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The Effect of Temperature and Heating Time on The Yield and Chemical Quality of Red Fruit (*Pandanus conoideus*) Oil Using Dry Extraction Method

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ABSTRACT

The quality of Red Fruit Oil (RFO) is influenced by the extraction method. The objective of this research was to study the effect of temperature and heating time of red fruit on the chemical quality of red fruit oil using the dry extraction method. This research was divided into two steps: 1) evaluation of the chemical quality (water content, free fatty acid (FFA), iodine value, and carotenoid total) of the red fruit oil during the steaming of red fruit grains (*drupa*) at 60 , 80 , and 100°C for 20, 80, and 60 minutes; and 2) evaluation of the chemical quality (water content, FFA, and total carotenoids) of RFO during the steaming of red fruit chunk of whole fruit (*cepallum*) at 100°C for 60 minutes and 120°C for 30 minutes. The results showed that increasing the temperature and heating time of red fruit grains increased the yield (1.20 to 5.95%) and decreased the FFA levels (4.5 to 2.7%); however, the total carotenoid content of oil tended to decrease (from 7570 to 7209 µg/mL). Heating at 100°C for 60 minutes did not affect the level of saturated fatty acids in RFO. The steaming process of the red fruit chunk of whole fruit before extraction could decrease the oil yield and total carotenoid levels, as well as lower the FFA level of oil than steaming of red fruit grains.

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1. INTRODUCTION

Red Fruit Oil (RFO) is produced by the extraction of red fruit grains (*Pandanus conoideus*). RFO has been known and used as drugs or supplements that are beneficial to health. Carotenoids (α-carotene, β-carotene, β-cryptoxanthin), tocopherols (α-tocopherol), and unsaturated fatty acids (oleic, linoleic, and palmitoleic acids) contribute to the efficacy of RFO as natural antioxidants (Fitria et al., 2020; Sarungallo et al., 2014, 2015a). Red fruit has been reported to exhibit high antioxidant activity (Wabula et al., 2019), primarily due to its substantial levels of carotenoids, tocopherols, and phenolic compounds (Murtiningrum et al., 2019; Sarungallo et al., 2015a, 2015b).

The potential health benefits of RFO include the growth of granulation tissue for healing diabetic wounds (Tondok et al., 2023), increased anti-inflammatory and immune cells (Atmaja et al., 2023; Rhee et al., 2020), and lowered blood sugar in mice (*Mus musculus*) (Rahayu et al., 2023). Based on these studies, RFO has the potential to be developed as a functional food product (Sarungallo et al., 2019; Yantewo et al., 2024). Nevertheless, the quality of RFO is influenced by the extraction method, which can be either wet or dry (Sarungallo et al., 2014). Oil extraction by the wet method through the heating process of red fruit *drupa* with water at high temperatures and uncontrolled heating time can lead to hydrolysis of oil, thus increasing the levels of free fatty acids (FFA) and

peroxide content, and also decreasing the amount of the active components of RFO (carotene and tocopherols) (Sarungallo et al., 2014). In contrast, the dry method of oil extraction, which involves steaming followed by compression, resulted in a reduction in FFA but led to an increase in RFO yield when compared to the wet extraction process (Pohan & Wardayani, 2006; Sarungallo et al., 2014). FFA is formed by lipid hydrolysis catalyzed by lipase, thereby causing a decrease in the quality of oil (Chew et al., 2022). In addition, a *drupa* of red fruit consists of a seed covered by pulp and attached to the outer side of the *pedicel* or pith (Aman et al., 2019). The ripe pulp is very soft and is easily hydrolyzed during the postharvest process (Sarungallo et al., 2025).

Using high-pressure heating of the fruit is intended to eliminate microorganisms, inactivation of lipase produces FFA and softens the fruit flesh (Chew et al., 2022). The high-pressure heating during oil extraction is strongly affected by temperature and heating duration. Lubis et al. (2012) reported an increase of RFO yield resulting from the increasing heating time using pressurized steam (autoclave). Pohan & Wardayani (2006) also proved that the reduction of red fruit heating and cooking time using autoclave can reduce the FFA and peroxide value of oil produced. Nevertheless, information regarding the effect of temperature and heating duration on FFA levels and the active component content of RFO is limited. Therefore, the aim of this study was to determine the effects of temperature and heating duration of red fruit *drupa* on the yield and chemical quality of RFO extracted using the drying method.

2. MATERIALS AND METHODS

2.1 Materials

The Red fruit Memeri used in this study was originated from Papua and cultivated in the Experimental Garden of Papua University, Manokwari (West Papua Province. Indonesia). The physiological maturity of ripe fruit was characterized by the darkness of the color of the fruit; the slope of the fruit position was 180° with approximately 50% of the leaf sheaths unwrapped and dried. The red fruit was ripened at room temperature for 3 days before extraction to soften the flesh. All chemicals and reagents used in this study were of reagent grade for chemical testing.

The equipment for RFO extraction using the dry method, including the pressurized steamer, was created in the Workshop of the Agricultural Technology Department, Papua University (Figure 1), using a hydraulic press, centrifuges, and dark bottles as packaging. Equipment for the chemical analysis of RFO included an analytical balance, oven, hot plate, water bath, titration apparatus, spectrophotometers, and other glassware.

Specification of pressurized steamer:

- Dimension:
  - Cylinder outer (dxh): 40 x 50 cm
  - Cylinder in (dxh): 30 x 20 cm
- Maximum capacity: 0.03 m^3/process; 12.5 kg material/process
- Maximum temperature: 120^oC
- Sources of heat: LPG; petroleum

Figure 1. Pressurized steamer of red fruit

2.2 Preparation the grains of red fruit for heating treatment

Extraction of RFO using dry extraction methods was determined by Sarungalo et al. (2014). After separating the *drupa* or grain of the pith of the red fruit, approximately 1 kg of the grains of red fruit was heated using a pressurized steamer to reach the treatment temperature (60, 80, and 100 °C), and maintained temperature during the treatment period (20, 40, and 60 minutes). The cooked grains of red fruit were compressed using a hydraulic press. The crude RFO was then separated using centrifugation at 2000 rpm for 10 minutes. The yield of RFO was packaged in a dark bottle.

2.3 Preparation the chunk of red fruit for heating

At this step, the *cepallum* (whole fruit) of the red fruit was cut into 4-5 pieces (± 20 cm). The pieces of fruit (± 5 kg) were heated using a pressurized steamer until they reached 100 and 120°C, and maintained the temperature for 60 and 30 minutes, respectively. Furthermore, RFO extraction was performed using the same process as the previous step.

2.4 Yield Determination

The yield of extracted oil red fruit was calculated using equation (1).

$$\text{Yield (\%)} = \frac{\text{weight of oil extracted (g)}}{\text{total weight seed (g)}} \text{x100} \quad (1)$$

2.5 Analysis of chemical qualities

Chemical properties of RFO analyzed were water content using the oven method (AOAC, 2005), free fatty acid (FFA) content using the titration method (AOCS, 2003), and iodine value using the Wijs method (AOAC, 2005). Total carotenoid content (TCC) of RFO was determined according to the method of Knockaert et al. (2012) with slight modifications. Two milligrams of each sample were dissolved in hexane, and 0.1% butylated hydroxytoluene (BHT) was added. The absorbance of the sample solution was measured spectrophotometrically at 470 nm using hexane and 0.1% BHT as a blank. TCC was calculated using equation (2).

$$\text{Total carotenoids (ppm)} = \frac{\text{A x volume (ml x } 10^4)}{\text{E}^{1\%}_{1\text{ cm}} \text{x weight of sample (g)}} \quad (2)$$

The absorbance at 470 nm was denoted as A, the volume referred to the total volume of the sample solution, and $\text{E}^{1\%}_{1\text{cm}}$ (the extinction coefficient) was specified as 2560 for β-carotene in hexane.

3. RESULTS AND DISCUSSION

3.1 The effect of temperature and heating time to chemical quality of RFO

3.1.1 The yield of RFO

The RFO yield increased with an increase in the heating time and steaming temperature from 1.20 to 5.95% (Figure 2). The increase in RFO yield due to the steam pressure cooker accelerated heat penetration into the tissue of the red fruit, causing softening of the flesh, protein coagulation, and damage to the cell wall, followed by oil release. However, the heating process also decreased the viscosity of oils, so that more oil was extracted using hydraulic pressing, thereby increasing the yield (Wae-hayee et al., 2022). Palm oil yield was also reported to increase with increasing temperature and sterilization time (Fauzi & Sarmidi, 2010), as well as lowering the viscosity of the oil so that it can be easily extracted (Wae-hayee et al., 2022).

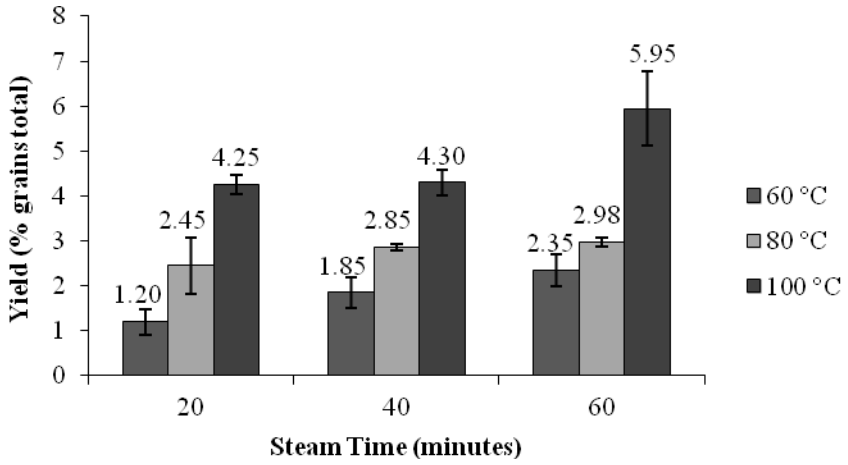

Figure 2. Relationship between yield of red fruit oil and heating temperature as well as steam time

The maximum oil yield at a heating temperature of 100°C for 60 minutes was only 5.95%. This indicated that the heat treatment at 100°C using the pressurized steamer equipment (Figure 1) was not enough to extract the maximum yield of RFO. An RFO yield of approximately 10.20% can be achieved using a pressurized steamer appliance at 120°C for 30 minutes (Pohan & Wardayani, 2006; Sarungallo et al., 2020).

3.1.2 Water content

The water content of the produced RFO ranged from 0.08 to 0.16% (Figure 3a). The water content of RFO decreased with increasing heating time. The range of water content of RFO was below the maximum water content standards for Crude Palm Oil (CPO) (maximum 0.5%) (SNI 01-2901–2006 (BSN, 2006)) and cooking oil (up to 0.3%) (SNI 01-3741–2002 (BSN, 2002)). This result indicated that the fruit preparation and extraction RFO method by the dry method was performed properly. Water content is important in determining oil quality because the presence of water can cause hydrolysis reactions that lead to damage of oil, characterized (indicated) by increasing levels of FFA (Chew et al., 2022; Ngando Ebongue et al., 2006).

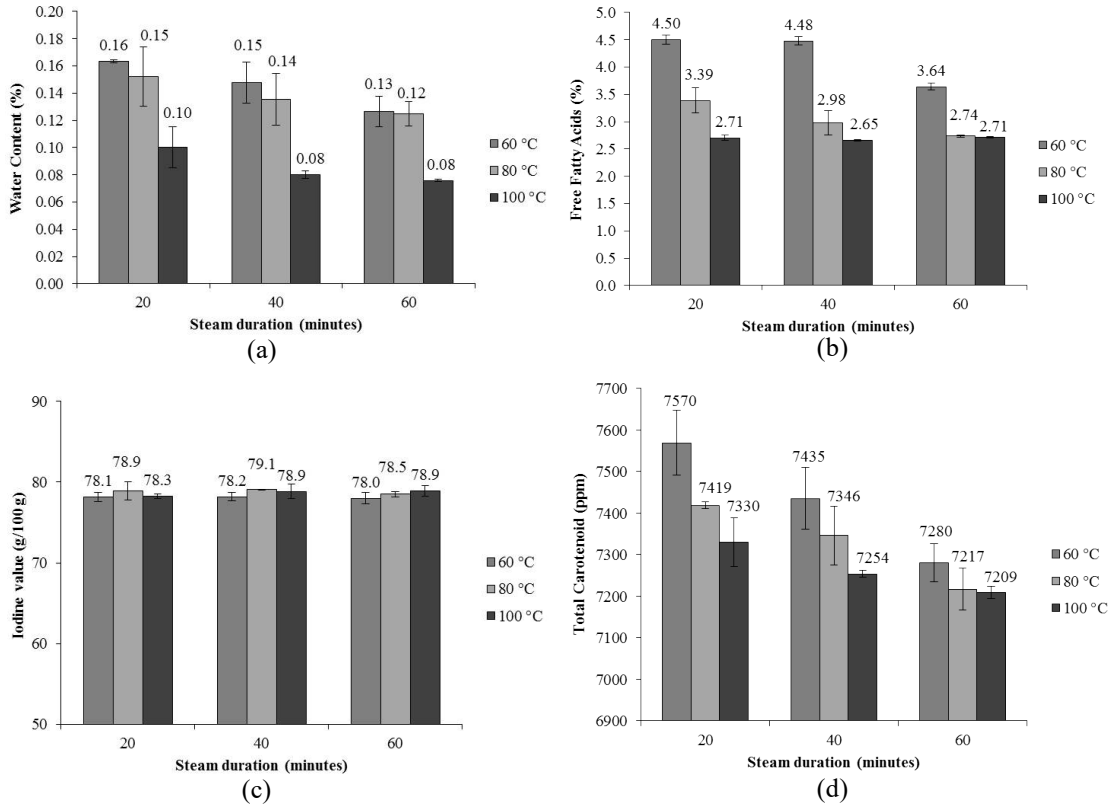

Figure 3. Relationship between heating temperature and steam time to (a) water content, (b) free fatty acids, (c) iodine value, and (d) total carotenoid of red fruit oil.

3.1.3 Free fatty acids (FFA)

The FFA levels of RFO decreased from 4.5 to 2.7% with increasing temperature and steaming time (Figure 3b). FFA indicates the occurrence of an oil hydrolysis reaction. Hydrolysis of fats can be triggered by the presence of water and lipase activity in the fruit, which can occur during the post-harvest period or during the oil extraction process (Chew et al., 2022; Ngando Ebongue et al., 2006).

The minimum FFA level of RFO (2.7%) was obtained after steaming at 100°C, which indicated that heating can inactivate the lipase enzyme. The enzyme is a protein that can be denatured at high temperatures. Ngando Ebongue et al. (2006)also reported that the activity of lipase in the mesocarp of oil palm was stable at around 20-50°C. However, in this study, an FFA content of approximately 4.5% was still observed at a steaming temperature of 60°C. This means that the temperature range of lipase activity of the red fruit might be higher than 50°C. FFA levels produced in this study agreed with those reported by Pohan & Wardayani (2006), who reported that the level of FFA red fruit oil obtained using the dry method was 2.8%.

The FFA level of RFO obtained in this study was higher than the maximum standard of FFA levels in 0.5% CPO (SNI 01-2901–2006 (BSN, 2006)). High levels of FFA in RFO could be triggered by the process of shelling the grain (*drupa*) before steaming. The shelling of the grain facilitated contact between the flesh of red fruit and water vapor during the steaming process potentially produced FFA. Therefore, grain shelling should be avoided during the steaming process.

3.1.4 Iodine Value

The level of unsaturation of oil fatty acids can also be expressed by the Iodine Value (IV). Observation of the changes in IV can be used to detect oxidative damage during the extraction process of RFO. Degradation of unsaturated fatty acids (USFAs) can be caused by oxidation, with a decline in IV. Figure 3c shows that IV of RFO was 78.0 to 79.1 g/100 g of oil and remind the same with the increasing temperature and steaming time.

The higher IV can also indicated that the steaming process at a temperature of 100°C for 60 minutes did not cause oxidation of fatty acids of RFO. Sarungallo et al. (2014) also reported that the IV and fatty acid composition of RFO extracted by wet and dry methods was not significantly different from that of RFO extracted by the Folch method (using solvent and without heating).

3.1.5 Total carotenoids content

RFO has a naturally intense red color due to very high carotenoid content (Sarungallo et al., 2015a). The total carotenoid content of RFO ranges from 7570 to 7209 µg/mL, but is lower than that of RFO extracted by the drying

method (10450 µg/mL), as reported by Pohan & Wardayani (2006). This difference might be due to the clone and extraction methods.

Figure 3d shows that the total carotenoid content of RFO decreased with increasing temperature and steaming time. The highest total carotenoid content was found in RFO, which was heated at 60°C for 20 minutes, and the lowest was obtained upon heating at 100°C for 60 minutes. According to Rodriguez-Concepcion et al. (2018), carotenoids are very sensitive to oxygen, light, temperature, and acidity because they have a structure with a conjugated double bond system that contains many reactive electrons and is easily oxidized. Fauzi & Sarmidi (2010) also reported that the palm oil extraction process on heat treatment (sterilization) for 0 to 40 minutes not only increased the yield of palm oil, but also increased the loss of β-carotene levels. Furthermore, it has also reported that treatment processes using heating, homogenization, and high pressure can cause isomerization and degradation of carotenoids in some food products (Knockaert et al., 2012). It was also noted that the total carotenoid content in RFO decreased with increasing temperature and storage duration (Sarungallo et al., 2018), indicating the need for proper handling of the oil after the extraction process.

3.2 The effect of heating temperature to chemical quality of RFO

Increasing the heating temperature from 100 to 120 °C increased the yield of RFO (from 7.27to 10.0%), as shown in Table 1. Oil yield was also reported to increase with increasing heating temperature (Lubis et al., 2012) and sterilization (0-60 minutes) of the palm fruit (Fauzi & Sarmidi, 2010).

Table 1. The effect of heating temperature on red fruit oil quality*

Temperature (°C)	Steam presurre (kPa(psi))	Steam duration (minutes)	Yield of oil (%, total of grains)	Water contents (%)	FFA (%)	Total carotenoid (µg/mL)
100	100 (14,5)	60	7.27±0.88	0.07±0.04	1.41±0.032	7790±66
120	197 (28,6)	30	10.0 ± 0.7	0.07±0.01	1.30±0.008	6339±170

*Value shown are the mean ± standard deviation; (n = 3)

Increasing the heating temperature from 100 to 120 °C reduced the FFA levels of RFO from 1.41 to 1.30% (Table 1). This result showed that increasing the temperature will cause denaturation of protein and deactivated lipase enzyme in hydrolyzing the oil (Chew et al., 2022), thus decreasing the FFA levels of the oil. Li et al. (2012) also reported that the FFA levels of palm oil extracted without heating were 24.3%, but the extraction method using a heating process at 100°C for 30 minutes lowered the lipase activity and decreased the FFA value (2.7%).

The total carotenoid content of RFO could be decreased from 7790 to 6339 µg/mL (Table 1) by increasing the temperature from 100 to 120 °C. Fauzi & Sarmidi (2010) also reported that sterilization process for 0-40 minutes during extraction of palm oil not only increased the yield of palm oil, but also increased the loss of β-carotene. As mentioned previously, carotenoids, as the active component of red fruit oil, are very sensitive to oxygen, light, temperature, and acidity because they have a structure with a conjugated double bond system that contains many reactive electrons and is easily oxidized (Rodriguez-Concepcion et al., 2018).

3.3 Effect of steaming grains and chunks of fruit on the yield and quality of red fruit oil

Part of the red fruit that extracted oil was the grain (*drupa*), embedded in the pith. The dry method of RFO extraction consisted of: 1) shelled grains of red fruit, steamed and then extracted the oil by hydraulic pressure, or 2) the whole fruit (*cepallum*) cut into pieces (grains still attached to the pith) and steamed, then the grains were removed from the pith and pressed hydraulically. The effects of different methods of red fruit steaming on oil quality was presented in Table 2. The steaming chunks of red fruit can improve the quality of oil compared to the steaming grains, which was characterized by higher yield and total carotenoid levels. and lower FFA levels.

Table 2. The effect of the red fruit steaming on its oil quality

Steaming process (100 °C, 60 minutes)*	Yield of oil (%, total grains)	Free Fatty Acid (%)	Total carotenoid (µg/mL)
Red fruit grains (*drupa*)	5.95±0.83	2.70±0.012	7209±15
Red fruit chunk of whole fruit (*cepallum*)	7.27±0.88	1.41±0.032	7790±82

*n (replication) = 3

The yield of RFO from red fruit grain (*drupa*) steaming was lower than that from steaming of chunks of fruit (the grains still attached to the pith). According to Sarungallo et al. (2025), with the increasing ripeness of red fruit, the grains of the fruit were more easily removed from the pith. Therefore, removal of grains from the pith using sharp objects (knife) reduced the flesh of the red fruit and the yield of RFO.

The FFA level of RFO from steamed grain extraction (Table 2) was also higher by approximately 2.7%. The removal of red fruit grains can cause injury and scrape grains, and the natural lipase enzyme in the red fruit flesh

will be active, and the fat hydrolyzed to produce FFA (Ngando Ebongue et al., 2006). Chew et al., (2022) also reported that the FFA of palm oil resulted from the action of endogenous lipase activity initiated by tissue injury during the harvesting process. Red fruit with a fat content of 50,8 - 55,58% (Sarungallo et al., 2016) was dominated by unsaturated fatty acids (Murtiningrum et al., 2019; Sarungallo et al., 2015b) that was highly susceptible to lipase activity. Therefore, steaming the chunks of whole fruit can minimize fat hydrolysis. Sarungallo et al. (2014) reported that the shelling process in RFO extraction produced higher FFA levels of approximately 7.24 and 8.50% for both the dry and wet methods, respectively. The difference in FFA levels could be due to the difference in red fruit clones. Ngando Ebongue et al. (2006) also reported that the endogenous lipase activity of palm fruits varied, and several varieties of palm with very low lipase activity had been identified. Furthermore, they explained that CPO extracted from palm fruit with low lipase activity also showed low levels of FFA. Therefore, it can be presumed that the lipase activity of the red fruit clone used in this study (Memeri-long clone) was lower than that of the Monsor clone, as reported by Sarungallo et al. (2014).

The total carotenoid content of the RFO extracted from steaming of grains (*drupa*) also tended to be lower than steaming of chunks of whole fruit (*cepallum*), as shown in Table 2. This was related to the characteristics of carotenoid compounds that had conjugated double bonds (Rodriguez-Concepcion et al., 2018). This double bond was very easily oxidized when in contact with oxygen that occurred during the separation of grains and pith of red fruit. Therefore, steaming the red fruit without the shelling process can minimize the reduction in the total carotenoid content of the oil during the extraction process.

4. CONCLUSION

Increased temperature (40 - 100°C) and steaming time (20 - 60 minutes) of the red fruit during RFO extraction process using the dry method can increase the oil yield (1.20 to 5.95%) and lower the levels of FFA (4.5 to 2.7%), but tend to reduce the levels of total carotenoids (7570 to 7209 µg/mL). The steaming process of red fruit at 100°C for 60 minutes did not affect the degree of fatty acid saturation of RFO. Steaming the chunks of *cepallum* (whole fruit) of red fruit before extraction could decrease the yield percentage, FFA content and carotenoid content in the RFO, compared to steaming the grains (*drupa*) of red fruit.

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