HYDROGEN
JURNAL KEPENDIDIKAN KIMIA
https://e-journal.undikma.ac.id/index.php/hydrogen/index

April 2026. 14(2)
e-ISSN: 2656-3061
p-ISSN: 2338-6487
pp. 387-394

Quality Analysis of Virgin Coconut Oil Resulting From a Combination of Fermentation and Controlled Heating Using Silica by Rice Husk Ash

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Article History
Received: 13-04-2026
Revised: 20-04-2026
Published: 30-04-2026

Keywords: VCO; Silica; Rice Husk Ash; Adsorption; Adsorbent.

Abstract
Virgin Coconut Oil (VCO) has unique characteristics such as a very clear color resembling mineral water, low water and free fatty acid content, and high lauric acid content. The purpose of this study was to compare the quality of physical, chemical, and organoleptic parameters of VCO before and after adsorption with rice husk ash silica. The method used was adsorption. The adsorbent is arranged to a height of 4 cm with a flow rate of 14 drops per minutes. The results showed that the clarity test before and after adsorption was 85.8% and 97.9%. The water content before and after adsorption was 0.29% and 0.07%; free fatty acids were 0.49% and 0.17%; peroxide value was 1.98 mg eq/kg and 1.48 mg eq/kg; and saponification value was 189.34 mg KOH/g and 229.24 mg KOH/g. The average organoleptic color test before and after adsorption was 3.07 and 4; ordor was 3.33 and 3.2; and tastes 2.8 and 2.4, meet SNI 7381:2008 and SNI 2015. Thus, it can be concluded that rice husk ash silica can improve the quality of VCO.

How to Cite: Rahmadani, F., Harimu, L., & Rahmanpiu. (2026). Quality Analysis of Virgin Coconut Oil Resulting From a Combination of Fermentation and Controlled Heating Using Silica by Rice Husk Ash. Hydrogen: Jurnal Kependidikan Kimia, 14(2), 387-394. https://doi.org/10.33394/hjkk.v14i2.20244

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INTRODUCTION

Virgin Coconut Oil (VCO) is a pure oil that contains very high levels of lauric acid, around 45–55% (Pontoh et al., 2008), 13–19% myristic acid, and 90–95% saturated fatty acids (Haeruddin et al., 2023). According to Basuki et al. (2019), VCO has various health benefits, such as counteracting free radicals, lowering cholesterol levels, functioning as a natural antioxidant in the body, and reducing the risk of heart disease and cancer.

VCO can be produced through several methods, namely enzymatic (Prasanna et al., 2024), centrifugation (Pitrianingsih et al., 2021), fishing, heating, and fermentation (Pontoh et al., 2008). The fermentation method takes a very long time, around 24-48 hours (Agarwal and Bosco, 2017), and produces less VCO than the heating method (Pontoh et al., 2008). Meanwhile, the heating method commonly used by the community is at a temperature of 200-250°C for a long time, causing oxidation and fat hydrolysis, which can cause the oil to smell rancid (Haeruddin et al., 2023). The amount of VCO produced by the enzymatic method was 27.7% (Jakfar et al., 2023); centrifugation yielded 39% (Pitrianingsih et al., 2021); fishing 15.27%, fermentation 13.97%, and heating 14.38% (Pontoh et al., 2008).

According to Jakfar et al. (2023), the water content produced by the enzymatic method is 0.046%, and by the centrifugation method is 0.25% (Anwar and Salima, 2016). According to Pontoh et al. (2008), VCO with The fishing method has a water content of 0.1566%. The heated material contains 0.13% water (Rachmawati and Sari, 2023). The fermented product contains 0.1% water (Syahriani et all. 2023).

It produces less than other methods, but other methods are more expensive, and the water content produced is higher than VCO production by fermentation, but it still meets SNI quality standards. Therefore, a combination of fermentation and controlled heating methods is used to obtain a large amount of VCO that is inexpensive and still meets SNI quality standards (Pontoh et all. 2008). To improve the quality of VCO, VCO purification is carried out using adsorbents.

VCO purification using adsorbents involves activated charcoal, zeolite (Fatimah and Sangi, 2010), rice husk- -ash (Fitriani et al., 2021), bentonite (Poli, 2016), and silica (Soylu et al., 2025). Rice husk ash contains very high silica, reaching 89.47–98%, so it can produce a lot of silica that can be used to absorb water (Padang et al., 2023). Silica contains siloxanes and silanols that can absorb water (Sulo et all., 2019), thereby improving the quality of VCO. Another advantage of rice husk ash is its economical price and abundant availability. According to Fitriani et al. (2021), the use of rice husk ash adsorbent to purify VCO can produce a water content of 0.4%.

METHOD

Tools and Materials

The equipment used includes: gas stove, porcelain dish, Erlenmeyer flask, burette, stand and clamp, *magnetic stirrer*, measuring cups of 5, 10, 50, 100, and 250 mL, measuring pipettes of 2, 5, and 10 mL, thermometer, oven, 50, 100, 250, and 500 mL beakers, *filler*, 30 cm column, *desiccator*, analytical balance, 10, 50, 100, 250, and 500 mL volumetric flasks, pan, stirring rod, spatula, spray bottle, plastic bottle, aluminum foil, and container. The materials used in this study included: coconuts, water, cotton, rice husk ash, sodium hydroxide (NaOH), distilled water, sulfuric acid (H_2SO_4), glacial acetic acid (CH_3COOH), potassium iodate (KIO_2), hydrochloric acid (HCl), potassium hydroxide (KOH), 96% ethanol, chloroform ($CHCl_3$), potassium iodate (KIO_3), potassium iodide (KI), amylum, sodium thiosulfate ($Na_2S_2O_3$), oxalic acid ($C_2H_2O_4$), and *phenolphthalein* (pp).

Silica Extraction

Take 20 grams of rice husk ash, add 120 mL of 12% NaOH solution, and heat at 85°C for 90 minutes while stirring using a *magnetic stirrer*. Then filter and add 0.5M $H_2SO_4$to the filtrate until a gel precipitate forms and let it sit for 18 hours. The gel precipitate is then filtered and washed with hot distilled water until neutral and dried in an oven at 110°C for 5 hours, then weighed for silica (Harimu et al., 2019).

Production of VCO

The coconuts used to make VCO are mature and unripe, with thick flesh and no odor. Next, 10 coconuts are separated from their shells, washed, drained, and grated. Then, 10 kg of grated coconut is weighed and water is added (ratio 1:1) and squeezed twice, until all the coconut milk in the coconut pulp is extracted. The mixture of coconut milk and water obtained is left to settle in 3 stages. In the first stage, the coconut milk is left to settle for two hours to separate the water (skim) and cream, resulting in skim (water) and cream. Then the skim (water) is separated and the cream is left to settle again for 2 hours, the skim (water) is separated and the cream is fermented again for 1 hour. After that, the cream obtained is heated at a controlled temperature of 60-90°C and the time when the oil is formed is recorded (Haerudin et al., 2023). After the oil is formed, it is purified with rice husk ash silica adsorbent arranged with an adsorbent height of 3-5 cm, then the silica is inserted into a filtration column with a length of 30 cm and a diameter of 3 cm. Next, 1 liter of VCO is inserted into the adsorption column, with a regulated flow rate 14 drops per minutes.

Cirality Test

Amount of 1 ml of VCO was dissolved in aquaedes using a 100 ml measuring flask. Next, measurements were taken with a UV Vis spectrophotometer at a wavelength of 650 nm. A transmittance percentage of 90%-100% proved that the mixture had a transparent and clear appearance (Asrawaty et al., 2020).

Water content Test

The weighing bottle is heated in an oven at 105˚C for 1 hour. It is then cooled in a desiccator for ½ hour and its weight is recorded. Next, 5 grams of VCO is weighed in the weighing bottle that has been weighed. Heat in an oven at 105˚C for 1 hour, cool in a desiccator for half an hour. Weigh the weighing bottle containing the sample. Repeat the heating and weighing until a constant weight is obtained. calculate the water content using the formula (Lestari and Cahyadi, 2023).

$$Water\ content = \frac{A-B}{A}\ 100\%$$

Description:

A = weight cup + sample before heating

B = weight cup + sample after heating

Free Fatty Acid Test

The oil sample is stirred in a liquid state, then weighed to 30 grams in an Erlenmeyer flask. Next, add 50 mL of 96% neutral alcohol and 5 drops of *phenolphthalein* (PP) indicator. Then titrate with a standardized 0.1 N NaOH solution until it turns pink and does not disappear for 30 seconds. Determination of free fatty acids is calculated using the formula (Lestari and Cahyadi, 2023).

$$\%FFA = \frac{V \times N \times 200}{m \times 10}$$

Description:

%FFA = Free fatty Acid Content (%)
V = Volume of NaOH tinrant
N = Normality of NaOH soliutiion
200 = BM Laurat Acid
m = sample weight (g)

Peroxide Value Test

Weigh a sample of 0.3 grams to 5 grams, add 10 mL of chloroform, and dissolve the sample by vigorously shaking the Erlenmeyer flask. Add 15 mL of glacial acetic acid and 1 mL of saturated potassium iodide solution. Immediately cover the Erlenmeyer flask and shake for approximately 5 minutes in a dark place at a temperature of 15°C - 25°C. Titrate with a 0.02 N sodium thiosulfate standard solution using starch solution as an indicator. Perform a blank determination. calculate peroxide value with equation (Lestari and Cahyadi, 2023).

$$PV = \frac{N \times (V_1 - V_0)}{m} \times 1000$$

Deacription:

%PV = peroxide value (%)
N = Normality of $Na_2S_2O_3$
V_1 = Sample titration volume
V_0 = Blank titration volume
M = weight sample

Saponification Value Test

The saponification value is determined using the acid-base titration method. Weigh 1.5 g of coconut oil sample into a 250 mL Erlenmeyer flask and add 50 mL of 0.5 N alcoholic KOH solution, then proceed to the optimization stage of the saponification heating time and temperature. The sample is heated for 35 minutes with a heating temperature variation of 60°C. Add 1 mL of *phenolphthalein* indicator solution to the flask and titrate with 0.5 N HCl until the pink color disappears completely. Record the volume of 0.5 N hydrochloric acid used in the titration. calculate Saponification value, carried out with equation (Haeruddin et al., 2023).

$$\text{saponification value} = \frac{56{,}1\,(B - C)N}{M}$$

Description:

B = Blank titration of volume
C = Sample titration of volume
N = Normality of HCl
M = weight sample

Organoleptic Properties Test

According to BSN (2008), organoleptic testing is prepared in the following manner:

Color Parameter

The oil is transferred into a test tube and observed with the naked eye. The analysis is conducted by 15 panelis. The color assessment criteria use a four-point scale: 4 (very clear), 3 (somewhat clear), 2 (cloudy), and 1 (very cloudy).

Odor Parameter

The oil is shaken in a container, then the container lid is opened. Smell the oil being tested at a distance of approximately 5 cm from the nose and then wave it toward the nose to detect its ordor. The analysis is carried out by at least 15 panelis. The ordor assessment criteria use a four-point scale: 4 (strong coconut ordor), 3 (slight coconut ordor), 2 (weak coconut ordor), and 1 (no coconut ordor).

Taste Parameter

Pour the oil into a clean teaspoon and taste it with your tongue. The analysis must be conducted by at least 15 panelis. The taste evaluation criteria use a four-point scale: 4 (strong coconut oil taste), 3 (less noticeable coconut oil taste), 2 (no coconut oil taste), and 1 (very little coconut oil taste).

RESULTS AND DISCUSSION

Production of VCO

The separation of coconut cream and skim (water) was carried out by settling for 2 hours. Repeated settling was carried out to reduce the water content in the VCO. Then, the cream obtained was heated to produce 600 mL of VCO with a yield of 8%. According to Hernawati and Jirana (2018), heating was carried out at a controlled temperature so that the VCO did not undergo hydrolysis. Excessive heating at high temperatures for long periods risks altering the oil structure and producing undesirable colors. The results obtained are less than the desired oil content. According to Sundasegaran and Mah (2020), when coconut milk is heated, the proteins, phospholipids, and natural emulsifiers from coconut meat begin to undergo damage or structural changes (*denaturation*). At around 90°C, the proteins that maintain emulsion stability lose their ability, causing oil droplets to merge into larger droplets, resulting in the formation of a layer of virgin oil.

Clarity

Clarity testing is conducted by measuring the transmittance value to assess the clarity level of VCO. The higher the transmittance value obtained, the clearer the oil because light can pass through the sample more easily. The results of VCO clarity testing using a combination of fermentation and controlled heating methods before and after adsorption are shown in Table 1.

Table 1. Clarity of VCO Before and After Adsorption

NO	Sample	Clarity (%T)
1	VCO before adsorption	85.8
2	VCO after adsorption	97.9

Before adsorption, the transmittance was 85.8%. The low clarity before adsorption was due to high water and free fatty acid content, which also reduced clarity. According to Ketaren (1986), the color of oil generally comes from various substances dissolved in it, such as free fatty acids, natural pigments (e.g., carotenoids), a small amount of water, and other colored compounds such as ketones and aldehydes. If the levels of these compounds are high, the oil will appear yellowish and less clear. The transmittance value after adsorption increased to 97.9%.

There was a 12.1% increase in transmittance because the impurities were bound by silanol and siloxane groups contained in silica. According to Harimu et al. (2019), silica contains silanol and siloxane, which function in the adsorption process that can bind polar compounds. According to Zubaydah et al. (2023), a transmittance value of 90-100% indicates that the oil has a clear and transparent appearance. A high transmittance value indicates that light is almost not scattered when passing through the solution, indicating fine and evenly distributed particles.

Water Content

Water content is one of the chemical parameters used to assess the quality of VCO, as the presence of water can affect the stability and quality of the oil. The presence of water in oil can affect the quality and shelf life of VCO. The water content, the VCO using a combination of fermentation and controlled heating methods, after adsorption are shown in Table 2.

Table 2. VCO Water Content Before and After Adsorption

No	Sample	Water Content (%)
1	VCO before adsorption	0.29
2	VCO after adsorption	0.07
3	SNI 2008	0.2

Table 2 shows that the water content of VCO before adsorption was 0.29%. High water content due to heating can cause hydrolysis. This is in line with Jatiputra's (2021) research, which found that water acts as a catalyst in hydrolysis reactions that cause rancidity and quality degradation. After adsorption, the water content decreased to 0.07%, which meets the SNI 2008 standard of a maximum water content of 0.2%. The water content decreased after purification with rice husk ash silica because there are silanol groups in silica that can absorb water. According to Sulo et al. (2019), the presence of silanol groups in silica is hydrophilic, making it effective in attracting and retaining polar molecules such as water. According to Fitriani et al. (2021), the use of rice husk ash adsorbent resulted in a VCO water content of 0.4%, indicating that silica rice husk ash adsorbent reduces water content more effectively compared to just using rice husk ash.

Free Fatty Acids

The free fatty acid content is used as one of the parameters to determine the quality of VCO, because an increase in its content indicates a decline in oil quality. The free fatty acids in VCO before and after adsorption can be seen in Table 3.

Table 3. Free Fatty Acids in VCO Before and After Adsorption

No	Sample	Free Fatty Acids (%)
1	VCO before adsorption	0.49
2	VCO after adsorption	0.17
3	SNI 2008	0.2

The results showed that the free fatty acid content before adsorption was 0.49%. This result did not meet the SNI 2008 requirement, which is a maximum free fatty acid content of 0.2%. The high free fatty acid content was influenced by the high water content. This is in line with the statement by Lestari and Cahyadi (2023), who stated that triglyceride hydrolysis reactions can occur due to the presence of water in oil. This reaction produces free fatty acids and glycerol, which leads to an increase in FFA levels and a decrease in oil quality. The free fatty acid level after adsorption was 0.17%. There was a significant decrease because silica contains silanol and silicic acid, which can adsorb free fatty acids. This is in line with the research by Sulo et al. (2019), which states that the presence of silanol groups on the surface of silica enables it to adsorb components such as water and free fatty acids. According to Fitriani et al. (2021), the use of rice husk ash adsorbent resulted in VCO free fatty acids of 0.197%, so that rice husk ash silica adsorbent reduced free fatty acids better than only use rice husk ash.

Peroxide Value

This oxidation process can cause rancidity, which is characterized by the appearance of an abnormal odor due to the formation of degradation compounds from the breakdown of unstable hydroperoxides into short-chain carbon compounds. The peroxide value of VCO before and after adsorption can be seen in Table 4.

Table 4. Peroxide Value of VCO Before and After Adsorption

No	Sample	Peroxide Value (mg eq/kg)
1	VCO before adsorption	1.98
2	VCO after adsorption	1.48
3.	SNI 2008	0.2

The peroxide value before adsorption was 1.98 mg eq/kg. The peroxide value in VCO still meets the SNI 2008 requirement of a maximum of 2.0 mg eq/kg. According to Pramitha and Juliadi (2019), free fatty acids are formed from the hydrolysis of triglycerides and can accelerate the oxidation of unsaturated fatty acids. Oxygen reacts with unsaturated fatty acids to form peroxides. The peroxide value decreased after adsorption to 1.48 mg eq/kg. This occurred because the free fatty acids bound to the adsorbent prevented the unsaturated fatty acids from reacting with oxygen, resulting in a low peroxide value. This is in line with the research by Fitriani et al. (2021), which shows that a decrease in free fatty acids is followed by a decrease in the peroxide value. According to Ojewumi et al. (2021), a low peroxide value means that the oil is still good and can be stored longer. Conversely, if the peroxide value is high, the oil has started to deteriorate due to oxidation and has become rancid. According to Fitriani et al. (2021), the peroxide value obtained decreased after adsorption with rice husk ash, namely 1.49 mg eq/kg. This shows that VCO adsorbed with rice husk ash silica produces a better peroxide value than just using rice husk ash.

Saponification Value

The saponification value is related to oil quality, as changes in its value can reflect the condition and degree of oil degradation. The saponification values of VCO before and after adsorption are shown in Table 5.

Table 5. Saponification Value of VCO Before and After Adsorption

No	Sample	Saponification Value (mg KOH/g)
1	VCO before adsorption	189.341
2	VCO after adsorption	229.24
3.	SNI 2015	180-265

The saponification value obtained before adsorption was 189.341 mg KOH/gram, which indicates that the saponification value before adsorption meets the SNI 2015 requirement of 180-265 mg KOH/gram. According to Haeruddin et al. (2023), the higher the fatty acid content, the lower the saponification value. This occurs because the higher the molecular weight of the fatty acid, the smaller the amount of triglycerides, thus requiring less KOH. According to Salanti et al. (2022), the saponification value is usually related to the molecular weight of a fat/oil. If the molecular weight of the oil is greater, the saponification value will be smaller, and vice versa. There was an increase in the saponification value after adsorption to 229.24 mg KOH/gram, which still meets the SNI 2015 requirement. According to research by Ojewumi et al. (2021), the saponification value of coconut oil increased after adsorption with rice husk ash to 215 mg KOH/gram. This indicates that the use of rice husk ash silica causes a more significant increase in the saponification value compared to using rice husk ash alone.

Organoleptic Properties Test

Color

VCO quality is assessed based on organoleptic quality, one of which is VCO color. This parameter is used to test the quality of VCO produced through a combination of fermentation and controlled heating methods. VCO quality can be improved by adsorption using rice husk ash silica. The results of the VCO quality test on the organoleptic color test using a combination of fermentation and controlled heating methods after adsorption are shown in Figure 1.

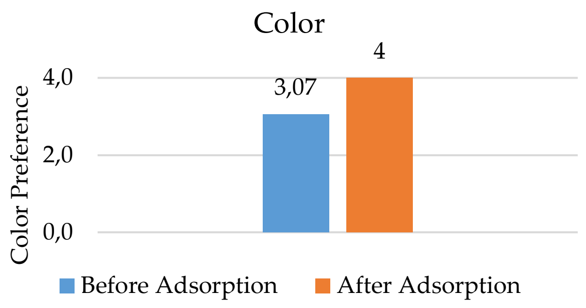

Figure 1. Average Organoleptic Color Test

Figure 1 shows that before adsorption, the average value was 3.07 (slightly clear). This occurred because VCO was obtained through a low-temperature heating process, so that colloidal particles in the form of emulsion components between protein and fat remained in the oil. According to Prasana et al. (2024), VCO is made from fresh coconut milk through a process without high-temperature heating. This means that the oil structure, such as triglycerides and natural coconut milk components, does not change significantly, resulting in some emulsion compounds and colloidal particles still being found in the oil produced. After adsorption, the average value is 4 (clear), which meets the quality requirements of SNI 7381:2008, where the color of good VCO is colorless to pale yellow.

Odor

Organoleptic testing is a quality test of VCO using human senses, one of which is smell. The purpose is to determine the quality of the VCO ordor. Through this test, the level of acceptance or preference can be determined based on the sensory experience of the panelists. The results of the VCO test from the combination of fermentation and controlled heating using rice husk ash silica are shown in Figure 2.

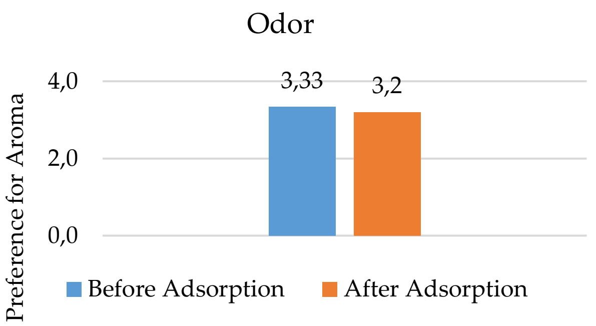

Figure 2. Average Results of VCO Organoleptic Ordor Test

Figure 2 shows that the average level of panelist preference for VCO before adsorption was 3.33 (slightly coconut-like ordor), which occurred because VCO contains natural volatile compounds such as capric acid. According to Dimzon et al. (2020), VCO contains volatile compounds such as carboxylic acids (decanoic acid/capric acid), ketones (2-heptanone), alcohols (ethanol), aldehydes (hexanal), esters (ethyl acetate), and hydrocarbons (n-hexane). After adsorption, the panelists' preference level decreased to 3.2 (reduced coconut ordor). The adsorption process can absorb natural volatile compounds in VCO that cause ordor. According to research by Kutluay and Temel (2021), adsorbents such as silica can remove volatile compounds.

Taste

Organoleptic taste testing is a sensory evaluation method used to assess the taste of VCO using human taste buds. This process generally involves panelists to evaluate the taste quality of VCO. The results of the VCO taste test, which is a combination of fermentation and controlled heating using rice husk ash silica, are shown in Figure 3.

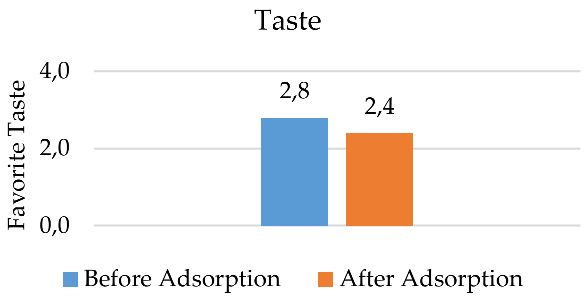

Figure 3. Average Results of VCO Taste Organoleptic Test

Figure 3 shows that before adsorption, the score was 2.8, while after adsorption, it was 2.4. This score indicates that the taste of the coconut oil produced was lacking. Another study by Gala et al., 2025, also states that the use of silica as an adsorbent can improve the clarity and stability of oil, but it affects the natural taste of oil. According to SNI 7381:2008, VCO has a distinctive coconut oil taste.

CONCLUSION

Based on the results of the study, it can be concluded that before adsorption, VCO had a slightly cloudy color, a coconut ordor, and a transmittance value of 85.8%. After adsorption, the color of VCO changed to clear, with less coconut ordor and a transmittance value of 97.9%. Before adsorption, it produced a water content of 0.29%, free fatty acids of 0.49%, a peroxide value of 1.98 mg eq/kg, and a saponification value of

189.341 mg KOH/g. After adsorption, VCO produced a water content of 0.07%, free fatty acids of 0.17%, a peroxide value of 1.48 mgeq/kg, and a saponification value of 229.24 mg KOH/g. Before adsorption, the average panelist preference levels were color 3.07, ordor 3.33, and taste 2.8. After adsorption, the color preference level became 4, ordor 3.2, and taste 2.4. Rice husk ash silica adsorbent can absorb water and impurities, thereby improving the quality of VCO

RECOMENDATION

To complete the information related to the purification of VCO using rice husk ash silica, further research is needed on optimizing adsorption conditions including variations in silica mass and contact time, to identify the optimal conditions that can enhance clarity without compromising the characteristic taste and aroma of coconut oil.

ACKNOWLEDGEMENTS

Thank you to everyone who has helped in this research, especially my supervisors in the chemistry education department at Halu Oleo University, Dr. Laharimu, S.Pd., M.Si, and Dr. Rahmanpiu, S.Pd., M.Si, as well as the examiners who provided input so that this research could be completed successfully.

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