OPTIMIZATION OF COCONUT COOKING OIL QUALITY BY ADJUSTING ACETIC ACID LEVELS AND HEATING TIME

OPTIMASI KUALITAS MINYAK GORENG KELAPA MELALUI PENGATURAN KONSENTRASI ASAM ASETAT DAN LAMA PEMANASAN

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Abstract

The traditional production of coconut oil utilizes the heating of coconut cream for oil extraction. Prolonged heating can damage the quality, increase fuel consumption, and shorten shelf life. This study focuses on the impact of acetic acid concentration and cooking duration on coconut oil quality. Employing a Factorial Randomized Block Design, two main factors were analyzed: acetic acid concentration (2% and 2.5%) and cooking duration (30, 45, 60 minutes). A control group with 0% acetic acid was also evaluated. Several parameters, such as oil yield, water content, acid number, peroxide value, impurities, and color were analyzed. The analysis of variance showed that each factor: the variation in acetic acid concentration and cooking duration, affected oil quality, but the interaction between them did not. Treatment with 2% acetic acid for 30 minutes yielded the best quality oil (according to the De Garmo method), with a 29% oil yield and superior quality (water content < 1%, Free Fatty Acid content as Lauric Acid (0.27%), and Brightness Value L* 43.68) compared to traditional commercial coconut cooking oil and successfully met several elements of the Indonesian National Standard for coconut cooking oil. Overall, acidification using acetic acid improved the quality of coconut oil, better than the control group, and is able to offer a more efficient and high-quality coconut cooking oil production method.

Keywords*: Coconut cooking oil, Heating time, Acetic acid, Oil Quality*

Abstrak

Produksi tradisional minyak kelapa umumnya menggunakan metode pemanasan santan kelapa untuk mengekstraksi minyaknya. Pemanasan yang terlalu lama dapat menurunkan kualitas minyak, meningkatkan konsumsi bahan bakar, serta memperpendek masa simpan. Penelitian ini bertujuan untuk mengevaluasi pengaruh konsentrasi asam asetat dan lama pemanasan terhadap kualitas minyak kelapa. Dengan menggunakan Rancangan Acak Kelompok Faktorial, dua faktor utama diteliti yaitu konsentrasi asam asetat (2% dan 2,5%) dan lama pemanasan (30, 45, 60 menit). Kelompok kontrol dengan 0% asam asetat juga dievaluasi. Parameter yang diamati meliputi rendemen minyak, kadar air, angka asam, angka peroksida, kadar kotoran, dan warna. Hasil analisis ragam menunjukkan bahwa masing-masing faktor, yaitu konsentrasi asam asetat dan lama pemanasan, berpengaruh signifikan terhadap kualitas minyak, namun interaksi antara keduanya tidak berpengaruh signifikan. Perlakuan terbaik diperoleh dari penggunaan asam asetat 2% dengan lama pemanasan 30 menit, menghasilkan minyak kelapa dengan kualitas terbaik (berdasarkan metode De Garmo), yaitu rendemen minyak sebesar 29% dengan kualitas unggul (kadar air <1%, kadar asam lemak bebas sebagai asam laurat 0,27%, dan nilai kecerahan L* sebesar 43,68) dibandingkan minyak kelapa komersial tradisional. Minyak ini juga memenuhi beberapa unsur Standar Nasional Indonesia (SNI) untuk minyak kelapa goreng. Secara keseluruhan, proses pengasaman menggunakan asam asetat dapat meningkatkan kualitas minyak kelapa dibandingkan kelompok kontrol serta menawarkan metode produksi minyak kelapa yang lebih efisien dengan kualitas yang lebih tinggi.

Kata kunci: *Minyak goreng Kelapa, Lama Pemanasan, Asam Asetat, Kualitas Minyak*

1. Introduction

The processing of coconut into coconut oil generally has two methods: traditional and modern. The modern method is performed dry by pressing copra (dried coconut) into a powder, which is then heated and pressed to extract the oil. The traditional method is usually done wet, by making coconut milk which is then heated to produce oil. Heating is done to eliminate the water content in the coconut milk (Che Man, Abdul Karim, & Teng, 1997; Suhardiyono, Man, Asbi, & Azudin, 1993). With these two available methods, the general public is more likely to use the traditional method to process oil, due to the limited availability of relatively expensive equipment. However, the traditional method has weaknesses that affect the quality of the produced coconut oil, namely the high cost of fuel used for heating and the relatively long heating time of the coconut milk which shortens the shelf life of the produced oil. There is a solution for processing coconut fruit into coconut oil using a modification from the traditional method to shorten the cooking time of the coconut milk, thus saving on fuel costs. The modification of the coconut oil processing technique used is the method of adding acid by using acetic acid during the separation of the coconut cream from its water part. The addition of acetic acid at a certain concentration to the coconut milk is presumed to shorten the cooking time of the coconut cream because the acid acts as a catalyst in the hydrolysis reaction breaking down the emulsion in the coconut milk, which facilitates the separation of the oil from its emulsion with protein.

Previous research has revealed that the amount of acetic acid added also accelerates the denaturation process of protein into oil (Aprilasani & Adiwarna, 2014; Mulyaningsih & P, 2004). However, when adding acetic acid, pH control is needed. The optimum pH to create isoelectric conditions is 4.5, with the optimum addition of acetic acid at a concentration of 2% (Aprilasani & Adiwarna, 2014). The highest yield was obtained with the addition of 2% acetic acid, but it was not significantly different from 1.5% and 1% (Rahim, 2020) and with the addition of acetic acid at concentrations of 2.5%, 3%, and 3.5%, there was a decrease in yield (Mulyaningsih & P, 2004; Rahim, 2020). Another study found that oil cooked for 30 minutes at a cooking temperature of 90℃ resulted in better quality oil than oil processed with traditional processing at temperature ranges around 110-140 ºC (Che Man et al., 1997).

The goal of this research is to find the concentration of acetic acid and the cooking duration that can produce high-quality coconut cooking oil according to SNI standards. The expected benefit of this research is to understand the characteristics of coconut cooking oil produced after being made with variations in acetic acid concentration and cooking duration. The hypothesis proposed in this study is that the variations in acetic acid concentration and cooking duration are presumed to have an effect on the characteristics of the produced coconut cooking oil.

2. Material and Methods

Material

The materials used in this study are coconut fruit (Cocos nucifera L) from Ledeng Market, Bandung, acetic acid/kitchen vinegar Dixi (Sidola, Bandung), distilled water (Smartlab, Bogor), 0.1 N KOH, 0.1 N HCl, acetic acid chloroform (2:1), 0.1 N sodium thiosulfate; starch indicator (Merck, Germany), saturated potassium iodide (KI) solution, acetate-isooctane solution, n-hexane solution, 95% ethanol, and amylum indicator.

Equipments

The equipment used in this study includes a Digital balance (OHAUS Shanghai, China), funnels and desiccators (Iwaki, Sumedang), ovens and incubators (IKA, Malaysia), 250 mL Erlenmeyer flasks, Asah 250 ml Erlenmeyer flasks, chemical glasses, weighing bottles, burettes, measuring flasks (Iwaki, Sumedang), stands and clamps, water baths (Iwaki, Sumedang), colorimeters (Mettler Toledo, Bekasi), 25 mL volumetric pipettes, 100 mL volumetric flasks, 10 mL burettes, 1 mL volumetric pipettes (Iwaki, Sumedang), Büchner funnels & vacuum, coconut milk strainers, plastic containers, and colorimeters (Konica Minolta, Jakarta).

Research Design

In this research, coconut oil is produced (extracted) using an acidification method with acetic acid (CH3COOH) as a catalyst for the hydrolysis reaction to break down the oil emulsion in water and protein. Variations in acetic acid concentration and cooking time are used as factors to determine the effect of acetic acid concentration and cooking time on the characteristics of coconut cooking oil. The experimental design used in this study is a factorial Randomized Block Design (RBD), with two factors each having two and three levels with three repetitions, resulting in 18 experiments.

The treatment design in this study consists of two factors, which are the concentration of acetic acid (K) and the cooking time of coconut cream (T), each comprising two and three levels, namely: k1 and k2 (2 and 2.5%), t1, t2, and t3 (30, 45, and 60 minutes).

k_1	=	2%	t_1	=	30 minutes
k_2	=	2,5%	t_2	=	45 minutes
			t_3	=	60 minutes

The response design performed on coconut cooking oil includes chemical response, physical response, and organoleptic response.The chemical responses to be performed on coconut cooking oil are the acid number test and the peroxide number test. The physical responses conducted on coconut oil in the main study include calculating the total yield, determining color (colorimetry), impurity content, and turbidity value (turbidimetry). The organoleptic response to be conducted on coconut cooking oil includes tests for color and aroma. The organoleptic testing is carried out by 30 semi-trained panelists. The organoleptic test is conducted using a hedonic or preference test.

Research stages

The methodology of this research consists of two stages: preliminary research and the main study. In the preliminary research, a control is made without the addition of acetic acid concentration with parameters measuring water content and yield. The main study aims to determine the effect of acetic acid concentration and cooking time on the characteristics of coconut cooking oil in this research.

Methods

The Acid Method Oil Processing Process.

The process of making coconut oil using the acid method is as follows:

1. Separation

Separation is the process of peeling the coconut from its husk. Then, the coconut meat is obtained by splitting the fruit into two parts or by cracking the shell.

2. Grating

The coconut is first split from its shell. Grating is done to reduce the size and break down the coconut meat so that the oil can be easily extracted.

3. Extraction dan Expression

The grated coconut is then mixed with warm coconut water at a temperature of 70°C in a 1:1 ratio (Suhardiyono et al., 1993) for the first and second pressing, and a 2:1 ratio for the third pressing.

4. Filtration

The result of the copra grating, which is the extracted and expressed grated coconut, is then filtered using a Buchner funnel with a vacuum pump to separate the coconut milk from the coconut pulp using a coconut milk strainer.

5. Separation of Cream and Skim Coconut Milk

The filtered coconut milk is placed in a plastic container and left to allow the separation of coconut cream and skim. After the separation of cream and skim in the decantation tank, the produced coconut cream is then separated into a different container.

6. Acidification

Acidification is done by adding acetic acid (kitchen vinegar) with concentrations of 2% and 2.5% to the coconut cream to approach isoelectric conditions. During the acidification process, the isoelectric pH that aims to break the oil emulsion in water is 3.7.

7. Soaking (incubation)

The soaking (incubation) process is aimed at perfecting the emulsion-breaking process. Incubation is done for 24 hours.

8. Heating

Heating is done on 500 ml of coconut cream at three levels, namely for 30, 45, and 60 minutes at a temperature (90 – 100°C). Heating is done to help evaporate the water still contained in the blondo (coconut oil residue) and oil. Heating is also done to help release the oil still contained in the coconut cream. Heating is performed while stirring until all the water evaporates.

9. Separation (Filtration)

Separation is done by filtering the heated oil and blondo using a Buchner funnel vacuum pump. Separation is done to separate the oil from the blondo.

10. Storage

Storage is done in a place at room temperature and shielded from direct sunlight. The oil is packaged in 250 mL plastic bottles and sealed with plastic wrap.

Oil Yield

The oil yield can be calculated based on the weight of the coconut oil obtained in grams compared to the initial weight of the coconut milk used in grams (Sudarmadji, Haryono, & Suhardi, 2010).

$$\text{Oil Yield(\%)} = \frac{\text{Oil Weight (g)}}{\text{Coconut milk Weight (g)}} \times 100\,\%$$

Moisture Content

The content of water and volatile substances is calculated based on the weight lost during heating in an oven at a temperature of 105 ± 1 °C (Sudarmadji et al., 2010)

Acid Value

The acid number represents the amount of milligrams of KOH (Potassium Hydroxide) needed to neutralize the free fatty acids in each gram of oil or fat (Ketaren, 1986). The acid number test uses the iodometric titration method.

Peroxide Value

The peroxide number is defined as the excess potassium iodide added to the sample, which will react with the peroxides in the fat or oil. The amount of iodine released is titrated with a standard thiosulfate solution using a starch indicator (AOCS, 2017). The peroxide number test uses the iodometric titration method.

Color determination (Colorimetry)

The color determination method used in this study is the Hunter Lab colorimetry test. Data collection for the Hunter Lab color determination method is carried out using a colorimeter.

Hedonic organoleptic test on Color and Aroma atttributes

Hedonic color and aroma testing are included in the organoleptic test. For the testing of aroma and color, the hedonic (preference) organoleptic test is used with 30 untrained panelists as testers. The scale for the hedonic test can be seen in Table 1 below.

Table 1. Hedonic Test Rating Scale

Parameter	Numeric scale
Like very much	6
Like	5
Somewhat like	4
Somewhat dislike	3
Dislike	2
Dislike very much	1

(Lawless & Heymann, 2010)

Impurity Amount

The impurity amount test in oil uses the results from the determination of water content whose weight is known.

Turbidimetry

Turbidimetry is a method for measuring the concentration of particulates in suspension based on the elastic scattering of light by particles. The turbidity measurement method is based on the comparison of the intensity of scattered light against the incoming light intensity and is measured directly (Khopkar, 2022).

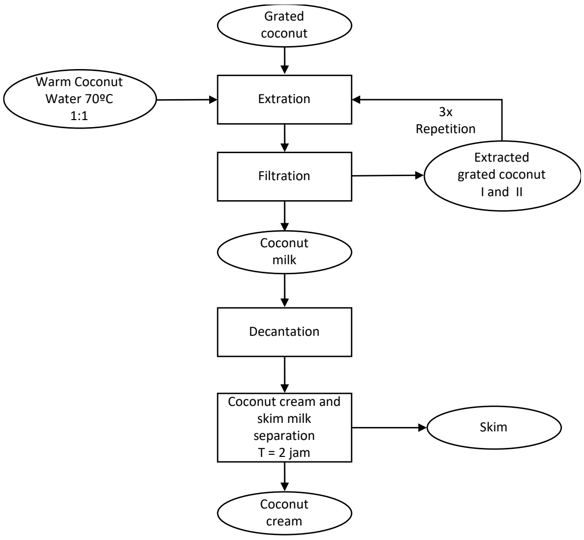

Figure 1. Flowchart of the making of coconut cream

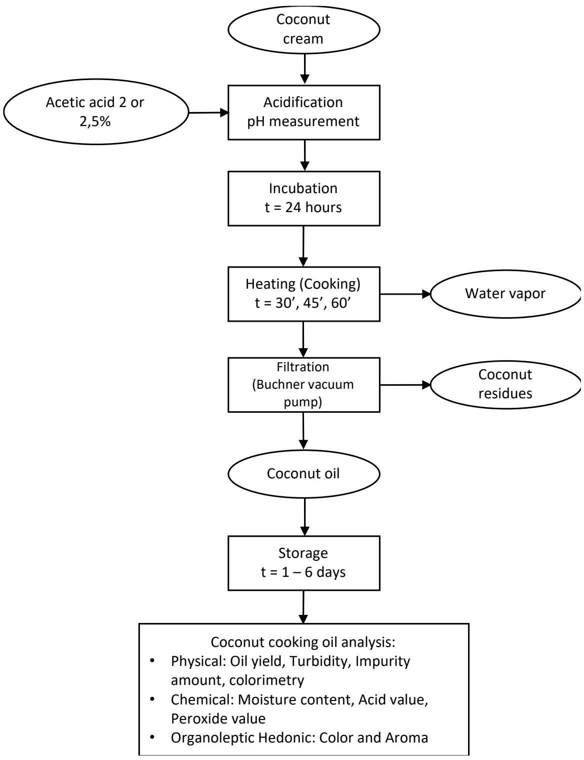

Figure 2. Main research flowchart of the making and analysis of coconut cooking oil

Statistical Analysis

The data from the experimental research was analyzed using SPSS Software version 2.6 with General Linear Model Multivariate analysis. The data processing was presented in ANOVA (Analysis of Variance) tables, which is a multivariate analysis technique aimed at identifying differences across more than two groups by comparing their variances. Experiments are conducted with three repetitions and analyzed using Two-way Analysis of Variance followed by Duncan's Multiple Range Test (DMRT) post-hoc test with P<0.05..

3. Results and Discusion

1. Oil Yield

The results of the analysis of variance (ANOVA) indicate that the interaction between acetic acid concentration treatment and cooking time does not significantly affect the yield of coconut cooking oil. However, each treatment individually has a significant effect on the yield of coconut cooking oil. The treatment of acetic acid concentration has a significant effect ($p < 0.05$) on the yield of coconut cooking oil. The treatment of cooking time also has a significant effect ($p < 0.05$) on the yield of coconut cooking oil.

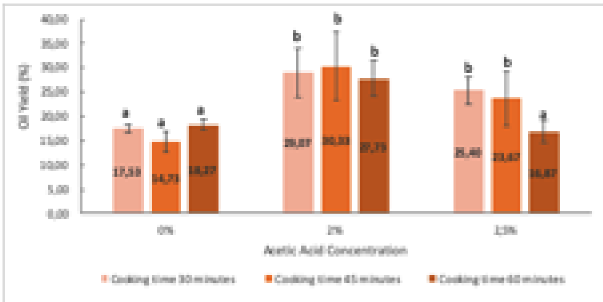

Figure 3. Oil yield (%) resulting from varying acetic acid concentration (%) and cooking time (minutes) treatment

Figure 3 shows that acetic acid treatments (2 and 2.5%) can increase the oil yield compared to the control. At an acetic acid concentration of 2%, the coconut milk has an average pH of 4.2, while at a concentration of 2.5%, the coconut milk has an average pH of 3.5. Although not statistically significant, the average yield from the 2.5% acetic acid treatment appears lower than the 2% treatment across all cooking durations. Acetic acid functions as an emulsion breaker in coconut milk, with the added acid acting to tear through the thin protein layer (Mulyaningsih & P, 2004). In coconut milk, proteins act as emulsifiers that bind water and oil, with hydrophobic groups binding fats and hydrophilic groups binding water (Burger & Zhang, 2019). The applied acetic acid will break the bonds between proteins and fats, allowing the oil to separate in the coconut milk. The acid will optimally break the coconut milk emulsion at a pH of 4.3 (Susanto, 2013). A study revealed that after the coconut milk emulsion breaks, the water phase has a pH of ± 4.5 (Setiaji & Sasmita, 1988). Thus, it is suspected that the coconut milk emulsion breaks optimally and reaches isoelectric pH conditions when adding acetic acid at a concentration of 2%. With the addition of acetic acid at a concentration of 2.5%, it is suspected that the pH has passed the isoelectric conditions, making the emulsion break less optimally. Excess acetic acid causes the coconut milk emulsion to become thinner and the oil molecules to disperse. The increased distance between oil molecules causes less oil to form. This condition causes the broken coconut milk emulsion to be suboptimal and results in less oil produced (Fachry, Arta, & Dewi, 2007). This is in line with the theory that states that when emulsion breaking is incomplete, a lot of oil is still trapped in the blondo (coconut residue) and is discarded (Fachry et al., 2007).

Among the three cooking durations tested, the highest yield was obtained at a cooking time of 30 minutes with an average yield of 24%, while the lowest yield was obtained at a cooking time of 60 minutes with a result of 20.96%. The research results show that the longer the cooking time, the lower the average yield of coconut oil.

2. Moisture Content

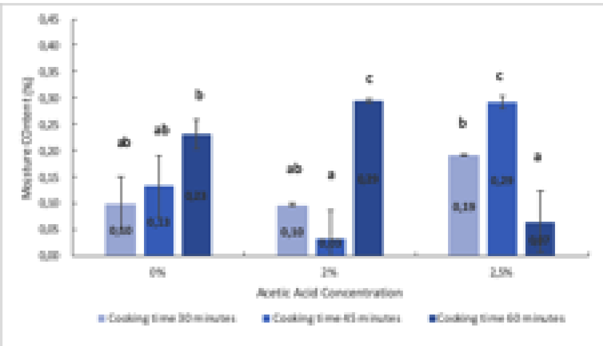

Figure 4. Moisture content (%) of cooking oil resulting from varying acetic acid concentration (%) and cooking time (minutes) treatment

The analysis of variance results show that the interaction between acetic acid concentration treatment and cooking duration does not have a significant effect on the water content of coconut cooking oil. However, each individual treatment significantly affects the water content of coconut cooking oil. Acetic acid concentration treatment has a significant effect ($p < 0.05$) on the water content of the oil. Oil treated with 2% acidification has a lower water content ($p < 0.05$) compared to that with 2.5% acetic acid acidification (Figure 4). This is suspected because, at the 2% acetic acid concentration, isoelectric pH conditions are achieved in the medium, where the breakdown of coconut milk emulsion occurs optimally.

The emulsion system in coconut milk is an oil-in-water emulsion with natural proteins in the coconut milk (globulin and albumin) acting as emulsifiers (Onsaard, Vittayanont, Srigam, & McClements, 2006). Proteins in the coconut milk emulsion are above the isoelectric pH, and the addition of acetic acid to the coconut milk will cause the proteins to move closer to the isoelectric pH. When the isoelectric pH is reached, proteins will denature, causing the coconut milk emulsion to break, and the oil separates from the water (Fachry et al., 2007). Oil globules contained in the coconut milk, surrounded by a thin layer of protein and phospholipids, break down because the protein has been denatured (Fachry et al., 2007). Since the protective layer of the oil globules has broken, the oil contained within in the form of oil droplets will join together. In principle, the breakdown of the coconut milk emulsion through protein denaturation is required for oil to come out of the emulsion (Diploma Kimia UII, 2009).

With the addition of 2.5% acetic acid concentration, it is suspected that the pH of the solution passes the isoelectric pH, so the emulsion breakdown occurs incompletely. When the coconut milk emulsion breakdown is incomplete and far from the isoelectric pH, there is still water trapped in the oil, which is not evaporated during the heating process. Therefore, oil with the addition of 2.5% acetic acid concentration has a relatively high-water content.

Oil cooked for 60 minutes (in the 2% acidification treatment and control) contains higher water ($p < 0.05$) compared to shorter cooking durations (Figure 4). Figure 4 shows the lowest water content in coconut cooking oil is produced by a cooking duration of 30 minutes with a water content of 0.13%. Whereas the highest water content is produced by a cooking duration of 60 minutes with a water content of 0.20%. This study indicates that longer heating durations can increase the water content in cooking oil. This contrasts with other research stating that the higher the cooking temperature and duration, the lower the water content [28]. This could be due to the rise in free fatty acids and other hydrolysis and oxidation products that contain water molecules (functional groups that are polar and/or have hydroxyl components (Sudarmadji et al., 2010), when the heating duration is extended, because heat acts as a catalyst for hydrolysis and oxidation reactions (Herlina, Astryaningsih, Windrati, & Nurhayati, 2018). A 60-minute heating duration at 2% acetic acid conditions is assumed to only be able to produce hydrolysis and oxidation products from fats but not yet able to evaporate them.

However, when coconut cream is treated with 2.5% acidification, cooking for 60 minutes actually decreases its water content to the lowest ($p < 0.05$) compared to shorter cooking durations (Figure 4). Cooking for 45 minutes is assumed to be just enough to produce a number of hydrolysis and oxidation products that contain water molecules but not enough to evaporate types of water bound to the products of hydrolysis of oil by heat catalysis. Thus, when measured by gravimetry, the water content is measured higher compared to the 60-minute treatment. Related to the lower pH of the solution at 2.5% acetic acid concentration (more free hydrogen groups in the solution), when cooking is performed for 60 minutes, these hydrolysis and oxidation products successfully evaporate, thus reducing the water content measured gravimetrically.

3. Acid Value

The variance analysis results show that the interaction between acetic acid concentration treatment and cooking duration significantly affects the acid number of coconut cooking oil. The cooking duration treatment also has a significant effect on the acid number of coconut cooking oil. However, the acetic acid concentration treatment does not have a significant effect ($p > 0.05$) on the acid number of coconut cooking oil.

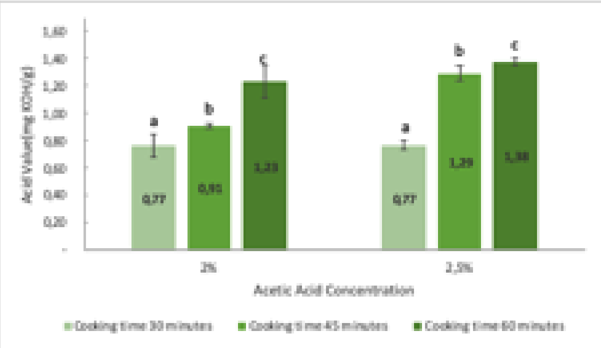

Figure 5. Acid value (mg KOH/g) of cooking oil resulting from varying acetic acid concentration (%) and cooking time (minutes) treatment

Figure 5 indicates that the higher the acetic acid concentration and the longer the cooking duration, the higher the acid number in the oil. The increase in fatty acids is due to higher water content at higher concentrations, making the oil more susceptible to hydrolysis. The high acid number correlates with the high water content (Che Man et al., 1997). The water content in the oil makes it more prone to hydrolysis. The hydrolysis reaction in oil produces free fatty acids and glycerol. Thus, the high amount of free fatty acids produced will correspond with the high acid number in the oil (Rahmadi, Abdiah, Dewi Sukarno, & Purnaningsih, 2013).

When compared with the acid number of the untreated sample, the study results show that treatments of 30-, 45-, and 60-minutes cooking duration have a smaller acid number.

Longer cooking duration results in a continuous temperature increase, so the hydrolyzed triglycerides into free fatty acids increase. This is supported by a theory stating that the longer the cooking duration, the higher the acid number in the oil (Ngatemin, Nurrahman, & Isworo, 2013). At high heating temperatures, almost all the triglycerides present in the oil have decomposed into free fatty acids. The more free fatty acids decomposed, the higher the acid number in the oil (Suroso, 2013).

4. Peroxide Value

The analysis of variance (ANOVA) calculations shows that the interaction between acetic acid concentration treatment and cooking duration does not have a significant effect ($p > 0.05$) on the peroxide number of coconut cooking oil. The acetic acid concentration treatment also does not have a significant effect ($p > 0.05$) on the peroxide number of coconut cooking oil. However, the cooking duration treatment has a significant effect ($p < 0.05$) on the acid number of coconut cooking oil (Figure 6). The average peroxide number produced ranges between 4.141 – 6.171 meq peroxide/100 grams. The increase in peroxide number is directly proportional to the increase in hydroperoxide concentration. Hydroperoxides are formed due to the oxidation reaction of unsaturated fatty acids with heating temperature as a catalyst. The longer the cooking duration on the oil, the higher the peroxide number in the coconut cooking oil.

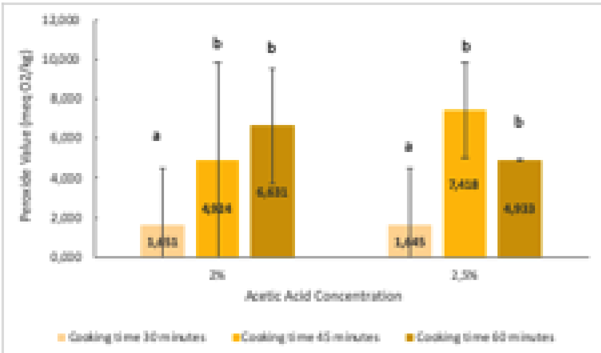

Figure 6. Peroxide value (meq O2/kg) of cooking oil resulting from varying acetic acid concentration (%) and cooking time (minutes) treatment

This happens because heat triggers the oxidation process, especially heat above 60℃ (Makfoed, D., W.M. Djagal, H. Pudji, A. Sri, R. Sri, S. Sudarminto, Suhardi., M. Soeharsono, 2002). Unsaturated fatty acids produced from long heating bind oxygen at their double bonds and then form peroxides (Rizkiya, 2010). The initiation of oxidation reaction is marked by the formation of free radicals. Unsaturated fatty acids in the oil have labile hydrogen on the carbon atoms adjacent to double bonds, thus forming free radicals. In the propagation stage, peroxide compounds begin to decompose forming peroxy and alkoxy radicals that will react with fatty acids to form new free radicals. In this stage, free radicals are continuously formed, also known as autooxidation reaction. In the final termination stage, compounds such as hydrocarbons, aldehydes, ketones, acids, and alcohols are produced (Sumatri, 2007). Free radicals act as strong initiators and promoters (catalysts) of further oxidation reactions, so the oxidative breakdown of fats continues. This causes the coconut cooking oil to continuously decrease in quality, with further damage potentially resulting in the formation of polymers in the form of aldehydes and ketones. Therefore, it is suspected that a longer cooking duration is able to increase oxidative products as the end products of oxidation.

Oil produced with 60 minutes of heating has a lower peroxide number than heating for 45 minutes (Figure 6). This is because peroxide products are very prone to decomposition, thus measured lower in longer heating (60 minutes). Products from peroxide decomposition during cooking are aldehydes and ketones. During storage, there is also an increase in the amount of free fatty acids in the oil as oxidation and hydrolysis products, which then cause physical and chemical changes in the oil (Nurhasnawati, 2017).

From the results in Figure 6, it can be seen that the highest peroxide number is produced by the treatment of 2.5% concentration with a cooking duration of 45 minutes, while the lowest peroxide number is produced by the treatment of 2.5% concentration with a cooking duration of 30 minutes.

5. Color (Colorimetry)

L* (Lightness)

Table 2. L* value (Lightness) of the coconut oil due to treatments of acetic acid concentration and cooking time

Acetic acid concentration	Cooking time	Nilai L* (lightness)
k_1 (2%)	t_1 (30 ‘)	43,68 ± 0.345 b
	t_2 (45 ‘)	43,97 ± 0.232 b
	t_3 (60 ‘)	42,59 ± 1.476 b
k_2 (2,5%)	t_1 (30 ‘)	42,43 ± 0.719 ab
	t_2 (45 ‘)	41,14 ± 0.933 a
	t_3 (60 ‘)	43,29 ± 1.492 ab

The variance analysis (ANOVA) results indicate that the interaction between the treatment of acetic acid concentration and the cooking duration significantly affects ($p < 0.05$) the L* value (brightness level) of coconut cooking oil. The treatment of acetic acid concentration significantly affects ($p < 0.05$) the L* value of coconut cooking oil. However, the treatment of cooking duration does not have a significant effect ($p > 0.05$) on the L* value of coconut cooking oil.

The brightness level of foodstuffs is influenced by the light absorbed and the composition of the foodstuffs themselves. An L* value above 40 indicates that the produced coconut cooking oil is bright (Lawless & Heymann, 2010). A dark color in the oil indicates oxidative damage, which is caused by the process of oxidation (Setiasih, 2008).

a* (Redness)

The variance analysis (ANOVA) results show that the interaction between the treatment of acetic acid concentration and the cooking duration does not have a significant effect ($p > 0.05$) on the a* value (redness level) of coconut cooking oil. The treatment of cooking duration does not have a significant effect ($p > 0.05$) on the L* value of coconut cooking oil. However, the treatment of acetic acid concentration significantly affects ($p < 0.05$) the L* value of coconut cooking oil.

The higher the concentration of acetic acid used, the higher the redness level produced. The brown color in the oil is caused by oxidation of tocopherols in the oil (Rizkiya, 2010). The color produced in the oil comes from substances extracted during the processing because the main contents of the oil, namely fatty acids and glycerides, do not cause the oil to be colored.

Table 1. a* (redness) of the coconut oil due to treatments of acetic acid concentration and cooking time

Acetic acid concentration	Cooking time	a* (redness)
k_1 (2%)	t_1 (30 ‘)	-0.75 ± 0.281
	t_2 (45 ‘)	-0.80 ± 0.032
	t_3 (60 ‘)	0.30 ± 0.829
k_2 (2,5%)	t_1 (30 ‘)	0.00 ± 0.344
	t_2 (45 ‘)	0.75 ± 0.148
	t_3 (60 ‘)	0.54 ± 0.477

b* (yellowness)

The variance analysis (ANOVA) results in Table 4 indicate that the interaction between the treatment of acetic acid concentration and the cooking duration does not have a significant effect ($p > 0.05$) on the b* value (yellowing level) of coconut cooking oil. The treatment of acetic acid concentration does not significantly affect ($p > 0.05$) the b* value of coconut cooking oil. However, the treatment of cooking duration significantly affects ($p < 0.05$) the b* value of coconut cooking oil.

The longer the cooking duration, the higher the b* value (yellowing level) in coconut cooking oil. This is supported by a theory stating that the higher the cooking temperature, the darker the color of the oil produced (Suroso, 2013).

Carotenoids are natural colorants in oil, and the hydrogenation of carotenoids causes the yellow color of the oil to disappear. At high heating temperatures, carotenoids are unstable, causing the yellow color in the oil to also disappear(Antonio, Ortega-regules, Parrodi, & Lozada-ram, 2023). The colorants in oil consist of α and β carotene, which show yellow, xanthophylls which show a yellowish-brown color, chlorophyll which shows a green color, and anthocyanins which show a reddish color. Other colors result from the degradation of natural colorants, namely dark colors caused by the oxidation of tocopherols (vitamin E), brown colors caused by rotten or damaged materials used in oil processing, yellow color present in unsaturated oils (Azis, Pomalingo, & Akolo, 2020).

Table 2. b* (yellowness) of the coconut oil due to treatments of acetic acid concentration and cooking time

Acetic acid concentration	Cooking time	b* (yellowness)
	t_1 (30 ')	5.12 ± 0.350 ab
k_1 (2%)	t_2 (45 ')	4.99 ± 0.295 a
	t_3 (60 ')	5.52 ± 1.040 b
	t_1 (30 ')	5.18 ± 0.564 ab
k_2 (2,5%)	t_2 (45 ')	4.22 ± 1.388 a
	t_3 (60 ')	6.92 ± 1.343 b

6. Turbidity

The variance analysis (ANOVA) results show that the interaction between the treatment of acetic acid concentration and the cooking duration does not have a significant effect ($p > 0.05$) on the turbidity value of coconut cooking oil. The treatment of acetic acid concentration does not have a significant effect ($p > 0.05$) on the turbidity value of coconut cooking oil. The treatment of cooking duration does not have a significant effect ($p > 0.05$) on the turbidity value of coconut cooking oil.

In the turbidity test, the impurities tested are those solubilized in the oil. Impurities in the oil consist of free fatty acids, mono- and diglycerides from the hydrolysis reaction of triglycerides, colorants from the oxidation and decomposition results such as ketones, aldehydes, etc. (Susanto, 2013).

Table 5. Turbidity (NTU) of cooking oil resulting from varying acetic acid concentration (%) and cooking time (minutes) treatment

Acetic acid concentration	Cooking time	Turbidity (NTU)
	t_1 (30 ')	0.00 ± 0.000
k_1 (2%)	t_2 (45 ')	0.00 ± 0.000
	t_3 (60 ')	0.99 ± 1.603
	t_1 (30 ')	0.00 ± 0.000
k_2 (2,5%)	t_2 (45 ')	3.80 ± 6.593
	t_3 (60 ')	0.56 ± 0.970

7. Impurity amount

The amount of impurities are substances not soluble in oil and can be filtered after the oil is dissolved in a solvent (n-hexane). The variance analysis (ANOVA) results show that the interaction between the treatment of acetic acid concentration and the cooking duration does not have a significant effect ($p > 0.05$) on the amount of impurities in coconut cooking oil. The treatment of acetic acid concentration does not have a significant effect ($p < 0.05$) on the number of impurities in coconut cooking oil. However, the treatment of cooking duration significantly affects ($p < 0.05$) the number of impurities in coconut cooking oil.

The longer the heating duration, the higher the number of impurities in the cooking oil, with average values ranging between 1.89% to 4.00% (Tabel 6). This could be caused by the high amount of free fatty acids that are hydrolyzed. The number of impurities produced is proportional to the longer the cooking duration, the higher the peroxide number in coconut cooking oil. A high peroxide number results from ongoing oxidation reactions as the cooking duration extends. It is known that impurities in oil consist of free fatty acids, mono- and diglycerides from the hydrolysis reaction of triglycerides, and colorants from oxidation and decomposition (Moehady & Hidayatulloh, 2020; Susanto, 2013) (Ketaren, 1986). The final products of the oxidation reaction, such as aldehydes and ketones, are impurities in coconut cooking oil.

Table 6. Impurities (%) of cooking oil resulting from varying acetic acid concentration (%) and cooking time (minutes) treatment

Acetic acid concentration	Cooking time	Impurities (%)
	t_1 (30 ')	1.51 ± 0.37 a
k_1 (2%)	t_2 (45 ')	3.85 ± 0.97 b
	t_3 (60 ')	4.78 ± 1.36 b
	t_1 (30 ')	2.27 ± 0.38 a
k_2 (2,5%)	t_2 (45 ')	2.61 ± 1.37 ab
	t_3 (60 ')	3.22 ± 2.15 ab

8. Hedonic of Color Attribute

The variance analysis (ANOVA) results indicate that the interaction between acetic acid concentration treatment and cooking duration does not significantly affect ($p < 0.05$) the organoleptic color attribute of coconut cooking oil. Cooking duration does not have a significant effect ($p > 0.05$) on the organoleptic color attribute of coconut cooking oil. However, the acetic acid concentration treatment significantly affects ($p < 0.05$) the color preference of coconut cooking oil.

The hedonic test shows that coconut cooking oil treated with 2% acetic acid is preferred over the 2.5% acetic acid treatment. This preference is due to the oil produced at a 2% concentration having a higher brightness level (L value). On average, panelists prefer the brighter yellow color of the oil. The color assessment from the 2% acetic acid concentration treatment with 45 minutes of cooking time is preferred, with an average score of 5.11, indicating a like threshold, whereas the 2% acetic acid concentration treatment with 60 minutes of cooking time has the lowest average score of 4.64, indicating a somewhat like threshold (Table 7).

Table 3. Hedonic color value of cooking oil resulting from varying acetic acid concentration (%) and cooking time (minutes) treatment

Acetic acid concentration	Cooking time	Hedonic color value
	t_1 (30 ‘)	4.99 ± 0.11 b
k_1 (2%)	t_2 (45 ‘)	5.11 ± 0.27 b
	t_3 (60 ‘)	4.64 ± 0.17 a
	t_1 (30 ‘)	4.65 ± 0.11 a
k_2 (2,5%)	t_2 (45 ‘)	4.65 ± 0.16 a
	t_3 (60 ‘)	4.66 ± 0.17 a

The results of the hedonic assessment of the color from the treatment with 2% acetic acid concentration and 45 minutes cooking time were more preferred, with an average value of 5.11 indicating a threshold of liking, while the treatment with 2% acetic acid concentration and 60 minutes cooking time had the lowest average value of 4.64 indicating a threshold of somewhat liking (Table 7).

9. Hedonic of Aroma attribute

The results of the analysis of variance (ANOVA) indicate that the interaction between the treatment of acetic acid concentration and the duration of cooking time does not have a significant effect ($p > 0.05$) on the organoleptic attribute of the aroma of coconut cooking oil. However, the treatment of acetic acid concentration has a significant effect ($p < 0.05$) on the organoleptic attribute of the aroma of coconut cooking oil. The treatment duration of cooking time also has a significant effect ($p < 0.05$) on the organoleptic attribute of the aroma of coconut cooking oil.

Table 8. Hedonic Aroma value of cooking oil resulting from varying acetic acid concentration (%) and cooking time (minutes) treatment

Acetic acid concentration	Cooking time	Hedonic Aroma value
	t_1 (30 ‘)	5.13 ± 0.05 b
k_1 (2%)	t_2 (45 ‘)	5.01 ± 0.13 ab
	t_3 (60 ‘)	4.65 ± 0.24 a
	t_1 (30 ‘)	4.70 ± 0.15 b
k_2 (2,5%)	t_2 (45 ‘)	4.67 ± 0.14 ab
	t_3 (60 ‘)	4.65 ± 0.30 a

The aroma hedonic value with 2% acetic acid concentration and 30 minutes of cooking time are more preferred by the panellist with an average value of 5.13, indicating a threshold of liking, while the treatment with 2% acetic acid concentration and 60 minutes of cooking time has the lowest average value of 4.65, indicating a threshold of somewhat liking (Table 8). The distinctive smell found in coconut oil is caused by nonyl methyl keton (Setiasih, & Sukarti, 2008). Coconut milk contains nonyl methyl ketone compounds, which become volatile at high temperatures and emit a pleasant smell (Mulyadi, Schreiner, & Dewi, 2018).

9. Best treatment

The calculation of the Productivity Value (NP) using the de Garmo method is used to determine the best treatment. The treatment of 2% acetic acid and cooking time of 30 minutes for a coconut milk curd volume of 500 ml with the parameter values as listed in Table 9 is the best compared to other treatments tested in this study (Table 9). This treatment, calculated with the de Garmo method, has the highest NP among other treatments (data not shown).

In comparison with other coconut oils tested as additional data in this study, the coconut oil produced from the best treatment of this study has better quality parameter values (for example: acid number of the best treatment is 0.77 compared to 1.17 mg KOH 0.1N/g of commercial coconut oil) for coconut cooking oil (Table 10). The other coconut oil used for comparison is commercial traditional coconut oil from Tasikmalaya, a major coconut-producing region in West Java. Compared with the quality requirements of the Indonesian National Standard (SNI) for coconut cooking oil, the oil from the best treatment falls into quality category I in terms of moisture content (Table 10) and is in quality category II in terms of acid number because its acid number is 0.77 mg KOH 0.1N/g - which is slightly higher than the maximum acid number for quality category I, which is max 0.6 mg KOH 0.1N/g (Table 10).

Table 9. Compilation of physical and chemical responses of cooking oil resulting from varying acetic acid concentration (%) and cooking time (minutes) treatment

Parameters	0% Acetic acid			2% Acetic acid			2.5% Acetic acid		
	30'	45'	60'	30'	45'	60'	30'	45'	60'
Oil yield (%)	17,53	14,73	18,27	29,07	30,33	27,73	25,40	23,67	16,87
Moisture content (%)	0,1	0,133	0,23	0,097	0,03	0,294	0,19	0,29	0,07
Acid value (mg KOH 0,1N/g)	-	-	-	0,77	0,91	1,23	0,77	1,29	1,38
FFA as lauric acid (%)	-	-	-	0,27	0,32	0,44	0,27	0,46	0,49
Peroxide value (meq O_2/kg)	-	-	-	1,65	4,92	6,63	1,65	7,42	4,93
Impurities (%)	-	-	-	1,52	3,85	4,78	2,27	2,61	3,22
Turbidity (%)	-	-	-	0,00	0,00	0,99	0,00	3,81	0,56
Color CIE L	-	-	-	43,68	43,97	42,59	42,43	41,14	43,29
Color CIE a	-	-	-	-0,75	-0,80	0,30	0,00	0,75	0,54
Color CIE b	-	-	-	5,12	4,99	5,52	5,18	4,22	6,92
Hedonic of Color	-	-	-	4,99	5,11	4,64	4,65	4,65	4,66
Hedonic of Aroma	-	-	-	5,13	5,01	4,65	4,70	4,67	4,65

*FFA: Free fatty acid

Table 10. Comparison of physical and chemical responses of the coconut oil from the best treatment to commercial coconut oil and SNI standards

Parameters	Treatment 2% acetic acid (30' cooking time)	Coconut cooking oil Traditional commercial	SNI Coconut cooking oil Grade I	SNI Coconut cooking oil Grade II	SNI Coconut oil
Oil yield (%)	29,07	-			-
Moisture content (%)	0,097	0,2	maks 0,1	maks 0,3	maks 0,3
Acid value (mg KOH 0,1N/g)	0,77	1,17	maks 0,6	maks 2	-
FFA* as lauric acid (%)	0,27	0,42	-	-	maks 0.1*
Peroxide value (meq O_2/kg)	1,65	0	-	-	maks 5
Impurities (%)	1,52	5,03	-	-	-
Turbidity (%)	0,00	0	-	-	-
Color CIE L	43,68	42,7	-	-	-
Color CIE a	-0,75	-0,62	-	-	-
Color CIE b	5,12	6,46	-	-	-
Hedonic of Color	4,99	-	-	-	-
Hedonic of Aroma	5,13	-	-	-	-

*FFA: Free fatty acid

4. Conclusion

Acetic acid concentration affects water content, yield, colorimetric L* value (brightness level), colorimetric a* value (redness level), hedonic organoleptic color attribute, and hedonic organoleptic aroma attribute.

Cooking duration affects water content, acid number, peroxide number, yield, colorimetric b* value (yellowness level), colorimetric H* value (Hue), impurity amount, and organoleptic color attribute. The interaction between acetic acid concentration and cooking duration affects the acid number, colorimetric L* value, and colorimetric a* value.

A 2% acetic acid treatment and 30 minutes of cooking time provided the best quality results (De Garmo method), with a 29% oil yield and superior quality (water content < 1%, Free Fatty Acid content as Lauric Acid at 0.27%, and Brightness Value L* at 43.68) compared to commercial traditional coconut cooking oil and successfully met several elements of the Indonesian National Standard (SNI) for coconut cooking oil. Overall, acidification using acetic acid can improve the quality of coconut oil, better than the control group, and can offer a more efficient and higher quality coconut cooking oil production method.

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