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Analysis of energy consumption in coconut oil production with bromelin enzyme extract

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Abstract

Indonesia has been facing the problem of domestic cooking oil since the beginning of 2022. This issue certainly does not reduce the number of people's consumption of cooking oil which causes the amount of energy consumption in the production process will also increasing. This study aims to obtain coconut oil in accordance with SNI 3741:2013, determine the effect of temperature and processing time as well as determine the amount of energy consumption in the coconut oil production process. One of the efficient ways to make coconut oil is by using the heating process method. This method will produce coconut oil that lasts longer because it has a lower water content. This study uses temperature variables with variations of 60 °C, 65 °C, 70 °C, 75 °C and 80 °C and heating time with variations of 90 minutes, 120 minutes and 150 minutes. Based on the research that has been done, it can be concluded that the best treatment is at temperature variation of 70 °C and heating time of 150 minutes which produces 355 ml of coconut oil with a fragrant smell of coconut oil and a clear golden yellow color with the water content of 0.0015 %, the free fatty acid content of 2.8205 %, the specific energy consumption (SEC) is 0.0066 and the required electricity cost is Rp.2.675,31. The coconut oil produced also complies with SNI 3741:2013 with the highest water content of 0.0024 % and the highest free fatty acid content of 3.3009 %. Specific Energy Consumption (SEC) values during the study ranged from 0.0038 to 0.0070 kWh/ml.

Keywords: bromelain enzyme, coconut oil, fatty acid content, heating, specific energy consumption (SEC).

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1. INTRODUCTION

Indonesia is known as the world's largest palm oil producer, but it has still faced the issue of domestic cooking oil since the beginning of 2022. The disruption of the cooking oil distribution chain occurred due to the increase in CPO prices on the world market from USD 1,100 to USD 1,340. Even palm oil waste has potential as a source of bioenergy because it contains lignocellulose (41-46,5% cellulose, 25,3–33,8% hemicellulose, and 27,6-32,5% lignin) so that it can be converted into biofuel through thermal cracking, adsorption, and distillation processes (Wulandari et al., 2022). and supported by the implementation of the B30 program, which has shifted the need for CPO (crude palm oil) from the food industry to the fuel industry (Handoyono, 2022). Palm oil is used to produce products in the form of crude palm, considering that the need for fossil fuel sources is increasing, encouraging various research and development of cheap, environmentally friendly fuels (Samosir et al., 2022). This issue

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does not reduce the number of people's consumptive needs for cooking oil; therefore, with the level of demand for cooking oil, which is one of the nine basic ingredients, the amount of energy consumption in the production process will also increase. Specific energy consumption (SEC) is a variable that describes how much energy is used to produce one unit of product (Lawrence et al., 2019). The value of specific energy consumption has a direct relationship with determining the index of the amount of energy used. By determining this index, information on energy use can be obtained, and efforts can be made to plan for the efficient use of fuel and electrical energy (Natashia, 2016).

In the past, domestic cooking oil demand was supplied by coconut oil (Mesu et al., 2018). Coconut oil is an oil obtained through a heating process without a chemical refining process that contains triglyceride compounds composed of various fatty acids (Poli, 2016). This oil has a fragrant and distinctive aroma, is colorless, and contains very high saturated fatty acids of around 91.60%, which makes it more stable at high temperatures. It is also not easily oxidized into carcinogenic glycerol, so it is healthier than palm oil (Mesu et al., 2018).

Based on data from the Central Bureau of Statistics in 2020, coconut fruit production in South Sumatra Province reached 62,302 tons (Director General of Plantations, 2017). With such great potential and a myriad of benefits offered, it is fitting that coconut oil can be used as an alternative to the issue of palm cooking oil and reduce people's dependence on palm oil which is increasingly scarce as a result of biofuel innovation.

Making coconut oil enzymatically using the crude papain enzyme takes a very long time. The protein denaturation process to separate oil from its protein lipo bonds takes around 20–24 hours with a fairly high yield of around 1,100 ml from 10 coconuts, with the quality of the oil produced meeting the standards (Perdani et al., 2019). Another study mentioned that making coconut oil by traditional heating is relatively easier with simple equipment and easy to use. However, this heating produces oil of poor quality because the process is carried out at high temperatures ranging from 130 to 150 °C and is uncontrolled for a long time, so that the proteins, fats, and antioxidants contained in it are denatured. In addition, the oil produced is not clear and cannot last long, which can only last about 2–3 weeks (Putri, 2015). Therefore, a technology is needed that is able to produce quality coconut oil that meets SNI 3741:2013 with a method that is hygiene-friendly, efficient, and user-friendly in an effort to fulfill the need for cooking oil at affordable prices in order to anticipate the issue of domestic cooking oil. One of the most efficient ways to process coconut oil is by heating. This method will produce oil that is more durable (not easily rancid) because it has a lower water content. So this study aims to obtain coconut oil that is in accordance with SNI 3741:2013, determine the effect of the best heating temperature and time, and determine the amount of energy consumption required in the manufacture of coconut oil as cooking oil.

2. MATERIALS AND METHODS

2.1 Tools and Materials

The study utilizes various materials such as old coconut, water, bromelain enzyme, KOH, 96% ethanol, and phenolphthalin indicator. It also employs several tools, including a stirred tank demulsifier for coconut oil, a stopwatch, 250-ml Erlenmeyer, a separating funnel, a coconut milk squeeze cloth, an analytical balance, a watch glass, a 250-ml beaker, a glass funnel, a multimeter, and a porcelain cup. The stirred tank demulsifier for coconut oil functions as a heating tank for coconut milk with a capacity of 5 liters, incorporating an anchor-type stirrer to facilitate protein denaturation. This disruption of protein stability and solubility induces protein coagulation and precipitation, ultimately leading to the separation of oil and water layers. Additionally, the stirred tank demulsifier for coconut oil is equipped with a separating funnel to assist in the separation process between skim and cream during coconut milk preparation.

2.2 Research Procedur

The research was carried out through three stages of the process, namely the preparation of raw materials to produce coconut milk, the process of making oil using stirred tank demulsifier coconut oil, and analyzing the characteristics of the products produced.The raw material preparation stage begins with coconut meat that has been cleaned and peeled of its aromatic skin, then grated and weighed as much as 1 kg. The grated coconut is added to 1 liter of water and then blended for 3 minutes to obtain pure coconut milk. The slurry formed is then squeezed using gauze so that pure coconut milk is produced. The coconut milk from the squeezed coconut is cooled in a refrigerator for 1 hour until two layers are formed consisting of the top layer in the form of cream and the bottom layer of skim. After forming two layers, the cream is separated from the skim using a separating funnel.

The cream and bromelain enzyme were then put into the stirred tank coconut oil demulsifier and heated at a constant temperature of 60 ^oC while stirring with a stirrer rotation speed of 600 rpm for a duration of 90 minutes. The processed oil is then cooled at room temperature until two layers are formed, consisting of the top layer (oil) and the bottom layer (degraded protein). The loss of protein stability in coconut milk is because the protein is denatured so that its solubility is reduced. This causes the protein to undergo a coagulation and precipitation process so that the water and oil layers are separated (Dali, 2015).

The bromelin enzyme will break down the oil in coconut milk into unstable emulgators so that water particles will be separated from the oil and coconut oil will be obtained as the final result. The proteolytic activity of the bromelain enzyme is at pH 4.0–8.9 and an optimum temperature of 35-80 ^oC (Poba, 2019). Hydrolysis that occurs between enzymes and proteins is the breaking of peptide bonds from substrate bonds, where protease enzymes serve as catalysts in cells and are unique (Saptarani, N.M., 2019). The oil was separated from the blondo using a filter cloth, and then the pure oil obtained was measured in volume and analyzed for its characteristics. The experiment was continued with a temperature-speed variation of 65 to 80 ^oC and a time variation of 90 to 150 minutes.

2.3 Coconut Oil Testing Based on SNI 3741: 2013

The coconut oil that has been produced is then subjected to several tests to determine its quality. The tests that will be carried out based on SNI 3741:2013. The testing procedure for the coconut oil that has been obtained is as follows.

2.3.1 Smell testing

In principle, this test is carried out using panelists' sense of smell. A sample of oil is taken and poured onto a clean and dry watch glass. Then the panelist smells the sample to determine the smell. The test was conducted by three panelists.

2.3.2 Color testing

In principle, this test is carried out using the sense of sight by panelists. A sample of oil is taken and poured onto a clean and dry watch glass. Then the panelist observes the sample to determine its color. The test was conducted by three panelists.

2.3.1 Moisture content testing

A sample of 5 ml was put into the cup and then closed and weighed. Then the cup and its contents were heated at a temperature of (130 ± 1) °C for 30 minutes. After that, the cup is closed again and cooled in a desiccator for 20 to 30 minutes, then weighed and recorded measurements, then calculated the water content (%) using equation 1.

$$\text{Moisture Content \%} = \frac{\text{W1} - \text{W2}}{\text{W1} - \text{W0}} \times 100\% \quad (1)$$

W0 represents the weight of the empty cup and lid (grams), W1 represents the weight of the cup, lid, and sample before drying (grams), and W2 represents the weight of the cup, lid, and sample after drying (grams).

2.3.2 Free Fatty Acid Numbers Testing

Testing the free fatty acid content of the sample begins with weighing 20 ml of sample into a 250 ml Erlenmeyer. Then the sample is dissolved in 50 ml of ethanol, and 5 drops of phenolphthalein solution (pp indicator) are added. The sample was then titrated with potassium hydroxide (0.1N until there was a color change to pink. The experiment was repeated three times, and then free fatty acid (%) was calculated using equation 2.

$$\%\text{FFA} = \frac{\text{V} \times \text{N} \times \text{BE Lauric Acid}}{\text{Massa Sample}} \times 100\% \quad (2)$$

V represents the volume of KOH solution (ml), N represents the normality of KOH solution (N), and BE represents the equivalent weight of lauric acid (gr/mol).

2.3.3 Specific Energy Consumption Testing

In principle, the amount of specific energy consumption (SEC) is calculated by dividing the amount of energy used by the amount of product produced. The amount of electrical energy utilized in this study is calculated based on equation 3.

$$Energy = \text{V} \times \text{A} \times \text{Cos}\ \theta \quad (3)$$

V represents voltage (voltage), A represents current strength (ampere), and Cos θ represents power factor (0.85 based on SPLN 70-1 regulation).

The voltage and current strength in this study were obtained from the data collection process using a multimeter and tangmeter. The power obtained from equation 3 was then divided by the length of the research process to obtain the amount of energy per unit time. The resulting value is then entered into equation 4 to obtain the amount of specific energy consumption in the coconut oil processing process.

$$SEC = \frac{Energy\ Used}{Products\ Amount} \quad (4)$$

SEC represents the specific energy consumption (kWh/ml), Energy Used represents the amount of energy used (kWh), and Product Amount represents the amount of product produced (ml).

3. RESULTS AND DISCUSSION

Based on the results of the calculation of the analysis of variance of the effect of temperature and heating time factors, there are very significant differences between treatments on the volume of coconut oil produced. The relationship between the volume of coconut oil, temperature, and heating time is shown in Figure 1. From the graph, it can be seen that both independent variables affect the amount of oil produced. Figure 1 shows that the highest volume of coconut oil produced from the treatment without the addition of bromelain enzyme extract is at a temperature of 70 ^{o}C and a heating time of 150 minutes, which is 355 ml, while the highest volume of coconut oil produced from the treatment without the addition of bromelain enzyme extract is at a temperature of 70 ^{o}C and a heating time of 150 minutes, which is 353 ml. The lowest volume of coconut oil produced from the treatment without the addition of bromelain enzyme extract is at a temperature of 60 °C and a heating time of 90 minutes, which is 231 ml, while the lowest volume of coconut oil produced from the treatment with the addition of bromelain enzyme extract is at a temperature of 60 °C and a heating time of 90 minutes, which is 232 ml. From Figure 1, it can be seen that as the temperature and heating time increase, the longer the contact of coconut milk with heat, the process of separating oil from coconut milk emulsion becomes more perfect and the volume of coconut oil produced will increase. In addition, the amount of coconut oil produced also depends on the quality of the coconut fruit. The older the coconut fruit that is used as raw material for making coconut oil, the higher the fat content in it, so that the oil produced will increase. Old coconuts will produce a loud sound when tapped, have brown coir, are usually thinner than young coconuts, and have hard and thick textured pulp (Azis et al., 2017).

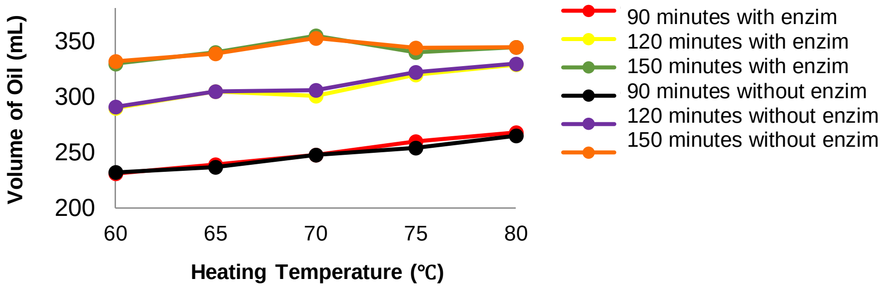

Figure 1. Graph of the Effect of Temperature and Heating Time on the Volume of Coconut Oil with and Without Bromelin Enzyme Extract

Hydrolyzed oil will reduce its quality because it will reduce the smoke point, change the color, and make it easier to absorb odors that trigger rancidity in oil (Hakim, 2021). The higher the water content, the higher the rancidity level of an oil (Patty, 2015). Aroma is one of the indicators that determines the delicacy of the material. Based on the analysis of variance, the level of panelists' liking for the aroma of coconut oil with the influence of temperature and heating time factors showed that there were very significant differences in each treatment. The results of panelists' preferences for the aroma of coconut oil are illustrated in Table 1.

3.1. Effect of Heating Temperature and Time on Coconut Oil Aroma

Table 1. Panelists' Favorability Result of Coconut Oil Aroma

Treatment	90 Minutes					120 Minutes					150 Minutes				
	60°C	65°C	70°C	75°C	80°C	60°C	65°C	70°C	75°C	80°C	60°C	65°C	70°C	75°C	80°C
With Bromelin	1,98	2,11	2,17	2,18	2,19	2,21	2,23	2,25	2,25	2,26	2,27	2,27	2,28	2,29	2,31
Without Bromelin	1,96	1,98	2,10	2,13	2,17	2,18	2,22	2,23	2,24	2,25	2,26	2,27	2,27	2,27	2,29

Description :
0.00-1.00: Rancida; 1.00-2.00: Tends to Rancid; 2.00-3.00: Fragrant.

The average panelist assessment of the aroma of coconut oil obtained through the process of adding bromelain enzyme to each sample ranged from 1.98 to 2.31, while the panelist assessment of the sample without the addition of bromelain enzyme ranged from 1.96 to 2.29. This value illustrates that the addition of the bromelain enzyme does not really affect the aroma of the coconut oil produced. Based on the research, the aroma of coconut oil ranges from rancid to fragrant. Rancidity in coconut oil can be characterized by a high water content. According to Rizkiya (2015), oil with a high water content tends to have a short shelf life as a result of the hydrolysis of fatty acids and glycerol. Hydrolyzed oil will reduce its quality because it will reduce the smoke point, changes the color and makes it easier for it to absorb odors that trigger rancidity in oil (Hakim, 2021). The higher the water content, the higher the rancidity level of an oil (Patty, 2015).

3.2 Effect of Heating Temperature and Time on Coconut Oil Color

Color is one of the parameters that play a role in food products. A direct measurement of color quality is a subjective or visual measurement of color. Based on the results of the analysis of variance, the level of panelists' liking for the color of coconut oil with the influence of temperature and heating time factors showed that there were very significant differences in each treatment. The results of panelists' preferences for coconut oil color are illustrated in Table 2. The average panelists' assessment of the color of coconut oil obtained through the process of adding bromelain enzyme extract to each ranged from 2.09 to 4.13, while the panelists' assessment of the sample without the addition of bromelain enzyme extract ranged from 2.06 to 4.09. This value indicates that the coconut oil produced in the study is light yellow clear to dark yellow clear. Table 2 shows that the longer and higher the heating temperature, the color, or yellowish level, and clarity of the oil will increase.

This happens because the relationship between the two independent variables increases, causing the process of separating oil from the coconut milk emulsion to be more perfect so that natural oil-soluble dyes (carotene), which are unsaturated hydrocarbons and are unstable at high temperatures, are degraded (Rizkiya, 2015). However, the lowest temperature of 60 ºC and the shortest heating time of 90 minutes produced a clear, light yellow oil color.

This happens because in this treatment, the natural color substances contained in the oil have not been damaged, so the yellowish level is lower.

Table 2. Results of Panelists' Preference for Coconut Oil Color

Treatment	90 Minutes					120 Minutes					150 Minutes				
	60℃	65℃	70℃	75℃	80℃	60℃	65℃	70℃	75℃	80℃	60℃	65℃	70℃	75℃	80℃
With Bromelin	2,09	2,12	2,16	2,18	2,20	2,25	2,30	3,00	3,19	3,21	3,30	3,40	4,00	4,10	4,13
Without Bromelin	2,06	2,10	2,13	2,17	2,19	2,24	2,28	2,29	3,17	3,19	3,28	3,39	3,39	4,08	4,09

Description:
1.00-2.00: Clear; 2.00-3.00: Light yellow, clear; 3.00-4.00: Clear, golden yellow; 4.00-5.00: Dark yellow, clear; 5.00-6.00: Clear brown.

3.3 Effect of Heating Temperature and Time on Moisture Content

One of the quality analyses of coconut oil produced is the analysis of moisture content and volatiles. This test is very important to do as a basis for estimating the durability of oil shelf life (Chairil et al., 2016). According to Rizkiya (2015), oil with a high moisture content tends to have a short shelf life as a result of the hydrolysis of fatty acids and glycerol. Hydrolyzed oil will reduce its quality because it will increase fatty acid levels, reduce smoke point, change color, and make it easier to absorb odors (Hakim, 2021). The data from the observation of moisture content and volatile substances in coconut oil produced with and without bromelain enzyme extract has been presented in Figure 2. This figure shows that there is not too much difference in the water content of coconut oil produced with and without the addition of bromelain enzyme extract. However, based on the results of the study, the water content contained in coconut oil processed without the addition of bromelain enzyme extract ranged from 0.0009 to 0.0025%, while the water content contained in the oil processed with the addition of bromelain enzyme extract ranged from 0.0004 to 0.00019%.

The bromelain enzyme extract contained in pineapple fruit is able to break down protein molecules into simpler ones so that the process of breaking down water molecules becomes stronger because the component of coconut meat that binds water is highly dependent on the number of relative groups of proteins that will be solved by the bromelain enzyme extract (Rizkiya, 2015). Based on the results of the research on water content that has been done, it can be stated that the coconut oil produced is suitable for consumption because it meets SNI 3741:2013, which is a maximum of 0.5 %.

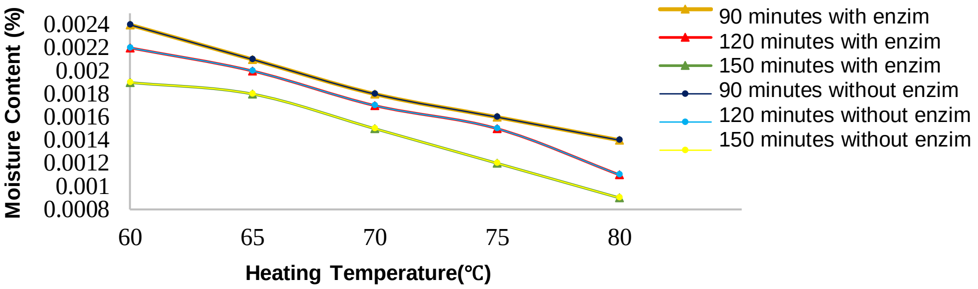

Figure 2. Graph of the Effect of Heating Temperature and Time on Moisture Content with and Without Bromelin Enzyme Extract

From the results of the analysis of variance of the effect of temperature and heating time factors, it shows that there is a very significant difference in the water content of the oil produced. This happens because the higher the temperature and heating time, the longer the contact of coconut oil with heat, which results in the evaporation process, resulting in a decrease in the water content of the oil. When the temperature increases and the heating time increases, the number of water molecules will decrease, which results in hydrogen bonds being broken and some molecules evaporating into gas (Rizkiya, 2015).The higher the water content contained in the oil, the lower the quality because the water content in it can accelerate the hydrolysis reaction and increase the peroxide number, which causes the nutritional value of the oil to be quickly damaged (Rizkiya, 2015).

3.4 Effect of Heating Temperature and Time on Free Fatty Acid Numbers

Testing free fatty acid content is one of the parameters that can be used as a basis for knowing the age of oil, oil purity, the level of damage, and the level of hydrolysis in oil. Fatty acids in food with levels of more than 0.2 % of the weight of fat will cause unwanted flavors and can poison the body (Henny et al., 2015). Free fatty acid levels (FFA) are fatty acids that have been released from ester bonds, where the determination is based on the dominant fatty acids contained therein. The higher the free fatty acid content, the lower the quality of the oil tested (Rizkiya, 2015). From the results of the analysis of free fatty acid levels in coconut oil processing with and without the addition of bromelain enzyme extract shown in Figure 3, it can be concluded that FFA levels in coconut oil produced with the addition of bromelain enzyme do not show significant differences with coconut oil without the addition of bromelain enzyme.

The absence of the effect of bromelain enzyme extract on FFA levels is because the bromelain enzyme does not affect the oxidation process in the oil and only serves to accelerate the process of breaking down protein molecules in coconut milk. High FFA levels are caused by the high water content in it, which will provoke the activity of fungi or microorganisms so that it will damage the quality of the oil produced

(Chairil et al., 2016). FFA levels in oil without bromelain enzyme ranged from 1.4060 to 3.2482 %, while the average FFA levels in coconut oil produced with the addition of bromelain enzyme extract ranged from 1.5797 to 3.3009 %.

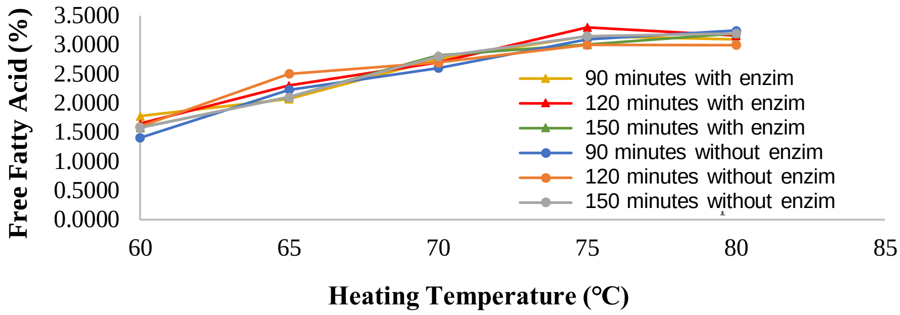

Figure 3. Graph of the Effect of Heating Temperature and Time on Free Fatty Acid Content with and Without Bromelin Enzyme Extract

Figure 3 shows the relationship between the two variables that affect the free fatty acid content of the oil. From the data obtained, it can be concluded that the oil produced is suitable for consumption because the free fatty acid content meets SNI 3741:2013, which is a maximum of 5 % (BSI, 2013). The results of the analysis of variance of the effect of temperature and heating time factors showed that there was a very significant difference in FFA levels. This happens because the higher the temperature and the longer the heating time, the faster the enzymatic reaction in the oil, so that the lipase enzyme and the water content contained in coconut milk can accelerate the reaction of fat hydrolysis into free fatty acids and glycerol, which results in the FFA content of the oil increasing (Rizkiya, 2015).

3.2. Effect of Heating Temperature and Time on Specific Energy Consumption

Specific Energy Consumption (SEC) is a variable that describes how much energy is used to produce one unit of product (Lawrence et al., 2019). This value is calculated by dividing the amount of energy used by the amount of product produced. From the specific energy consumption tests that have been carried out, the results of the specific energy consumption analysis are presented in Figure 4. From the results of the calculation of the analysis of variance, the effect of temperature and heating time factors gave a very significant difference to the Specific Energy Consumption (SEC) value. Figure 4 shows the amount of energy consumption required to produce coconut oil with and without the addition of bromelain enzyme extract. From the graph, it can be seen that the SEC required will increase as the heating temperature and time increase. The SEC value produced in the process of making coconut oil without bromelain enzyme extract ranges from 0.0047 to 0.0060 kWh/ml, while the SEC value required to produce coconut oil with the addition of bromelain enzyme extract ranges from 0.0038 to 0.0070 kWh/ml.

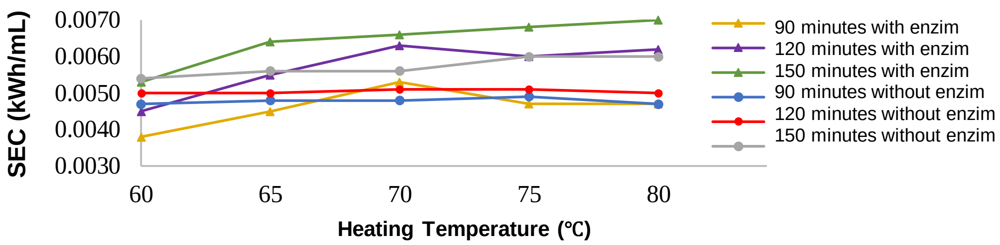

Figure 4. Graph of Specific Energy Consumption Analysis with Bromelin Enzyme Extract

From the graph, it can be seen that the amount of energy consumption required to produce coconut oil without and with the addition of bromelain enzyme extract requires Specific Energy Consumption (SEC), which is getting bigger as the temperature and heating time increase. The SEC value that increases with the length of time occurs because of the strong electric current required by the Stirred Tank Demulsifier Coconut Oil Tool. Electric current is the amount of electric charge that moves per unit time (Esye et al., 2021). Based on the calculation results, the electricity tariff required during the research will also increase as the temperature and heating time increase.

The electricity tariff needed in making coconut oil without the addition of bromelain enzyme extract ranges from Rp1,461.54 to Rp2,811.41, while the electricity tariff needed in making coconut oil with the addition of bromelain enzyme extract ranges from Rp1,498.61 to Rp2,806.36, so it can be concluded that the longer the time and the higher the heating temperature, the more electrical energy will be wasted.

4. CONCLUSION

The manufacture of coconut oil with and without the addition of bromelain enzyme extract has the same optimum conditions to produce the highest volume of coconut oil, which is at a temperature of 70 ^{o}C and a time of 150 minutes, which is as much as 353 ml and 355 ml, respectively. The resulting oil also meets the characteristics based on SNI 3741:2013, shown in Table 3.

Table 3. Differences in Characteristics of Research Results and SNI 3741: 2013

	SNI 3741:2013	Research Results	
		With Bromelin Enzyme Extract	Without Bromelin Enzyme Extract
Moisture content	Max 0.5 %	0.00019%	0.0025%
FTA	Max 5 %	3.3009 %.	3.2482 %

The highest specific energy consumption (SEC) in the process with the addition of bromelain enzyme extract is 0.0070 kWh/ml, and the electricity tariff is Rp2,806.36, while in the manufacture of coconut oil without the addition of bromelain enzyme extract, it takes 0.0060 kWh/ml with an electricity tariff of Rp2,811.4. Along with the increase in temperature and heating time, the volume of coconut oil produced, the free fatty acid content, the specific energy consumption (SEC), and the required electricity load will increase. However, the water content of the coconut oil produced will be smaller. The SEC value will increase with increasing temperature and heating time because the required electric current strength will be greater.

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