IJMSE International Journal of Mathematics and Science Education

E-ISSN: 3047-1648
P-ISSN: 3047-1974

*Research Article*

# The Relationship Between Growing Altitude and Oil Yield and Fatty Acid Composition of VCO from Coconuts in West Timor

**Jasman Jasman[1*], Idalia Norceb[2], Angnes Amtahanb[3], and Yosep Lawab[4]**

[1] Department of Chemical Education, Faculty of Education and Teachers Training, Universitas Nusa Cendana, Kupang Nusa Tenggara Timur, Indonesia 85001, Email: jasman@staf.undana.ac.id

[2-4] Biochemistry Chemistry Research Group, Department of Chemical Education, Faculty of Education and Teachers Training, Universitas Nusa Cendana, Kupang 85001, Nusa Tenggara Timur, Indonesia, Email: yosef_lawa@staf.undana.ac.id

* Corresponding Author : Jasman Jasman

**Abstract:** The aim of this study is to show the yield, quality, and the fatty acids composition of VCO produced from coconut growing in several location having different altitudes in West Timor. In addition, it also determined the correlation between the yield, quality, and the composition at one side and the altitude at other side. The coconut samples were taken from six locations at different altitudes. Virgin coconut oil is fermented using baker's yeast (Saccharomyces cerevisiae). The oil yield was calculated based on the oil volume ratio to the coconut cream volume, and the composition of fatty acid was then determined by a gas chromatography-mass spectrophotometer (GC-MS). The results showed that the quality of VCO obtained in this study is very good based on Indonesian National Standard (SNI) No. 7381:2008. The higher the growing location of coconut, the oil yield decreases slightly, the peroxide number increases slightly, the water content and free fatty acids are decrease. The correlation between the altitude of the coconut growing location and the fatty acid composition: lauric acid (strong and positive); palmitic and oleic acids (strong and negative); linoleic acid (very strong and negative); capric, myristic, and stearic acids (very weak and negative).

**Keywords:** Acid Composition, Height, Results, Virgin Coconut Oil.

## 1. Introduction

This article aims to reveal the possibility of a relationship between the altitude of the coconut growing location on the one hand and the oil content, oil quality and fatty acid composition in the coconut oil. Coconut plants on Timor Island grow at locations with varying altitudes from the coast to the hillsides. In addition, from several of our previous studies it was found that Virgin Coconut Oil (VCO) produced from coconuts on Timor Island has very high lauric acid content (> 50%), exceeding the standards set by the Indonesian National Standard (SNI No. 7381: 2008) and the Asian and Pacific Coconut Community (APCC). Each component of fatty acids in it has certain benefit for human health, so knowledge about the relationship between fatty acid composition and the altitude where coconuts grow, is expected to allow VCO producers to adjust the source of raw materials with the desired properties.

The study was conducted by making VCO from coconuts originating from various regions with different altitudes in the West Timor region. The characteristics of this VCO were evaluated in the form of yield, peroxide number, acid number, water content, and fatty acid composition. Furthermore, a correlation analysis between the altitude of the coconut growing place and each of the VCO characteristics was conducted.

The quality of the VCO produced in this research is very good. There is a correlation between the characteristics of VCO and the altitude of the coconut growing place, however, the correlation values shown are not all categories strong or very strong.

**Received:** 31 March, 2025
**Revised:** 14 April, 2025
**Accepted:** 28 April, 2025
**Online Available:** 30 April, 2025
**Curr. Ver.:** 30 April, 2025

## 2. Literature Review

Coconut plants have been known for thousands of years, and during this time, it has had economic value for humans. The coconut plant is called the "tree of life" because almost all its parts can be used for human life. Many coconut products, including coconut oil, coconut cake, tender coconut water, coconut shell, copra, raw kernel, building materials, roof, craft, decoration, and various foodstuffs (DebMandal & Mandal, 2011). Coconut oil is the most essential food product from coconuts. Coconut oil, edible oil that has been consumed in tropical countries for thousands of years was produced by crushing copra. The production of coconut oil in the world has been increasing over the past decade mainly because of increasing global demand for the essential oil. It is estimated that consumption of coconut oil now reaching to 3.5 MT/annum. This amount is approximately 2.5% of world vegetable oil production (Pham, 2016). Prior to the advent of the American edible oil industry in the 1940s, one of the major sources of dietary fats is coconut oil aside the dairy and animal fats (Nieto & Lorenzo, 2022). Coconut oil can be used in food processing, body care, and medicine. Some experts believe eating foods containing coconut provides several benefits, including preventing dyslipidemia (Beegum et al., 2022) and neurodegenerative disease caused by menopause (Balderan et al., 2023). Coconut oil have the activity of antibacterial (Hussain et al., 2020), antifungal (Kamel & Abbas, 2018), anti-inflammatory and antioxidant (Made et al., 2023), hepatoprotective (Ahmad et al., 2024), antiviral (Ghorbannezhad et al., 2022), immuno stimulant (Nazeam, 2022) (Yuniwarti et al., n.d.) and anti hypoglycemic (Beegum et al., 2022).

The main compound in coconut oil is a triacylglycerol (triglyceride), which chemically consists of fatty acids and glycerol. The types of fatty acids usually present in coconut oil are caproic, caprylic, capric, lauric, myristic, palmitic, stearic, arachidic, oleic, and linoleic acid. Apart from the fatty acids and triglycerides, there are also polyphenols, tocopherols, traces of vitamins, minerals, and plant sterol (Sandupama, 2022). Virgin coconut oil (VCO) is one of the most popular coconut products in recent years which obtained from fresh and mature coconut kernel by mechanical or natural means without chemical refining (Srivastava et al., 2018). VCO is considered a superior product of coconut because it has many health benefits, such as preventing the oxidation of low-density lipoprotein and increasing the antioxidant enzymes (Srivastava et al., 2018). VCO can strengthen the immune system; prevent the atherosclerosis, the obesity, and heart diseases; stimulate metabolism; conditioning the skin and hair; as an aromatherapy; and oil for massage, various cosmetics, and skin care products (Dumancas et al., 2016). Clinical studies have revealed that by moisturizing and soothing the skin, VCO may improves the symptoms of skin disorders (Varma et al., 2019).

Coconut plants (Cocos nucifera L.) grow considerably in tropical areas, especially on the coast. More than 90 countries in the world produce coconuts and their derivative products, which are concentrated in Asia and the Pacific (Pham, 2016). Although it grows more in coastal areas, this plant can still grow in areas with an altitude of up to 1000 meters above sea level. For commercial purposes, coconut plants can be cultivated at an optimum altitude of 0-450 meters with rainfall of 1300-2300/year and minimum sunshine of 120 h/month (Jasman, 2019). The effect of the altitude of growing place or habitat on fatty acid composition in various organisms has been reported: 1) In olive oil from fresh Mastoides cultivar grown at an altitude of 800 meters, the unsaturated fatty acid content was higher than that of grown at an altitude of 100 meters (Dumancas et al., 2016); 2) Al-Shdiefat (2019) reported that the ratio of fatty acids in olive oil is significantly affected by the altitude of the area where it is grown. Olive oil from the highlands, such as the Kufranja region (Jordan), has better qualities than that obtained from the Jordan Valley. However, the influence of environmental variables, especially the altitude at which coconuts grow, on the composition of fatty acids and other compounds in coconut oil has not been widely reported. Therefore, this study attempts to reveal the correlation between altitude and the quality of coconut oil and the composition of fatty acids in the coconut oil. The finding about fatty acids composition have advantages in considering coconuts from which location that more suitable for making VCO with certain efficacy. As we know that the composition of the fatty acids affects the efficacy of the VCO, for example, VCO which contains a lot of short and medium-chain fatty acids, has vigorous antimicrobial activity (Szabó et al., 2023), while VCO, which includes a lot of unsaturated fatty acids, can prevent heart disease (Briggs et al., 2017) and obesity (Haldar et al., 2022).

## 3. Methods

### 3.1. Materials and Reagent

a. Fresh matured coconut fruit, obtained from six locations with different altitudes listed in the Table 1.

**Table 1.** Location and altitude of coconut fruit sampling sites

| No | Location | Altitudes (meters above sea level) |
|---|---|---|
| 1 | Lasiana Village, Sub district of Kelapa Lima, Kupang City | 50 |
| 2 | Kualin, District of South Central Timor | 238 |
| 3 | Nonbes Village, Subdistrict of Amarasi, District of Kupang | 400 |
| 4 | Baun, district of Kupang | 430 |
| 5 | Noemuti, district of North Central Timor | 512 |
| 6 | Soe City, District of South Central Timor | 900 |

b. Baker's yeast (brand: PakMaya) was obtained from grocery store in Kupang.
c. Distilled water and starch indicator 1% provided by Chemistry Laboratory of Nusa Cendana University.
d. Chemicals: Alcohol 96%, sodium hydroxide, phenolphthalein, acetic acid, chloroform, sodium hydroxide, potassium hydroxide, boron tri hydride, potassium iodide, and sodium thiosulphate were purchased from Merck (Singapore).

### 3.2. Fatty acid composition Determination

Fatty acid composition determination was performed at the Laboratory of Organic Chemistry at Gadjah Mada University Indonesia using GC-MS (GC-MS-QP2010S Shimadzu, Japan, column: Rtx 5MS 30 meters, column temperature 50 °C, injection temperature 300 oC, carrier gas: helium, injection mode: split, column flow 0.55 mL/min).

### 3.3. Extraction of virgin coconut oil

The coconut fruit was peeled, cleaned, and drained. Two kilogram of the coconut flesh was grated and mixed with 4 litters of warm water (50°C) in a basin. The mixture was then kneaded, wrapped in a filter cloth, and squeezed for coconut milk. The obtained coconut milk was appeased for 2 h until two layers were formed; the top was coconut cream and the bottom was water. The water layer was then removed by suction using a small plastic hose. In a 500 mL Erlenmeyer flask, the starter was prepared by mixing 200 mL coconut milk, 50 mL coconut water, and 2 g baker's yeast. The mixture was stirred until it became homogeneous, then covered and incubated at room temperature for 12 h.

As much as 237.5 mL of coconut cream was poured into a 500 ml Erlenmeyer flask, added by 12.5 mL of starter, and then shaken slowly until the mixture was homogeneous. The flask was sealed and incubated at 30 °C for 24 h at static condition. The result of fermentation composed of three layers: water, oil, and floating dregs called "blondo" (in Indonesian). The oil layer was then separated by suctioning it using a small plastic hose. The obtained oil was then filtered using filter paper for clarification. The yield of coconut oil was then calculated according to Jasman et al. (2021).

$$\text{Yield (\%)} = V_o/V_c \times 100 \quad (1)$$

where Vo is the volume of oil, and Vc is the volume of coconut cream, measured in mL.

### 3.4. Determination of peroxide value

Five grams of oil was put into a 250 mL Erlenmeyer flask then added with 30 mL of acetic acid-chloroform solution. The mixture was shaken until homogeneous then saturated potassium iodide solution was added. Next, the mixture was allowed to stand for 1 minute, then 30 mL of distilled water was added, and titrated with 0.1 N $Na_2S_2O_3$ until the yellow colour was almost no longer visible. The solution was then added with 0.5 mL of 1% starch indicator then titrated again until the blue colour began to disappear. Milli-equivalents of peroxide per 1000 g of sample represent the peroxide value.

Peroxide value=(V x N x 1000)/(mass of sample (g)) (2)

where V = volume of $Na_2S_2O_3$ solution (mL) and N = normality of $Na_2S_2O_3$ solution.

### 3.5. Determination of the free fatty acid value

Ten grams of coconut oil was put into a 250 mL Erlenmeyer flask, added 25 mL of 95% alcohol, and refluxed for 1 hour. Next, the mixture was cooled and then three drops of phenolphthalein indicator were added. Finally, the mixture was titrated with 0.1 N KOH solution until the colour turn pink. The acid number was then calculated based on the equation (3).

Acid number = (V × N × MW )/(mass of sample (g)) (3)

where V = volume of KOH solution; N = normality of the KOH solution; and MW = molecular weight of KOH.

### 3.6. Determination of the moisture and volatile matter content

The Procedure was adapted from Jasman et al., (2021). An amount of 2.00 grams of sample placed into bottle scales. Consecutively, the bottle was heated in oven for 5 h at 105 °C, after which the oil was cooled in a desiccator and reweighed. This Procedure was repeated until a constant weight was achieved. The moisture of oil was calculated as follow:

Moisture (%) = (B0-B1 )/B0× 100 (4)

where B0 = weight of oil before heating, and B1 = weight of oil after heating.

### 3.7. Determination of the fatty acid composition

An amount of 1.0 mL of VCO was added to 1.5 mL of NaOH solution in methanol and heated in a water bath at 80°C for 5 min. After that, the solution was added with $BF_3$, dissolved in 2.0 mL of methanol, heated for 25 min, and cooled respectively. After cooling, 1.0 mL of n-hexane was added, and then 1.0 μL of ester layer formed at the top was taken by a syringe and then injected into GC-MS (Suirta et al., 2021).

### 3.8. Statistical analysis

The statistical analysis conducted in this study is correlation analysis. This is used to see the relationship between the altitude of the coconut growing place and the yield of VCO produced and also with the composition of fatty acids contained in the VCO.

## 4. Results

### 4.1. Yield and quality of VCO

Data of yield, peroxide number, acid number, and moisture content obtained in this study can be seen in Table 2.

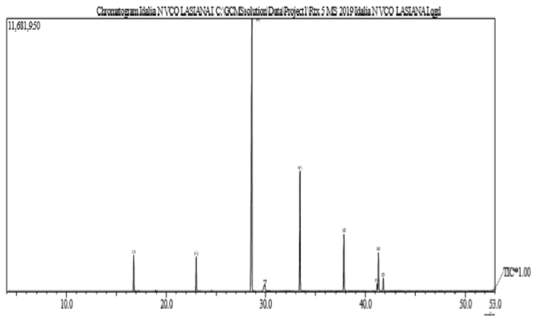
**Table 2.** Yield and quality of VCO

| No | Locations | Altitudes (meters above sea level) | Yield (%) | Peroxide Number (meq/g) | Acid Number (%) | Moisture/volatile content (%) |
|---|---|---|---|---|---|---|
| 1 | Lasiana Village, Sub district of Kelapa Lima, Kupang City | 50 | 28.60±0.76 | 0.017±0.011 | 0.11±0.02 | 0.023±0.006 |

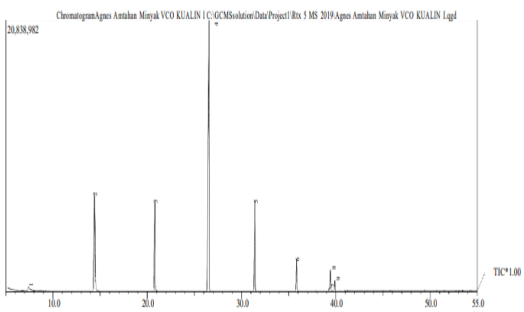
| | | | | | | |
|---|---|---|---|---|---|---|
| 2 | Kualin, District of South Central Timor | 238 | 26.08±0.56 | 0.01±0.01 | 0.10±0.02 | 0.02±0.00 |
| 3 | Nonbes Village, Subdistrict of Amarasi, District of Kupang | 400 | 26.80 ±0.40 | 0.033±0.006 | 0.093±0.01 | 0.007±0.011 |
| 4 | Baun, district of Kupang | 430 | 30.70±1.50 | 0.03±0.02 | 0.09±0.03 | 0.01±0.01 |
| 5 | Noemuti, district of North Central Timor | 512 | 28.89±0.99 | 0.02±0.01 | 0.09±0.03 | 0.02±0.01 |
| 6 | Soe City, District of South Central Timor | 900 | 26.10±0.56 | 0.023±0.011 | 0.08±0.02 | 0.007±0.011 |
| r1 = correlation with altitude | | | r = -0.25 | r = 0.35 | r = -0.97 | r = -0.68 |
| Indonesian's Standard (SNI) | | | | 3.0 | 0.2 | 0.1-0.5 |

### 4.2. Fatty Acids Composition

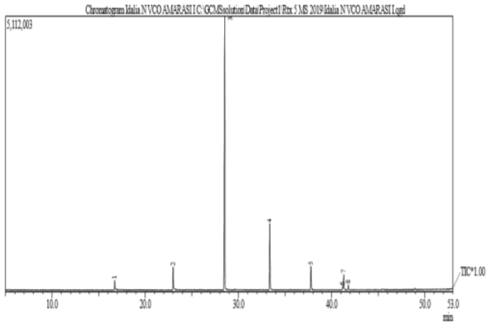
Based on the analysis using GC-MS, data were obtained about the type of fatty acids and their composition in VCO produced from coconut samples grown at locations with altitudes of 50, 238, 400, 430, 512, and 900 meters, respectively, as shown in the Figure 1. The data is also displayed in Table 2 which is also equipped with correlation values between fatty acid composition and the altitude of the coconut plant location. Furthermore, a graph showing the tendency of changes in the composition of fatty acid based on the altitude is shown in Figure 1.



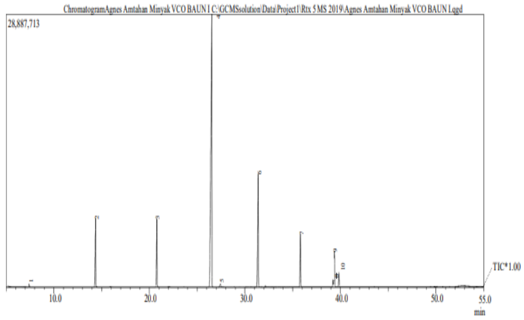

50 masl



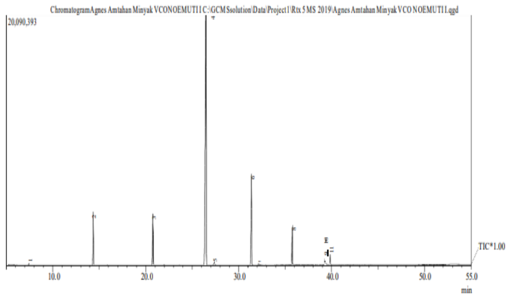

238 masl



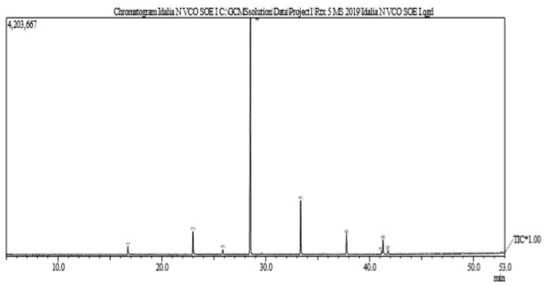
400 masl



430 masl



512 masl



900 masl

(Note: masl = meters above sea level)

**Figure 1.** Chromatograms of oil from different altitude

**Tabel 3.** Correlation between the fatty acids composition and the altitude of growing location

| No | FA | Average composition of fatty acids (%) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Lasiana (50 masl) | Kualin (238 masl) | Nonbes (400 masl) | Baun (430 masl) | Noemuti (512 masl) | Soe (900 masl) | Correlation |
| 1 | C8:0 | 4.79 ± 0.73 | 10.98±2.75 | 2.08 ± 0.25 | 7.16±0.70 | 9.07±0.88 | 1.95 ± 0.42 | *r = -0.38* |
| 2 | C10:0 | 4.80 ± 0.44 | 11.66±0.67 | 5.34 ± 0.20 | 7.10±0.72 | 8.99±0.71 | 5.8 ± 0.08 | *r = -0.11* |
| 3 | C12:0 | 55.15 ± 1.7 | 51.66±2.33 | 63.87 ± 0.4 | 58.58±2.25 | 54.31±1.70 | 65.3 ± 1.30 | *r = 0.67* |
| 4 | C14:0 | 16.72 ± 1.5 | 12.90±1.28 | 15.98 ±0.32 | 14.62±0.31 | 15.20±2.24 | 14.65 ± 0.20 | *r = -0.23* |
| 5 | C16:0 | 7.51 ± 0.67 | 5.40±0.40 | 6.15 ± 0.05 | 6.28±0.28 | 5.48±1.08 | 5.47 ± 0.16 | *r = -0.65* |
| 6 | C18:0 | 0.93 ± 0.16 | 0.77±0.14 | 0.74 ± 0.08 | 0.51±0.05 | 0.45±0.03 | 0.89 ± 0.13 | *r = -0.12* |
| 7 | C18:1 | 5.32 ± 0.5 | 4.51±0.45 | 4.38 ± 0.31 | 3.56±0.13 | 3.67±0.37 | 4.18 ± 0.08 | *r = -0.59* |
| 8 | C18:2 | 2.03 ± 0.2 | 2.02±0.18 | 1.46 ± 0.09 | 1.29±0.07 | 1.45±0.10 | 1.27 ± 0.06 | *r = -0.82* |

Note: Caprylic acid (C8:0); capric acid (C10:0); lauric acid (C12:0); myristic acid (C14:0); palmitic acid (C16:0); stearic acid (C18:0); oleic acid (C18:1); linoleic acid (C18:2)

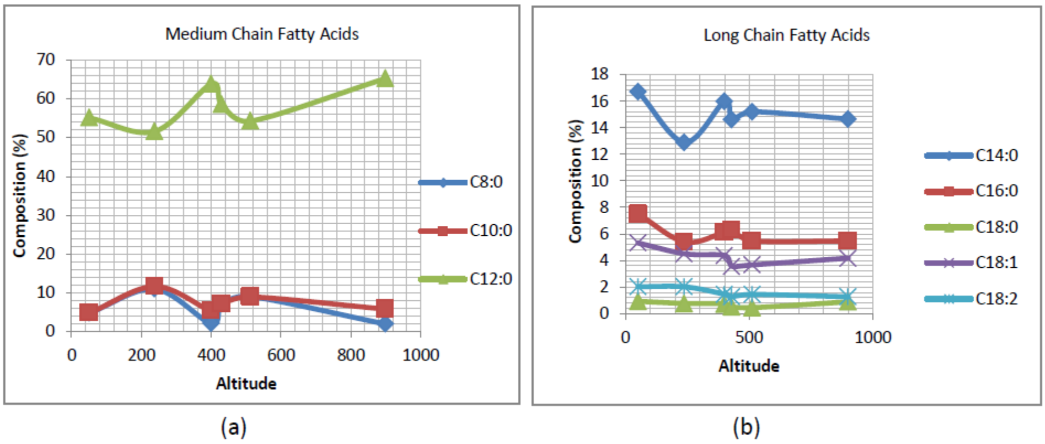



**Figure 2.** Graph of changes in fatty acid composition based on growing altitude.

## 5. Discussion

### 5.1. The Oil Yield

Based on the table 2 it can be seen that the higher the location where the coconut grows, the lower the yield of VCO produced. This phenomenon can generally be associated with the air temperature of the location. When the location getting higher, the air temperature getting lower. Every 100 meters, the air temperature will decrease by 0.60-0.65 oC (Jumin, 2002). A decrease in ambient air temperature will affect the activity of enzymes involved in plant metabolism, including the synthesis of oil in coconut plants. The equation related the enzymatic reaction rate to temperature (Peterson et al., 2007) shows that the reaction rate has an optimum temperature, the temperature at which the enzymatic reaction rate has the maximum value. If the temperature is less or more than the optimum temperature, the enzymatic reaction rate decreases. The further a reaction temperature from the optimum value the lower the reaction rate.

Kazemi et al. (2017) stated that changes in altitude can affect the amount of essential oil as a result of various parameters such as climate conditions including air temperature. For example, for oil palm, the maximum air temperature for efficient photosynthesis is 38 °C, while average monthly temperatures below 18 °C can drastically reduce the oil content (Woittiez et al., 2017). For coconut plants, Gomes & Prado (2007) stated that these plants require a hot climate with temperatures between 22-34 °C without temperatures below 15 °C. Meanwhile, according to Beveridge et al.(2022), the ideal temperature for the growth and yield of coconut fruit is between 27 and 32 °C in a humid environment.

### 5.2. Peroxide value

Based on the data in Table 2, it appears that the peroxide value of VCO obtained from coconuts from different altitudes meets the Indonesian National Standard, so it can be said that the VCOs have good quality. The correlation between altitude and peroxide number is positive although very weak. A positive correlation means that the higher the location of coconut growth, the VCO produced tends to have a higher peroxide number. This can happen because the low temperature in the highlands reduces stress on coconut plants so that the production of antioxidant compounds is lower (Sebastian et al., 2014). The formation of antioxidants at low altitudes can be greater to compensate for high temperature stress (Hasanuzzaman et al., 2020). However, the correlation obtained here is very weak, may be because there are many factors affect both the synthesis of antioxidant (Hasanuzzaman et al., 2020) and the extraction method (Mohammed et al., 2024).

### 5.3. Moisture content

Table 2 shows that the water content of the VCO obtained here meets the Indonesian National Standard (SNI 7381:2008) on VCO. The data also shows that there is a negative correlation ($r = -0.68$) between the altitude of growth and the water content in VCO. This may be because the higher the place of growth of the coconut, the lower the groundwater thus the water content in the coconut flesh is also lower. This is in accordance with the statement that coconuts from lowlands tend to produce VCO with higher water content because the water content in the flesh is also higher. Conversely, coconuts from highlands tend to produce VCO with lower water content, because the fat content is more dominant than water (Chan & Elevitch, 2006). However, this conclusion cannot be confirmed as true because there are other factors that affect the water content of the coconut oil produced, one of which is the extraction method. (Nair & Fernando, 2024; Jayanthi & Arumugam 2023).

### 5.4. Free Fatty Acid Value (Acid Number)

Based on Table 2, it appears that the acid number of the VCO produced meets the requirements of the Indonesian National Standard (SNI 7381:2008 concerning VCO). The data also shows that there is a very strong and negative correlation value ($r = -0.97$) between the height of the coconut growing location and the VCO acid number. This means that the higher the location of the growth, the lower the acid number or the lower the free fatty acid content. This is in line with the correlation value between height and water content. The explanation for this is that the low water content causes a reduction in the hydrolysis reaction to the glyceride molecule so that free fatty acids are also low. However, the acid number can also be influenced by other factors such as enzyme content and incubation time (Ayuningtyas et al 2023).

### 5.5. Fatty Acids Composition

Based on the Table 3 and Figure 2 above, it can be seen that medium chain fatty acids (MCFA) C8:0 and C10:0 tend to decrease with increasing altitude of the coconut growing location, while C12:0 tends to increase. However, this tendency fluctuates with a sharp increase in C12:0 at an altitude of around 400 meters above sea level which is accompanied by a sharp decrease in C8:0 and C10:0 production. There has not been any previous data to support this finding. Another thing that is clearly visible is that the composition along the graph for C12:0 is much higher than other types of fatty acids and this confirms the reason why coconut oil is called lauric oil (Dayrit, 2014; Silalahi, 2020; Cargill, 2025). The lauric acid composition achieved in this study, namely between 55.15-65.3%, is much higher than that determined by APCC (Asian and Pacific Coconut Community), namely 45.0-56% and the lauric acid of market VCO, which generally ranges from 48-55.4% (Novarianto & Tulalo, 2007). This may be due to the type of soil and climate conditions in province of East Nusa Tenggara, particularly in Timor Island. Sandy soil and high potassium content contribute to the oil content in coconut flesh (Neenu & Bhat, 2022). Soil with a pH range of 5.5 to 6.5 is ideal for coconut growth (PNS/BAFS, 2018) may also ideal for development of oil in its flesh part.

In the case of long chain fatty acids (LCFA), the correlation between the composition and the altitude are very weak appear in C14:0 and C18:0. Meanwhile, in C16:0 and C18:1, there is a fairly strong correlation between its composition and the altitude. Furthermore, for C18:2, the correlation between composition and altitude appears to be very strong. All LCFA have a tendency to decrease with increasing altitude which indicated by negative correlation.

When comparing saturated and unsaturated fatty acids at C18, it appears that in saturated fatty acids (C18:0), the correlation between composition and height is very weak; in monounsaturated fatty acids (C18:1) the correlation is strong; and in polyunsaturated fatty acids (C18:2) the correlation is very strong. It can also be seen that the composition C18:1>C18:2>C18:0. These data may be a new finding, but there have not been other research confirmed its validity.

Statistical analysis using one-way ANOVA showed that there is a significant difference ($p<0.05$) between lauric acid levels from the lowlands (200 meters) and lauric acid from the highlands (400-900 meters). VCO from the highlands contain lauric acid percentage more than those from the lowlands. These results are different from those obtained by Novarianto and Tulalo (2007), who stated that the lauric acid content of coconut from the lowlands was higher than that of the highlands. So far as we have investigated, there has not been any references discuss this phenomenon, but we suppose that the differences are caused by soil and climatic conditions. Though there are differences in the lauric acid content, the overall lauric acid and medium chain fatty acid (MCFA) content is much higher than the long chain fatty acid (LCFA) content. The high MCFA content makes VCO healthy for consumption because MCFA molecules are easily metabolized into energy in the body (Patil & Benjakul, 2018). The high composition of MCFA, especially lauric acid in VCO, provides the advantage of antimicrobial properties (Khoramnia et al., 2013; Batovska et al., 2009). The advantage of VCO produced from coconut plants on Timor Island is its high lauric acid content.

The composition of long-chain fatty acids (C14 or more) is also significantly different in the VCO from the highlands and those from the lowlands, where LCFA is more abundant in the VCO from the lowlands. The composition of saturated and unsaturated fatty acids was also significantly different ($p <0.05$) between VCO from the lowlands and VCO from the highlands. VCO from the highlands (400-900 meters) contains more saturated fatty acids than VCO from the lowlands, and the opposite happens for unsaturated fatty acids. These results are related to the study of Harris & James (1969), which stated that the increase in unsaturated fatty acids was associated with increased oxygen concentrations at low temperatures. At high oxygen concentrations, the formation of unsaturated fatty acids increased with increasing temperature. Because the air temperature in the lowlands is higher, the high oxygen concentration causes the formation of more unsaturated fatty acids than in the highlands. This result is in line with the results of a study by Montaño et al. (2016), Rondanini et al. (2014), and Nissim et al. (2020), who showed that the Arbequina variety olive oil from a hotter area contained higher linoleic acid (unsaturated fatty acid) compared to oleic acid (saturated fatty acid). This result is also in line with the results of research from Izquierdo & Aguirrezábal (2008), which states that the content of unsaturated fatty acids from sunflowers increases at higher temperatures.

The differences in the types of fatty acids and their composition are thought to be the result of differences in various factors, for example, soil type and climate factors as occur in other plants such as Juniperus communis (Kazemi et al., 2017), altitude factor in hazelnut plants (Beyhan et al., 2011) and in olive plants (Al-Shdiefat, 2019).

## 6. Conclusion

The higher the place where the coconut grows, the lower the VCO yield produced, so the height where the coconut grows affects the VCO yield produced. The peroxide value, FFA value, and water content in VCO from the three regions studied did not have significant differences, and all met APCC standards and SNI. VCO from high areas tend to contains more lauric acid than those from low places. VCO from common areas contains more long-chain fatty acids (C14 or more) than those of high regions. VCO from high areas contains more saturated fatty acids than low areas.

The quality of VCO obtained in this study is very good based on Indonesian National Standard (SNI) No. 7381:2008. The correlation between VCO yield and the height of the coconut growing place in this study is very weak and negative, which means that the height of the growing place does not necessarily determine the amount of oil obtained, but there is a slight tendency that the higher the coconut growing location, the lower the oil content.

There is an indication but very weak that the higher the coconut growing location, the higher the peroxide number of the oil produced. There is a tendency that the higher the coconut growing location, the lower the water content in the VCO produced. The same tendency also occurs in the free fatty acid content and the fatty acids composition except for lauric acid. This trend is quite strong for palmitic and oleic acid, very strong for linoleic acid but very weak for capric, caprylic, and myristic acids. In contrast, the composition of lauric acid tends to be in line with the increase in altitude of the coconut growing location.

## Limitation

The limitations of this research are that some variables, such as soil type, sunlight and rainfall, cannot be controlled.

## References


[1] Agri-Pure Lauric Oils. [Online]. Tersedia: https://www.cargill.com/bioindustrial/agri-pure-lauric-oils (diakses: 30 Apr. 2025).
[2] B. Ahmad, W. Khan, T. U. Haq, S. Ahmad, M. Zahoor, A. Alotaibi, dan R. Ullah, "Beneficial effects of coconut oil (Cocos nucifera) on hematobiochemical and histopathological markers in CCL4-intoxicated rabbits," Braz. J. Biol., vol. 84, pp. 1–8, 2024, doi: 10.1590/1519-6984.252555.
[3] S. M. M. Al-Shdiefat, "Effect of the Planting Location (Elevation) on the Composition of Fatty Acids in Olive Oil," J. Agric. Sci., vol. 11, no. 2, pp. 271–275, 2019, doi: 10.5539/jas.v11n2p271.
[4] I. P. Ayuningtyas dan W. Broto, "The Preparation of Virgin Coconut Oil Using Acid from Passion Fruit Extract at Different Temperature and Incubation Time," J. Appl. Food Technol., vol. 10, no. 1, pp. 23–26, 2023.
[5] A. Balderan, Y. Farrokhifar, M. Hosseini, E. Khordad, S. Kakhki, dan F. Beheshti, "Assessment of the neuroprotective effect of Cocos nucifera L. oil on learning and behavior impairment in ovariectomized rats," Avicenna J. Phytomed., vol. 13, no. 6, pp. 665–674, 2023, doi: 10.22038/AJP.2023.22724.
[6] D. I. Batovska, I. T. Todorova, I. V. Tsvetkova, dan H. M. Najdenski, "Antibacterial study of the medium chain fatty acids and their 1-monoglycerides: Individual effects and synergistic relationships," Pak. J. Microbiol., vol. 58, no. 1, pp. 43–47, 2009.
[7] P. P. S. Beegum, R. Pandiselvam, S. V. Ramesh, S. H. Thube, dan T. P. Pandian, "Coconut as an Antimicrobial Agent: Antibacterial effect," Qual. Assur. Saf. Crops Foods, vol. 14, no. 2, pp. 86–100, 2022, doi: 10.15586/qas.v14i2.1040.
[8] F. C. Beveridge, S. Kalaipandian, C. Yang, dan S. W. Adkins, "Fruit Biology of Coconut (Cocos nucifera L.)," Plants, vol. 11, no. 23, 2022, doi: 10.3390/plants11233293.
[9] Ö. Beyhan, M. Elmastaş, N. Genc, dan H. Akşit, "Effect of altitude on fatty acid composition in Turkish hazelnut (Coryllus avellana L.) varieties," Afr. J. Biotechnol., vol. 10, no. 71, pp. 16064–16068, 2011, doi: 10.5897/AJB11.2424.
[10] M. A. Briggs, K. S. Petersen, dan P. M. Kris-Etherton, "Saturated fatty acids and cardiovascular disease: Replacements for saturated fat to reduce cardiovascular risk," Healthcare, vol. 5, no. 2, 2017, doi: 10.3390/healthcare5020029.
[11] E. Chan dan C. R. Elevitch, "Cocos nucifera (coconut)," dalam Species Profiles for Pacific Island Agroforestry, C. R. Elevitch, Ed. Hōlualoa, Hawai: Permanent Agriculture Resources (PAR), 2006.
[12] F. M. Dayrit, "The Properties of Lauric Acid and Their Significance in Coconut Oil," J. Am. Oil Chem. Soc., vol. 92, no. 1, pp. 1–15, 2014, doi: 10.1007/s11746-014-2562-7.
[13] M. DebMandal dan S. Mandal, "Coconut (Cocos nucifera L.: Arecaceae): In health promotion and disease prevention," Asian Pac. J. Trop. Med., vol. 4, no. 3, pp. 241–247, 2011, doi: 10.1016/S1995-7645(11)60078-3.
[14] G. G. Dumancas et al., "Health benefits of virgin coconut oil," dalam Vegetable Oil: Properties, Uses and Benefits, Nova Science Publishers, 2016.
[15] G. Ghorbannezhad, A. R. Derakhshan, dan B. Daneshfard, "Potential Therapeutic Effects of Virgin Coconut Oil on COVID-19," Tanaffos, vol. 21, no. 4, pp. 405–407, 2022.
[16] F. P. Gomes dan C. H. B. A. Prado, "Ecophysiology of coconut palm under water stress," Braz. J. Plant Physiol., vol. 19, no. 4, pp. 377–391, 2007, doi: 10.1590/S1677-04202007000400008.
[17] S. Haldar et al., "Increased Consumption of Unsaturated Fatty Acids Improves Body Composition in a Hypercholesterolemic Chinese Population," Front. Nutr., vol. 9, Apr. 2022, doi: 10.3389/fnut.2022.869351.
[18] M. Hasanuzzaman et al., "Reactive Oxygen Species and Antioxidant Defense in Plants under Abiotic Stress: Revisiting the Crucial Role of a Universal Defense Regulator," Antioxidants, vol. 9, p. 681, 2020, doi: 10.3390/antiox9080681.
[19] M. S. Hussain, F. T. Al-alaq, N. S. Al-khafaji, dan H. O. M. Al-dahmoshi, "Antibacterial Effect of Virgin and Refined Coconut Oils on Pathogenic Bacteria: A Review," Int. J. Food Microbiol. Technol., vol. 14, no. 4, pp. 6042–6048, 2020.
[20] N. G. Izquierdo dan L. A. N. Aguirrezábal, "Genetic variability in the response of fatty acid composition to minimum night temperature during grain filling in sunflower," Field Crops Res., vol. 106, no. 2, pp. 116–125, 2008, doi: 10.1016/j.fcr.2007.10.016.
[21] Jasman, Minyak Kelapa: Teknik Pembuatan Secara Fermentasi, Bani Marsi, Ed., 1st ed. P MIPA PRESS, 2019.
[22] Jasman, E. A. Lawe, dan Sudirman, "Evaluation of yield and quality of virgin coconut oil produced using repeated batch fermentation with baker's yeast," Agrivita, vol. 55, no. 1, pp. 51–56, 2021, doi: 10.34044/j.anres.2021.55.1.07.
[23] P. Jayanthi dan R. Arumugam, "Influence of environmental and agronomic factors on coconut (Cocos nucifera L.) endosperm water content," J. Trop. Agric., vol. 61, no. 1, pp. 45–52, 2023.
[24] H. Jumin, Dasar-dasar Agronomi. Jakarta: P.T. Raja Grafindo, 2002.
[25] R. Kamel dan H. Abbas, "Rationale For The Use Of Coconut Oil-Based Anti-Mycotic Pessaries To Combat Recurrent Vaginal Infection: In Vitro / In Vivo Evaluation And Preliminary Prospective Clinical Investigation," Int. J. Appl. Pharm., vol. 10, no. 5, 2018.

[26] S. Y. Kazemi, J. Nabavi, H. Zali, dan J. Ghorbani, "Effect of Altitude and Soil on the Essential Oils Composition of Juniperus communis," J. Essent. Oil-Bear. Plants, vol. 20, no. 5, pp. 1380–1390, 2017, doi: 10.1080/0972060X.2017.1387080.

[27] A. Khoramnia, A. Ebrahimpour, R. Ghanbari, Z. Ajdari, dan O. M. Lai, "Improvement of medium chain fatty acid content and antimicrobial activity of coconut oil via solid-state fermentation using a Malaysian Geotrichum candidum," Biomed Res. Int., vol. 2013, pp. 7–9, 2013, doi: 10.1155/2013/954542.

[28] N. Made, R. Trismayanti, K. Handono, dan D. Handayani, "Virgin Coconut Oil Supplementation as Ulcerative Colitis Prevention: Does it work? Clinical Correlation," J. Mol. Chem. Sci., vol. 6, pp. 3178–3187, 2023, doi: 10.26655/JMCHEMSCI.2023.12.31.

[29] N. K. Mohammed, Z. T. Samir, M. A. Jassin, dan S. K. Saeed, "Effect of different extraction methods on physicochemical properties, antioxidant activity, of virgin coconut oil," Mater. Today Proc., vol. 42, no. 4, 2021