth bar with a frequency of 5 and a residual of 20, it suggests that for three observations, the model predicted a foam response that was 25 units higher than the actual observed value. The positive sign indicates an overprediction by the model.

4.4.6 Microbe versus waste oil, aqua, NaOH and dust

Regression Equation

Microbe = 9.7 - 0.1332 Waste Oil + 0.0000 Aqua – 0.083 NaOH + 0.999 Dust

Table 4.34: Coefficient's data for Microbe

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	9.7	12.8	0.76	0.460	
Waste Oil	-0.1332	0.0612	-2.18	0.049	1.00
Aqua	0.0000	0.106	0.00	1.000	1.00
NaOH	-0.083	0.530	-0.16	0.877	1.00
Dust	0.999	0.865	1.15	0.269	1.00

Table 4.35: Model Summary's data for Microbe

S	R-sg	R-sg(adj)	R-sg(pred)
3.67138	31.91%	10.69%	0.00%

Table 4.36: Analysis of Variance for Microbe

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	4	82.144	20.5334	1.52	0.253
Waste Oil	1	63.840	68.8401	4.74	0.049
Aqua	1	0.000	0.0000	0.00	1.000
NaOH	1	0.333	0.3333	0.02	0.877
Dust	1	17.960	13.4790	1.33	0.269
Error	13	175.227	17.9600		
Lack-of-Fit	10	175.277	17.5227	*	*
Pure Error	3	0.000	0.0000		
Total	17	257.360			

Table 4.37: Fits and Diagnostics for Unusual Observations for Microbe

Obs	Microbe	Fit	Resid	Std Resid
16	0.01	6.17	-6.16	-2.15 R

R Large residual

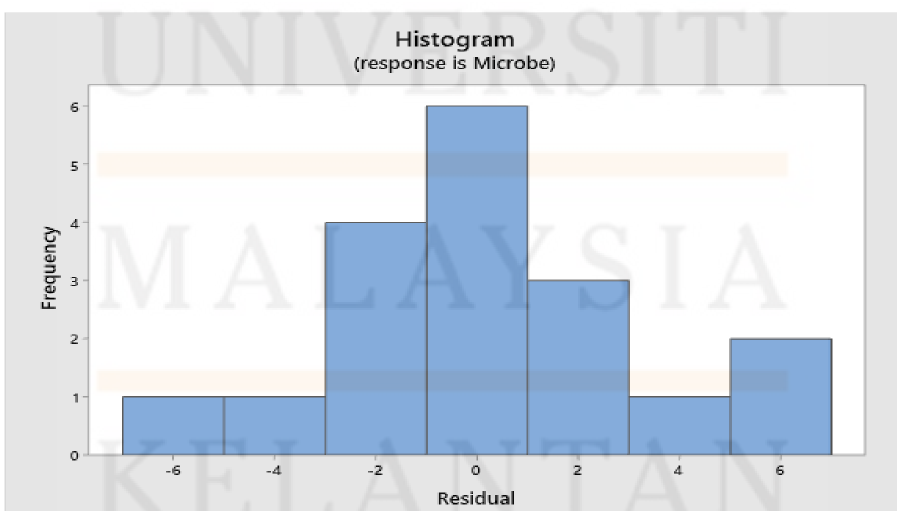

Figure 4.22: Response for Microbe

Based on Table 4.34, we can see the coefficients' data based on regression equation. Factors that cause more to appear due to dust, which is as much as 0.999. For standard error coefficients, smaller standard errors usually indicate more accurate and reliable coefficient estimates, a smaller standard error usually indicates a more accurate and reliable coefficient estimate, the smallest error we found in this experiment was waste oil by 0.0612. A low standard error contributes to a high T value, resulting in a lower P value. A low p-value for a coefficient implies that the corresponding independent variable is likely to have a statistically significant effect on the dependent variable. The p-value is below the chosen significance level usually <0.05. In this regression analysis, the p value of 0.049 for the coefficient associated with waste oil suggests that the effect of waste oil is statistically significant at the 0.05 significance level. This means evidence to reject the null hypothesis that the true coefficient for dust is zero, and that it is possible that waste oil and dust has a meaningful effect on the dependent variable. The Variance Inflation Factor (VIF) is a measure of multicollinearity in regression analysis. A VIF value greater than 1 indicates the presence of multicollinearity, and a VIF greater than 5 is considered cause for concern. The statement shows that all VIF values are 1.00, suggesting very low multicollinearity between the independent variables in this regression model. A VIF value of 1.00 is positive, indicating that multicollinearity is not a significant concern in this regression model. This allows for a more reliable interpretation of the effects of individual variables on the dependent variable. For fit and diagnostic was mentioned in Table 4.37, proper expectations in fitted of microbe is 6.17 and the residuals is -6.16.

Based on Figure 4.22, the third bar has a frequency of 4 and a balance of -2. For four observations, the model predicted a texture response that was 2 units lower than the actual observed value. A negative sign indicates a poor prediction by the model. Residuals approaching zero, that is the fourth bar with a frequency of 4 and a residual of 0 indicate an accurate prediction where the model closely matches the actual data. In the fifth bar with a frequency of 3 and a residual of 2, it suggests that for three observations, the model predicted a microbe response that was 5 units higher than the actual observed value. The positive sign indicates an overprediction by the model.

4.4.7 pH versus waste oil, aqua, NaOH and dust

Regression Equation

pH = 17.14 + 0.0028 Waste Oil - 0.0333 Aqua – 0.167 NaOH + 0.278 Dust

Table 4.38: Coefficient's data for cost

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	17.14	3.73	4.60	0.001	
Waste Oil	0.0028	0.0178	0.16	0.879	1.00
Aqua	-0.0333	0.0309	-1.08	0.300	1.00
NaOH	-0.167	0.154	-1.08	0.300	1.00
Dust	0.278	0.252	1.10	0.290	1.00

Table 4.39: Model summary's data for cost

S	R-sg	R-sg(adj)	R-sg(pred)
1.06919	21.55%	0.00%	0.00%

Table 4.40: Analysis of Variance for cost

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	4	4.0833	1.02083	0.89	0.496
Waste Oil	1	0.0278	0.02778	0.02	0.879
Aqua	1	1.3333	1.33333	1.17	0.300
NaOH	1	1.3333	1.33333	1.17	0.300
Dust	1	1.3889	1.38889	1.21	0.290
Error	13	14.8611	1.14316		
Lack-of-Fit	10	10.3611	1.03611	0.69	0.713
Pure Error	3	4.5000	1.50000		
Total	17	18.9444			

Table 4.41: Fits and Diagnostics for Unusual Observations for cost

Obs	pH	Fit	Resid	Std Resid
6	9.000	11.139	-2.139	-2.40 R
18	10.000	11.944	-1.944	-2.18

R Large residual

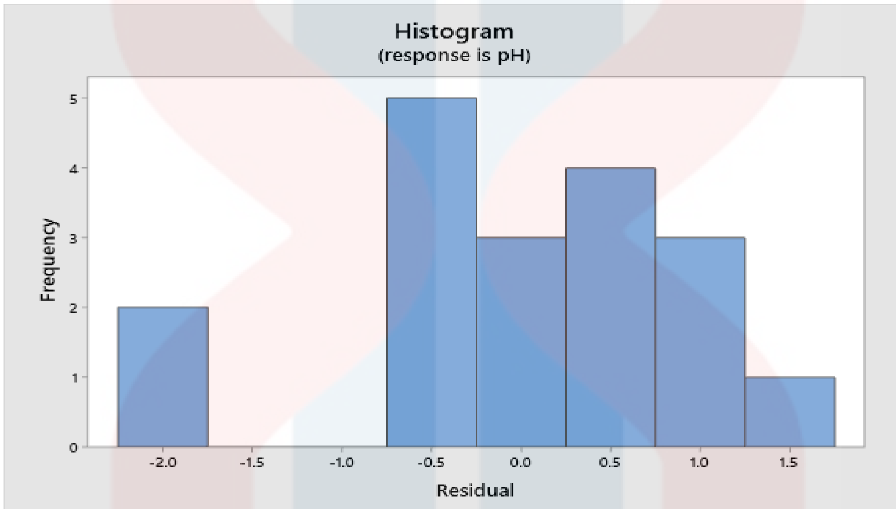

Figure 4.23: Response for pH

Based on Table 4.38, we can see the coefficients' data based on regression equation. Factors that cause more to pH due to dust, which is as much as 0.278 and waste oil which is 0.0028. For standard error coefficients, smaller standard errors usually indicate more accurate and reliable coefficient estimates, a smaller standard error usually indicates a more accurate and reliable coefficient estimate, the smallest error we found in this experiment was waste oil by 0.0178. A low standard error contributes to a high T value, resulting in a lower P value. A low p-value for a coefficient implies that the corresponding independent variable is likely to have a statistically significant effect on the dependent variable. The p-value is below the chosen significance level usually <0.05. In this regression analysis, the whole p-value have 0.05>. indicates that there is insufficient evidence to reject the null hypothesis. In this regression analysis, a high p-value for the coefficient implies that the corresponding variable may not have a statistically significant effect on the dependent variable. The Variance Inflation Factor (VIF) is a measure of multicollinearity in regression analysis. A VIF value greater than 1 indicates the presence of multicollinearity, and a VIF greater than 5 is considered cause for concern. The statement shows that all VIF values are

1.00, suggesting very low multicollinearity between the independent variables in this regression model. A VIF value of 1.00 is positive, indicating that multicollinearity is not a significant concern in this regression model. This allows for a more reliable interpretation of the effects of individual variables on the dependent variable. For fit and diagnostic was mentioned in Table 4.41, proper expectations in fitted of cost for observation 6 is 11.139 and the residuals is -2.139. For observation 18, for fitted is 11.944 and the residuals -1.944.

Based on Figure 4.23, the fourth bar has a frequency of 5 and a balance of -0.5. For four observations, the model predicted a texture response that was 4.5 units lower than the actual observed value. A negative sign indicates a poor prediction by the model. Residuals approaching zero, that is the fifth bar with a frequency of 3 and a residual of 0 indicate an accurate prediction where the model closely matches the actual data. In the sixth bar with a frequency of 4 and a residual of 0.5, it suggests that for three observations, the model predicted a microbe response that was 4.5 units higher than the actual observed value. The positive sign indicates an overprediction by the model.

4.4.8 Moisture content versus waste oil, aqua, NaOH and dust

Regression Equation

Moisture content = 12.3 - 0.004 Waste Oil + 0.362 Aqua – 0.92 NaOH + 5.49 Dust

Table 4.42: Coefficient's data for Moisture content

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	12.3	36.5	0.34	0.741	
Waste Oil	-0.004	0.174	-0.03	0.980	1.00
Aqua	0.362	0.302	1.20	0.252	1.00
NaOH	-0.92	1.51	-0.61	0.554	1.00
Dust	5.49	2.46	2.23	0.044	1.00

Table 4.43: Model Summary's data for Moisture content

S	R-sg	R-sg(adj)	R-sg(pred)
10.4567	34.25%	14.02%	0.00%

Table 4.44: Analysis of Variance for Moisture content

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	4	740.40	185.009	1.69	0.211
Waste Oil	1	0.07	0.070	0.00	0.980
Aqua	1	157.47	157.470	1.44	0.252
NaOH	1	40.44	40.443	0.37	0.554
Dust	1	542.41	542.412	4.96	0.044
Error	13	1421.44	109.342		
Lack-of-Fit	10	743.64	74.364	0.33	0.920
Pure Error	3	677.80	225.934		
Total	17	2161.84			

Table 4.45: Fits and Diagnostics for Unusual Observations for Moisture content

Obs	Moisture content	Fit	Resid	Std Resid
6	5.54	27.23	-21.69	-2.49 R

R Large residual

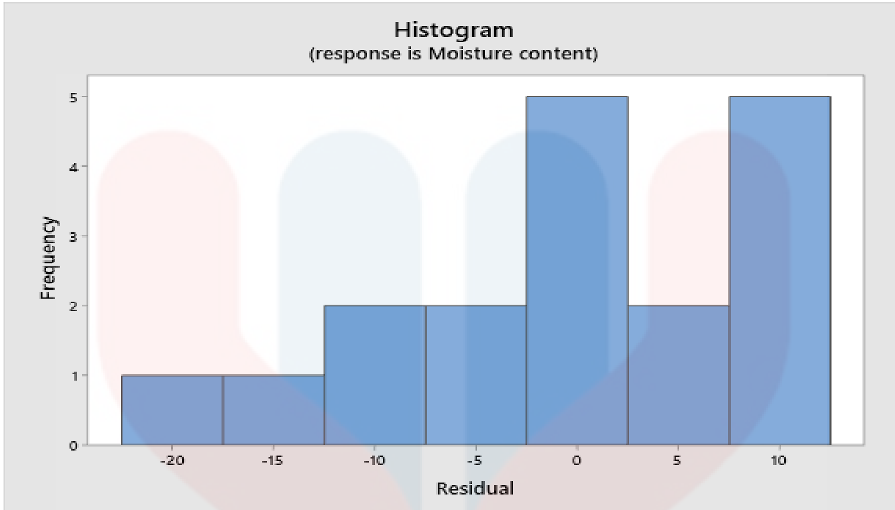

Figure 4.24: Response for Moisture Content

Based on Table 4.42, we can see the coefficients' data based on regression equation. Factors that cause more to moisture content due to aqua, which is as much as 0.362 and dust is 5.49. For standard error coefficients, smaller standard errors usually indicate more accurate and reliable coefficient estimates, a smaller standard error usually indicates a more accurate and reliable coefficient estimate, the smallest error we found in this experiment was waste oil by 0.174. A low standard error contributes to a high T value, resulting in a lower P value. A low p-value for a coefficient implies that the corresponding independent variable is likely to have a statistically significant effect on the dependent variable. The p-value is below the chosen significance level usually <0.05. In this regression analysis, the p value of 0.044 for the coefficient associated with dust suggests that the effect of dust is statistically significant at the 0.05 significance level. This means evidence to reject the null hypothesis that the true coefficient for dust is zero, and that it is possible that waste oil and dust has a meaningful effect on the dependent variable. The Variance Inflation Factor (VIF) is a measure of multicollinearity in regression analysis. A VIF value greater than 1 indicates the presence of multicollinearity, and a VIF greater than 5 is considered cause for concern. The statement shows that all VIF values are 1.00, suggesting very low multicollinearity between the independent variables in this regression model. A VIF value of 1.00 is positive, indicating that multicollinearity is not a significant concern in this regression model. This allows for a more reliable interpretation of the effects of individual variables on the dependent variable. For fit and diagnostic was mentioned in Table 4.45, proper expectations in fitted of moisture content is 27.23 and the residuals is -21.69.

Based on Figure 4.24, the third bar has a frequency of 2 and a balance of -10. For four observations, the model predicted a moisture content response that was 8 units lower than the actual observed value. A negative sign indicates a poor prediction by the model. Residuals approaching zero, that is the fifth bar with a frequency of 5 and a residual of 0 indicate an accurate prediction where the model closely matches the actual data. In the seventh bar with a frequency of 5 and a residual of 10, it suggests that for three observations, the model predicted a moisture content response that was 15 units higher than the actual observed value. The positive sign indicates an overprediction by the model.

4.4.9 Cost versus waste oil, aqua, NaOH and dust

Regression Equation

Cost = 5.15 - 0.00875 Waste Oil + 0.0120 Aqua + 0.0150 NaOH + 0.3200 Dust

Table 4.46: Coefficient's data for Cost

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	5.15	1.31	3.92	0.002	
Waste Oil	-0.00875	0.00628	-1.39	0.187	1.00
Aqua	0.0120	0.0109	1.10	0.290	1.00
NaOH	0.0150	0.0544	0.28	0.787	1.00
Dust	0.3200	0.0889	3.60	0.003	1.00

Table 4.47: Model Summary's data for Cost

S	R-sg	R-sg(adj)	R-sg(pred)
0.377071	55.47%	41.77%	23.53%

Table 4.48: Analysis of Variance for Cost

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	4	2.30242	0.57561	4.05	0.024
Waste Oil	1	0.27563	0.27563	1.94	0.187
Aqua	1	0.17280	0.17280	1.22	0.290
NaOH	1	0.01080	0.01080	0.08	0.787
Dust	1	1.84320	1.84320	12.96	0.003
Error	13	1.84838	0.14218		
Lack-of-Fit	10	0.66038	0.06604	0.17	0.987
Pure Error	3	1.18800	0.39600		
Total	17	4.15080			

Table 4.49: Fits and Diagnostics for Unusual Observations for Cost

Obs	Cost	Fit	Resid	Std Resid
2	5.000	5.842	-0.842	-2.41 R

R Large residual

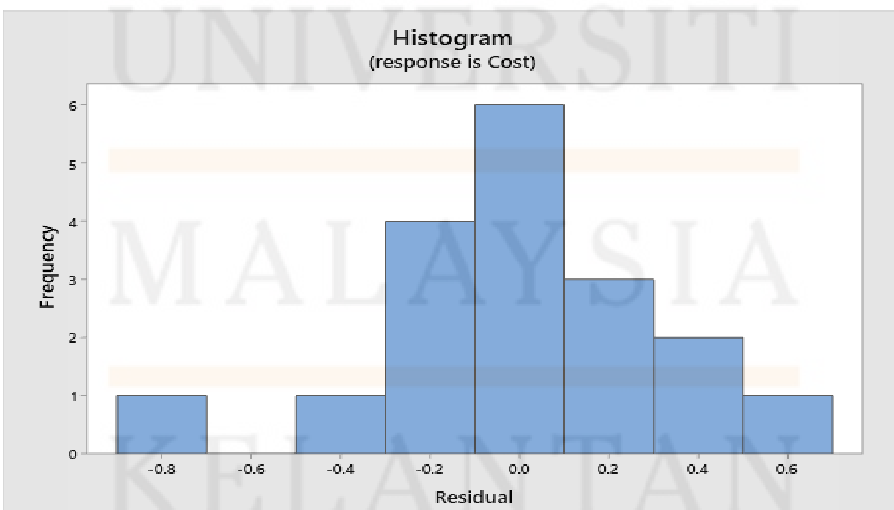

Figure 4.25: Response for Cost

Based on Table 4.46, we can see the coefficients' data based on regression equation. Factors that cause more to cost due to aqua, which is as much as 0.0120. Another factor is NaOH is 0.0150 and dust is 0.3200. For standard error coefficients, smaller standard errors usually indicate more accurate and reliable coefficient estimates, a smaller standard error usually indicates a more accurate and reliable coefficient estimate, the smallest error we found in this experiment was waste oil by 0.00628. A low standard error contributes to a high T value, resulting in a lower P value. A low p-value for a coefficient implies that the corresponding independent variable is likely to have a statistically significant effect on the dependent variable. The p-value is below the chosen significance level usually <0.05. In this regression analysis, the p value of 0.003 for the coefficient associated with dust suggests that the effect of dust is statistically significant at the 0.05 significance level. This means evidence to reject the null hypothesis that the true coefficient for dust is zero, and that it is possible that dust has a meaningful effect on the dependent variable. The Variance Inflation Factor (VIF) is a measure of multicollinearity in regression analysis. A VIF value greater than 1 indicates the presence of multicollinearity, and a VIF greater than 5 is considered cause for concern. The statement shows that all VIF values are 1.00, suggesting very low multicollinearity between the independent variables in this regression model. A VIF value of 1.00 is positive, indicating that multicollinearity is not a significant concern in this regression model. This allows for a more reliable interpretation of the effects of individual variables on the dependent variable. For fit and diagnostic was mentioned in Table 4.49, proper expectations in fitted of cost is 5.842 and the residuals is -0.842.

Based on Figure 4.25, the fourth bar has a frequency of 4 and a balance of -0.2. For four observations, the model predicted a cost response that was 3.8 units lower than the actual observed value. A negative sign indicates a poor prediction by the model. Residuals approaching zero, that is the fifth bar with a frequency of 6 and a residual of 0 indicate an accurate prediction where the model closely matches the actual data. In the seventh bar with a frequency of 3 and a residual of 0.2, it suggests that for three observations, the model predicted a cost response that was 3.2 units higher than the actual observed value. The positive sign indicates an overprediction by the model.

The regression analysis findings unveil a nuanced understanding of the intricate dynamics shaping key attributes in bar soap production, particularly emphasizing the role of particulate matter, notably dust, in influencing soap appearance. Dust emerges as a pivotal factor, underscoring its significance in creating a visually dynamic and textured surface. This textured quality attributed to dust becomes a distinguishing and unique feature, carrying implications for market competitiveness and consumer appeal (Von Holdt et al., 2019). The influential role of dust in shaping soap appearance is underscored, highlighting its pivotal contribution to creating a visually dynamic and textured surface. This distinctive quality attributed to dust becomes a hallmark feature, bearing implications for market competitiveness and consumer appeal. The prominence of dust's influence on soap appearance implies that the incorporation of particulate matter extends beyond functional considerations, reaching into the realm of aesthetics. The introduction of a textured surface by dust imparts a unique visual character to the soap, the size, shape, and elemental content of dust particles vary. Alkaline metal and other soluble particles make up dust. By creating covalent connections between the mud and the solid surface, the soluble component changes the base of the solution and increases the surface. As a result, mud residues that stick to the substrate surface alter its texture, optical and tribological qualities, and surface hydrophobicity, among other chemical and physical features. Such a modification may lessen the solid substrate's effectiveness in a particular bar soap (Yilbas et al., 2019). In the context of appearance, the Standard Error (SE) analysis serves to gauge the reliability of the estimated impact of waste oil on the visual characteristics of the soap. Usually generated when the soap is cooled down too quickly during the manufacturing process, the Glycerine River is a visible layer of glycerine that flows through the soap and gives it a transparent or translucent appearance. The chance of Glycerine Rivers developing could be impacted by the usage of infused waste cooking oil in soap production. A tiny pocket or hollow known as a "lye pocket" develops in soap when there is too much lye added to the mixture. The risk of Lye Pockets is not always increased when leftover cooking oil is used to make soap. When soap is subjected to excessive humidity or is cooled too slowly, a process known as jellying takes place, giving the soap a mottled or uneven look and making it mushy and jelly-like (Rasyidi, 2023). A lower SE signifies a more precise estimate, indicating a robust influence of waste oil on appearance. This precision suggests that waste oil consistently contributes to the creation of a visually dynamic and textured surface, further aligning the soap with the preferences of consumers seeking unique and engaging products.

Shifting the focus to aroma, the pivotal influence of waste oil is underscored, recognized for its distinct and pleasant fragrance sourced from cooking processes or industrial activities. Waste oil enhances the soap's sensory experience by contributing to a delightful aroma, enriching the overall appeal of the product and creating a unique olfactory experience for consumers. This discussion on waste oil's influence on aroma brings attention to the sensory dimension of soap. Standard Error (SE) scrutiny further validates the reliability of waste oil's impact on fragrance. A lower SE in this context implies a more dependable estimate, reinforcing the notion that waste oil consistently contributes to a distinct and pleasant aroma, thereby enriching the sensory experience of the soap. The produced coconut oil had an unusual fruity and floral aroma due to the significant rise in major esters such as ethyl acetate, butanoic acid methyl ester, 3-methyl butanoic acid ethyl ester, and hexanoic acid ethyl ester following fermentation (Zhang et al., 2020). The psychophysiological processes of humans are significantly influenced by the aromatic qualities of these goods. Consumers are exposed to waste oil through skin contact and inhalation. The components of waste oil have certain molecular characteristics that give them sensory qualities. Its low polarity, relatively high vapour pressure, some fat-solving capacity, and surface activity are all present. Up to the end of the 19th century, natural scents from plants and animals were the most common. Nowadays, synthetic scents are used more often than natural ones because of their consistent and dependable quality (Sowndhararajan, 2016)

Texture, considered a critical aspect of user satisfaction, stands out as a key attribute influenced by the presence of dust. Particulate additives, such as dust, play a crucial role in contributing to tactile qualities, ultimately creating a textured surface that is anticipated to resonate positively with consumers. The discussion regarding the influence of dust on texture underscores the thoughtful consideration given to tactile experiences in soap formulation. The textured surface introduced by dust adds a layer of complexity to the soap, setting it apart in a competitive market where sensory experiences significantly influence consumer preferences. In the context of texture, a critical attribute, the Standard Error (SE) analysis provides insights into the reliability of waste oil's influence on tactile qualities. A lower SE in this context indicates a more precise estimate, reinforcing the understanding that waste oil consistently plays a significant role in shaping the textured surface of the soap, positively enhancing the user's sensory experience.

Colour, recognized as a fundamental element in soap aesthetics, exemplifies the collaborative influence of waste oil and dust. Waste oil contributes colour richness, while dust introduces natural hues, resulting in a diverse and visually appealing colour palette. This harmonious blend is strategically chosen to cater to consumer preferences for vibrant and natural variations, aligning the soap with contemporary aesthetic trends. The discussion on the collaborative influence of waste oil and dust on soap colour emphasizes the intentional selection of ingredients to achieve a visually appealing product. Study is done on how this procedure affects the regenerated waste cooking oil's density, flash point, and colour. The flash point and density of WCO are crucial aspects of the finished product since it is frequently utilised as a raw material to produce bio-lubricants. Furthermore, the colour indicates the elimination of waxes and other undesirable substances (Mannu et al., 2018). The combination of waste oil's colour enhancing properties with the natural hues introduced by dust showcases soap manufacturers' efforts to create a diverse and aesthetically pleasing colour palette. The analysis extends to the realm of colour, where the Standard Error (SE) helps evaluate the precision of waste oil's impact on the soap's visual palette. A lower SE signifies a more reliable estimate, suggesting that waste oil consistently collaborates with other factors to create a diverse and visually appealing colour palette in the soap.

The significance of foam in soap formulation, crucial for user satisfaction, is highlighted with both waste oil and aqua playing vital roles. Waste oil contributes to stability and lathering properties, while aqua influences overall foam quality. In the context of soap formulation, the discussion on the significance of foam underscores the dual influence of waste oil and aqua. Waste oil's contribution to stability and lathering properties speaks to its role in enhancing the functional aspects of the soap, ensuring that it effectively cleanses. On the other hand, aqua's influence on overall foam quality suggests its impact on the sensory experience during use. The call for striking a delicate balance emphasizes the intricate formulation process that soap manufacturers undertake. Achieving the right combination of waste oil and aqua is crucial for optimizing both the functional and sensory aspects of the soap. The stabilising effect of particles on foams and emulsions is determined by their energy of attachment to a fluid-liquid interface, which is based on their hydrophilicity or hydrophobicity towards water or oil at the interface. A particle's wettability, as measured by the contact angle with water, determines its hydrophobicity. In general, hydrophilic particles prefer to stay in water, while hydrophobic particles typically have quite large contact angles and preferring to stay in oil. Particles that are hydrophilic and intermediately hydrophobic can stabilise foams. They can build up and impede the aqueous phase's film drainage as well, stabilising liquid films by dividing bubbles and encircling them with dense, coherent particle shells (Amani et al., 2022). In the context of foam, Standard Error (SE) analysis is instrumental in understanding the reliability of waste oil's influence on lathering properties. A lower SE suggests a more precise estimate, affirming that waste oil consistently contributes to stability and lathering properties, ensuring an effective and enjoyable lathering experience during soap use.

The discussion on microbial content's influence by waste oil and NaOH underscores key factors contributing to the soap's hygiene aspect. Waste oil, known for its potential antimicrobial properties, brings an additional layer of cleanliness to the soap formulation. In light of previous studies, the rough evaluation of the antimicrobial efficiency of soaps produced from different oils reveals that palm oil-based soaps exhibit the least effectiveness (Antonic et al., 2021). In parallel, NaOH's role in influencing microbial content emphasizes its significance in maintaining cleanliness. As a fundamental component in soap-making, NaOH contributes to the soap's alkalinity, creating an environment less conducive to microbial growth. According to other research, NaOH was noted to exhibit the most potent antimicrobial activity (Zhu et al., 2019). This dual influence of waste oil and NaOH on microbial content showcases a holistic approach to ensuring the soap's effectiveness in promoting cleanliness. The discussion on pH levels reveals a nuanced understanding of how waste oil and dust collectively shape the chemical composition of the soap. Waste oil, introducing fatty acids, has a specific impact on the soap's acidity (Punvichai & Pioch, 2019). This aspect is crucial as it influences the overall pH level, ensuring that the soap maintains a balance that is compatible with the skin. Simultaneously, the influence of dust in altering the alkaline balance adds another layer of complexity to the soap's pH composition (CP et al., 2021). The joint influence of waste oil and dust reflects a careful and deliberate consideration of the chemical components. This meticulous approach is aimed at creating a soap with a pH level that not only ensures effective cleansing but also prioritizes user safety and comfort. The emphasis on maintaining a skin-compatible pH level is significant in the context of soap formulation. It aligns with consumer expectations for skincare products that not only deliver cleanliness but also consider the physiological aspects of the skin. Microbial content and pH levels, vital for hygiene, are subject to Standard Error (SE) analysis to assess the reliability of waste oil's impact. A lower SE in these dimensions implies more precise estimates, highlighting the consistent contribution of waste oil to the soap's cleanliness and pH balance.

The discussion on moisture content delves into the dual influence of aqua and dust, highlighting their respective roles in shaping the hydrating properties of the soap. Aqua's direct contribution to moisture content is fundamental, providing a hydrating element that is essential for skincare (Aguiar et al., 2022). This direct influence aligns with consumer expectations for soaps to offer not only cleansing but also a moisturizing effect. Furthermore, the acknowledgment of dust enhancing the soap's ability to retain moisture adds another layer to the discussion. This dual influence underscores a holistic approach to skincare, emphasizing the soap's role in not just cleaning the skin but also nourishing it. The consideration of both aqua and dust in the formulation reflects a commitment to meeting consumer expectations for a comprehensive and high-quality product. SE analysis extends to moisture content, evaluating the precision of waste oil's impact on hydrating properties. A lower SE suggests a more reliable estimate, reinforcing the understanding that waste oil consistently contributes to the soap's ability to cleanse and nourish the skin.

The examination of the cost of production sheds light on the intricate dynamics influenced by aqua, NaOH, and dust. Aqua and NaOH, recognized as fundamental components in soap formulation, are directly acknowledged for their impact on the soap's chemistry and manufacturing process. These elements play pivotal roles in determining the soap's chemical composition, alkalinity, and overall functionality, making them indispensable in the production process. The strategic consideration of dust in the cost analysis underscores its role in contributing to cost efficiencies without imposing a significant burden on production expenses. This highlights a thoughtful approach to ingredient selection, where dust not only enhances certain qualities in the soap but does so in a manner that aligns with economic considerations. The inclusion of dust as a cost-effective component demonstrates a nuanced understanding of how ingredient choices can influence the overall economic viability of soap production. This discussion reflects the soap manufacturer's commitment to optimizing the production process, balancing the functional and economic aspects of ingredient selection. By acknowledging the role of aqua, NaOH, and dust in the cost of production, the soap formulation aims to strike a delicate equilibrium between quality and cost-effectiveness, ensuring a competitive and sustainable position in the market. In the context of cost, SE analysis assesses the reliability of waste oil's influence on production expenses. A lower SE indicates a more precise estimate, affirming the consistent impact of waste oil on cost efficiencies without significantly increasing production expenses. In summary, the analysis of Standard Error provides a nuanced evaluation of the reliability and precision of waste oil's influence on various attributes in bar soap production. The lower the SE, the more dependable the estimate, reinforcing the consistent and robust role of waste oil in shaping the diverse facets of the soap.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In conclusion, this study investigated the development of a bar soap formulation with the addition of agarwood using the Taguchi design of experiment (DOE) method. The aim was to optimize mechanical properties such as pH, moisture content, foaming, and antimicrobial properties, while also considering cost. Additionally, user satisfaction with the developed product was assessed using a Hedonic Test questionnaire.

The results of the study revealed several key findings. Sample 15 was identified as having the best appearance, texture, and color, indicating its overall superior visual and tactile qualities. Sample 13 was favored for its aroma, suggesting that the addition of agarwood contributed positively to the scent profile of the soap. Samples 6 and 18 exhibited optimal pH levels, which are crucial for ensuring the soap is gentle on the skin. Samples 4 and 5 demonstrated the highest foaming capacity, with a 90% foam rating, indicating good lathering properties. Sample 17 showed the best antimicrobial properties, with a clear zone of 9 mm, suggesting effective germ-fighting capabilities. Sample 1 was deemed the most cost-effective, priced at RM 5.48, making it an economically viable option. Finally, sample 18 had the highest moisture content at 49.31%, indicating its potential to hydrate and moisturize the skin effectively.

The optimized soap formulation based on the Taguchi method would be sample 15 for its superior appearance, texture, and color, sample 13 for aroma, samples 6 and 18 for pH balance, samples 4 and 5 for foaming ability, sample 17 for antimicrobial efficacy, and sample 1 for cost-effectiveness. These findings suggest that the developed soap formulation has the potential to meet the desired mechanical properties and user satisfaction.

In summary, this study provided valuable insights into the strategic decisions and meticulous considerations involved in soap development. The application of the Taguchi method, coupled with in-depth analyses, allowed for the optimization of soap formulations, emphasizing quality, user satisfaction, and cost-effectiveness. The findings of this study contribute to the broader understanding of soap manufacturing processes and offer practical implications for soap producers seeking to enhance their products in a competitive market.

5.2 Recommendations

Based on the comprehensive findings of this study, several recommendations are proposed to further optimize soap development and production processes. Firstly, considering the positive impact of waste oil on various soap attributes, it is recommended that soap manufacturers continue to incorporate waste oil strategically in their formulations. Waste oil has demonstrated its efficacy in enhancing aroma, texture, color, foam, and microbial properties, aligning with consumer preferences for high-quality and multifunctional soap products.

Secondly, the strategic use of dust, as indicated by its effectiveness in cost optimization, should be carefully considered by soap manufacturers. The SN ratio graph for dust showcased its role in minimizing undesirable variations while contributing to cost efficiencies. This suggests that the inclusion of dust can be a judicious choice for soap formulations aiming to balance quality and economic considerations.

Thirdly, the study underscores the importance of particulate matter, especially dust, in shaping soap appearance. Manufacturers are encouraged to explore and leverage the potential of particulate additives for creating visually dynamic and textured surfaces, setting their products apart in a competitive market.

Additionally, the emphasis on achieving optimal pH levels for skin compatibility and the acknowledgment of moisture content's influence on soap shelf life and skin-friendly characteristics highlight the importance of maintaining a delicate balance in soap formulations. Manufacturers are recommended to continue prioritizing these aspects to meet consumer expectations for skincare products that deliver both cleanliness and skin nourishment.

In conclusion, the recommendations aim to guide soap manufacturers toward formulating products that not only meet regulatory standards but also resonate with consumer preferences, ensuring a competitive edge in the dynamic soap market. The study's insights can serve as a valuable resource for industry professionals seeking to enhance the quality, efficacy, and cost-effectiveness of their soap formulations.

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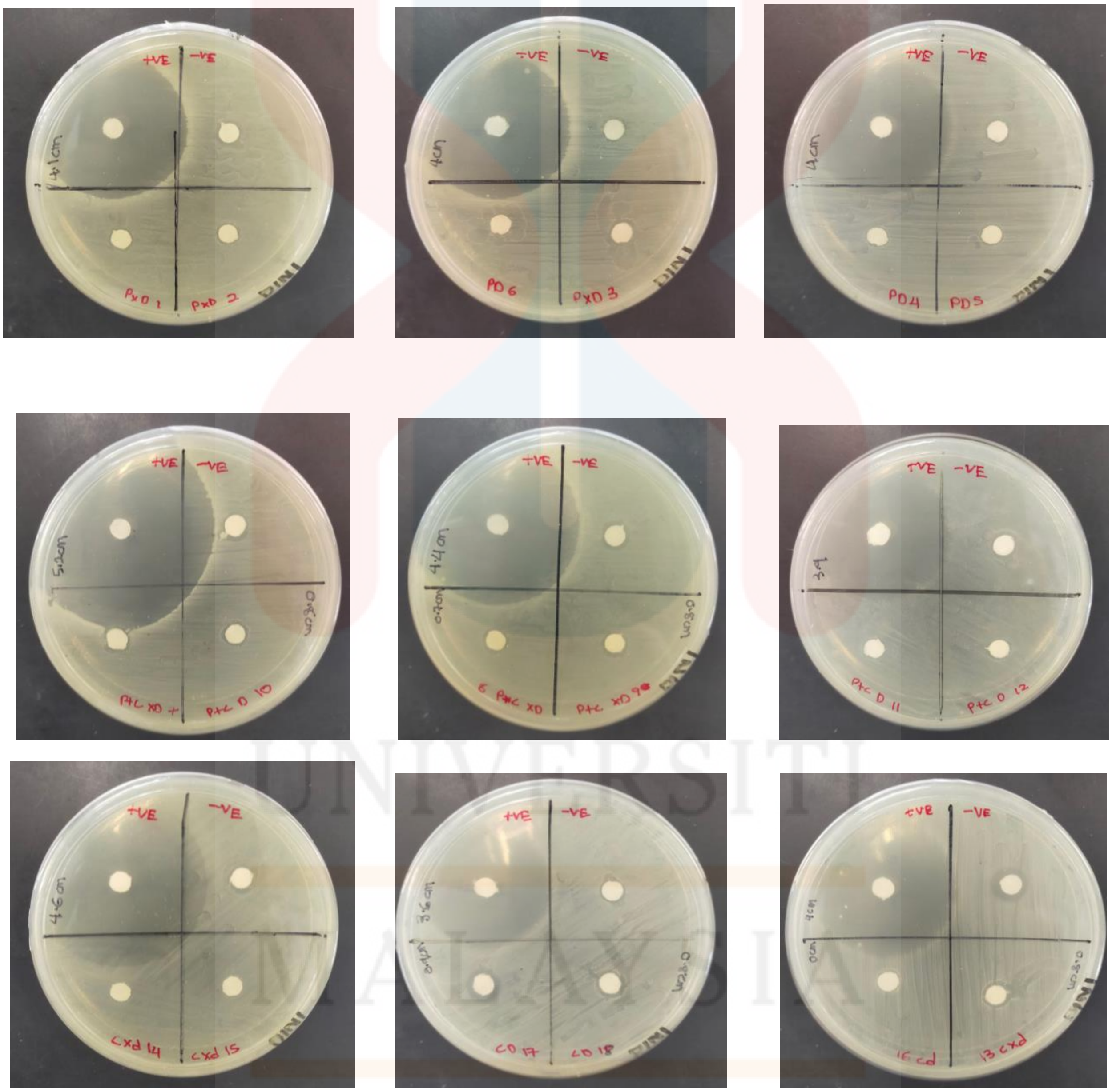
APPENDIX A

The Result of Antimicrobial of Bar Soap



Initial height of foam

After height of foam

APPENDIX B

Excel Average Result for Appear

Appear	Respondant	sample 1	sample 2	sample 3	sample 4	sample 5	sample 6	sample 7	sample 8	sample 9	sample 10	sample 11	sample 12	sample 13	sample 14	sample 15	sample 16	sample 17	sample 18
	1	5	3	4	5	4	4	4	4	6	6	6	4	3	8	8	5	3	5
	2	6	5	5	8	8	8	8	9	5	5	9	5	7	7	9	8	6	8
	3	3	3	3	7	6	3	5	7	6	4	5	4	8	8	9	8	6	7
	4	4	2	2	9	7	6	6	7	1	4	5	4	9	10	10	10	9	10
	5	3	1	2	5	7	3	5	4	3	4	5	3	4	7	5	7	9	8
	6	4	4	3	2	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	7	4	4	3	2	5	3	5	5	4	4	4	3	4	6	7	7	6	7
	8	4	4	3	2	5	3	5	5	4	4	4	3	4	6	7	7	6	7
	9	4	4	3	2	5	3	5	5	4	4	3	4	6	7	7	4	4	4
	10	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	11	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	12	6	6	6	6	6	6	5	5	5	5	5	5	5	5	5	5	5	5
	13	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	14	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	15	4	2	2	8	5	1	2	5	3	5	4	1	7	9	9	8	7	9
	Average	4.6	4	3.866667	5.2	5.6	4.4	5.066667	5.466667	4.466667	4.73333333	5.0666667	4.1333333	5.53333333	6.6	6.8	6.33333333	5.8	6.4

Excel Average Result for Aroma

Aroma	Respondant	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12	Sample 13	Sample 14	Sample 15	Sample 16	Sample 17	Sample 18
	1	4	4	4	4	4	2	2	2	2	2	2	2	2	2	2	2	2	2
	2	7	7	7	7	7	7	7	7	7	6	7	6	7	6	6	6	6	6
	3	5	5	4	4	4	4	5	6	4	5	4	4	4	5	5	5	4	4
	4	5	4	4	4	4	5	5	4	5	3	4	3	5	5	5	5	5	5
	5	4	5	6	4	5	6	4	3	4	5	4	2	3	5	6	7	5	4
	6	4	4	4	1	4	3	2	1	4	4	4	5	5	6	1	1	1	1
	7	5	4	4	4	4	4	4	4	4	3	3	6	6	4	6	5	5	4
	8	5	4	4	4	4	4	4	4	4	4	4	4	6	4	6	5	5	4
	9	4	4	4	4	4	4	4	4	4	4	5	5	6	4	4	4	4	4
	10	2	2	2	2	3	3	3	4	4	2	2	1	2	4	1	1	1	1
	11	6	5	5	5	5	5	6	4	4	6	6	6	5	5	5	1	1	1
	12	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	13	5	5	5	5	5	5	5	5	5	5	5	5	4	4	4	4	4	4
	14	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	15	6	3	3	5	5	6	6	4	3	4	3	2	7	4	7	4	5	5
	Average	4.533333	4.133333	4.133333	3.933333	4.266667	4.266667	4.2	3.866667	4	3.93333333	3.9333333	3.8	4.53333333	4.26666667	4.2666667	3.7333333	3.6	3.4

Excel Average Result for Texture

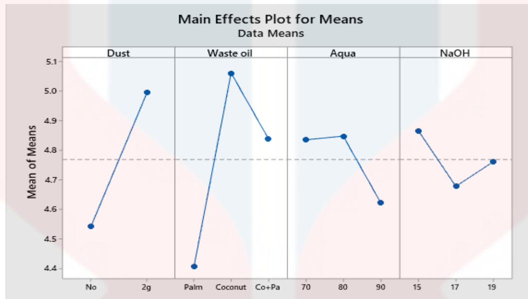
Texture	Respondant	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12	Sample 13	Sample 14	Sample 15	Sample 16	Sample 17	Sample 18
	1	5	4	4	5	4	4	4	4	6	6	6	4	5	5	7	4	4	4
	2	8	8	7	9	7	8	9	9	6	7	7	7	6	6	10	10	7	8
	3	6	5	5	6	5	3	5	6	5	5	6	6	6	7	8	8	6	7
	4	5	3	2	9	7	4	5	6	5	5	5	4	8	10	10	10	9	10
	5	5	4	3	5	6	4	3	5	4	6	3	4	4	6	4	5	7	5
	6	4	4	3	2	4	5	4	3	2	1	4	4	4	4	5	5	1	1
	7	3	4	3	3	4	3	5	6	4	5	3	3	4	8	8	8	7	5
	8	3	4	3	3	4	3	5	6	4	5	3	3	4	8	8	8	7	5
	9	3	4	3	4	3	4	3	4	3	4	3	4	3	4	3	4	3	4
	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	11	4	4	4	4	4	4	4	4	4	5	5	5	5	5	4	4	4	4
	12	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	13	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	14	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	15	5	2	1	5	7	2	2	3	4	3	2	1	4	4	8	7	6	8
	Average	4.533333	4.2	3.666667	4.8	4.8	4.066667	4.4	4.866667	4.266667	4.6	4.26666667	4.13333333	4.66666667	5.6	6.13333333	6	5.2	5.2

Excel Average Result for Colour

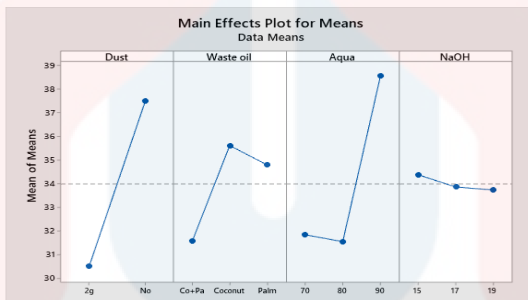
Colour	Respondant	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12	Sample 13	Sample 14	Sample 15	Sample 16	Sample 17	Sample 18
	1	9	9	6	6	5	4	4	4	9	7	7	4	9	9	9	4	4	6
	2	8	9	8	7	7	6	7	9	9	7	6	6	9	9	10	10	8	8
	3	8	6	6	7	6	4	6	5	5	4	5	5	7	7	8	8	7	8
	4	10	10	10	8	8	9	7	8	6	6	8	8	10	10	10	9	7	8
	5	7	5	7	6	3	3	4	6	4	4	5	2	5	8	7	4	7	7
	6	3	4	3	1	1	1	1	1	2	2	2	3	4	3	2	4	4	4
	7	5	4	4	5	5	4	6	6	4	6	5	4	7	6	7	6	6	5
	8	5	4	4	5	5	4	6	6	4	6	5	4	7	6	7	6	6	5
	9	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	11	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	12	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	13	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	14	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	15	6	7	6	7	7	4	2	3	4	1	6	1	6	9	9	8	5	8
	Average	5.666667	5.466667	5.133333	5	4.666667	4.133333	4.4	4.733333	4.666667	4.4	4.8	4	5.8	6	6.133333	5.46666667	5.13333333	5.46666667

APPENDIX C

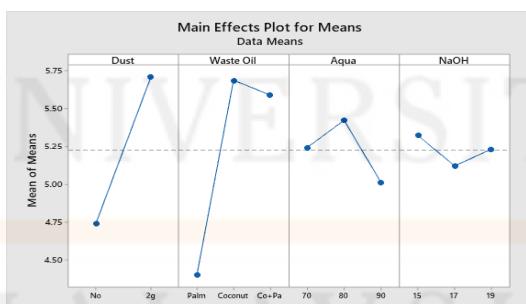
Means for Hedonic



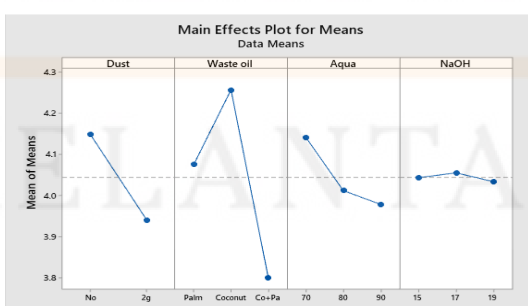
Means for Properties



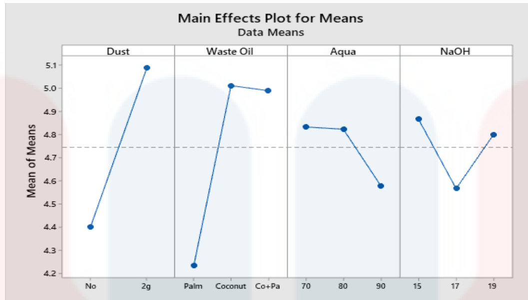
Means for Appearance



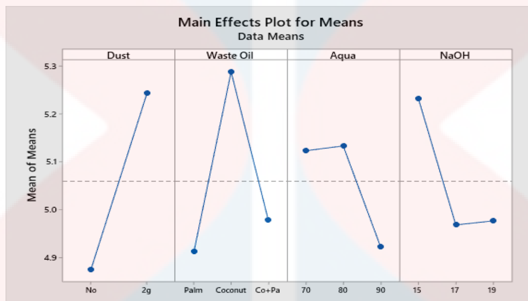
Means for aroma



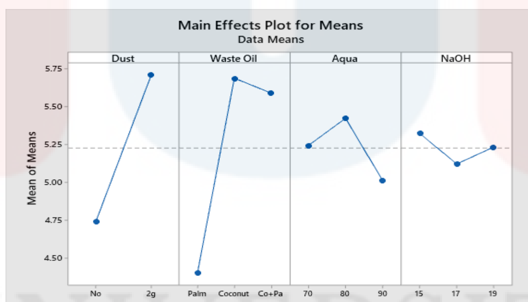
Means for Texture



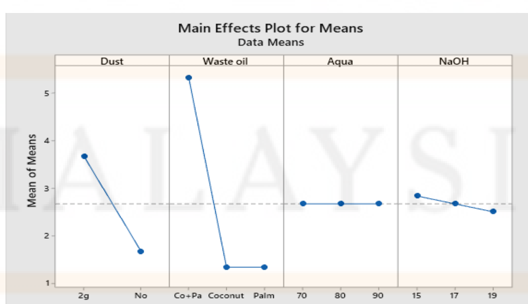
Means for Colour



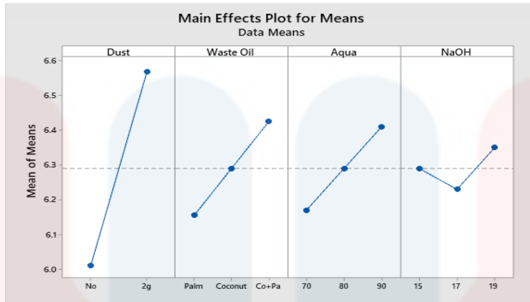
Means for Foam



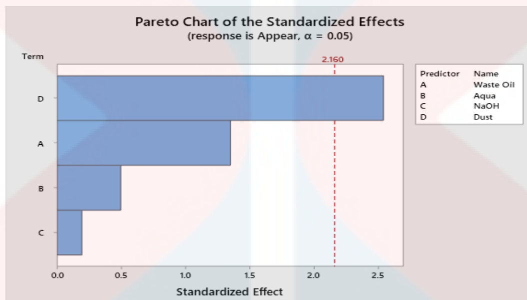
Means for Microbe



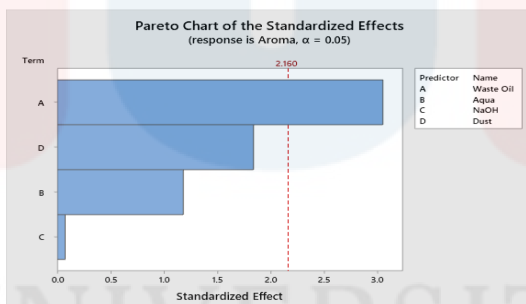
Means for Cost



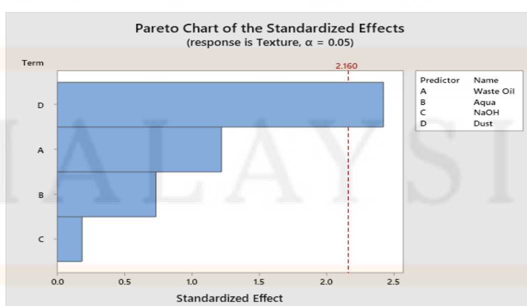
Standardized Effects for Appear



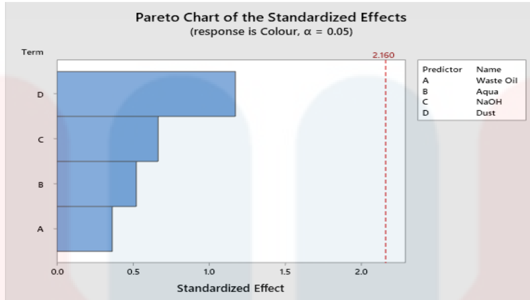
Standardized Effects for Aroma



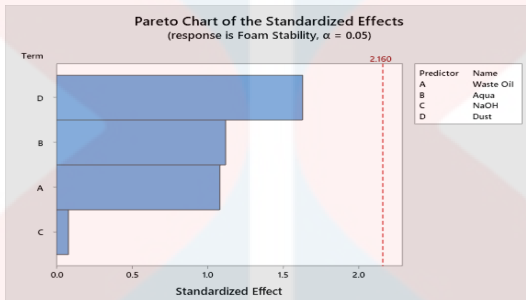
Standardized Effects for Texture



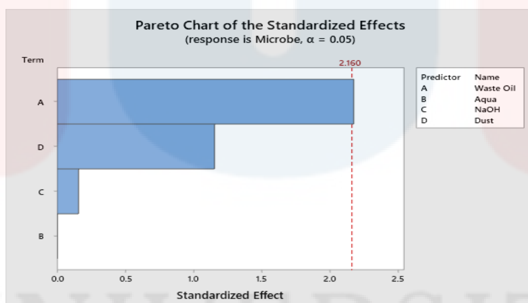
Standardized Effects for Colour



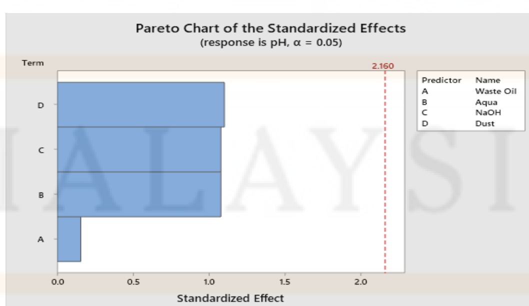
Standardized Effects for Foam



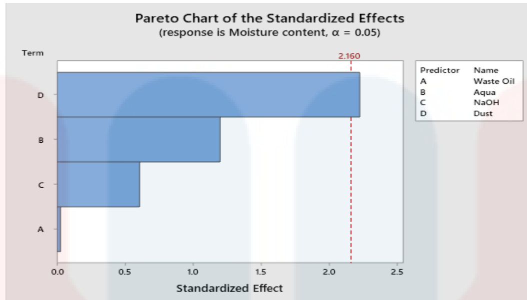
Standardized Effects for Microbe



Standardized Effects for pH



Standardized Effects for Moisture Content



Standardized Effects for Cost