

COMPARATIVE EFFECTIVENESS OF ACID AND WATER DEGUMMING METHODS IN CRUDE PALM OIL (CPO) PRETREATMENT

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ABSTRACT

Crude Palm Oil (CPO) is the primary raw material in the cooking oil industry; it must be refined to improve its quality and stability. Degumming is a critical pretreatment step in CPO refining, as it removes phospholipids that can affect the oil quality. This study aimed to evaluate the effects of two degumming methods, acid degumming and water degumming, on various quality parameters of CPO, including moisture content, free fatty acids (FFA), tocopherols, beta-carotene, and peroxide levels. The results showed that both degumming methods significantly reduced the FFA content and peroxide number. Acid and water degumming were effective in lowering the FFA content and removing impurities from crude palm oil (CPO). They reduced the FFA level by 79.8-80.7% and by 15.9-17.3% for the peroxide number. Although reductions in α -tocopherol were observed, they remained acceptable and did not affect nutritional value.

Keywords: crude palm oil, acid degumming, water degumming, oil quality, oxidative stability

INTRODUCTION

Crude palm oil (CPO) is one of Indonesia's top commodities and is vital to both the food and non-food sectors. Due to its high triglyceride content, CPO is a major raw material used to produce biodiesel, margarine, cooking oil, and soap (Helwani et al., 2021). However, CPO must undergo several refining procedures to eliminate contaminants that could lower the stability and quality of the final product before it can be utilized extensively (Setyawardhani and Satiawardana, 2025).

CPO must undergo chemical and physical purification procedures, such as degumming, bleaching, and deodorization, to lower the water content, FFA, free fats, phospholipids, and other contaminants to make it safe and stable (Hidayati et al., 2023; Alhaji et al., 2024). An extra washing step prior to purification helps suppress pollutants like 3-MCPDE to meet European Union requirements during stringent regulations (Hidayati et al., 2023). The goal of the purification process is to preserve the color, odor, thermal stability, and shelf life of the final product. The difficulty lies in preventing

the production of hazardous compounds during the processing.

Degumming, the removal of phospholipid molecules from oil, is a crucial stage in the refining process. Polar, emulsifying substances called phospholipids can make oil unstable when heated or stored, and phospholipids are classified as either hydratable or non-hydratable in CPO (Bourtsala and Galanopoulou, 2019). To successfully separate each of these types from the oil phase, specific handling is required.

The elimination of phospholipids, which are polar emulsifying substances that may lead to instability during processing or storage, is a crucial stage in oil purification, particularly degumming. Hydratable phospholipids (HP), which are readily separated with water, and non-hydratable phospholipids (NHP), which attach firmly and require acidic or enzymatic treatment for successful separation, are the two forms of phospholipids found in oil (Pan et al., 2024). For instance, adding acids such as citric or phosphoric acid during the degumming process helps change NHP into a form that is

easier to separate by causing flocculation, followed by centrifugation.

Acid and water degumming are two common degumming techniques used in the industry. While acid degumming entails adding an acid, usually phosphoric acid (H_3PO_4), to change non-hydratable phospholipids into a state that can be eliminated by hydration, water degumming employs warm water to remove hydratable phospholipids, such as lecithin. These two techniques are frequently coupled to improve oil quality, as they differ in their ability to lower phospholipid and oil pollutant levels (Matthäus and Pudiel, 2014).

Moisture content, free fatty acids (FFA), carotenoids, tocopherols, and peroxide value are a few of the quality indicators of palm oil that are greatly affected by the degumming process. The oxidative stability of the oil is enhanced by the controlled application of acid degumming, which successfully lowers the FFA and peroxide values without reducing minor components such as tocopherols. The moisture level may be regulated to $\pm 0.25\%$, and the carotenoid concentration remains at approximately 381.350 ppm under ideal conditions (80 °C) (Nidzam et al., 2022; Hidayat et al., 2024; Manurung, 2023). To ensure that degummed oil satisfies both national and international requirements, it is crucial to evaluate these quality factors.

This study aimed to evaluate the effects of acid and water degumming techniques on the physicochemical characteristics of CPO, including moisture content, free fatty acids (FFA), β -carotene, tocopherol, and peroxide value. The efficacy of each technique in creating a productive and standard-compliant CPO purification process is anticipated to be determined by comparing acid degumming with water degumming.

MATERIALS AND METHODE

Materials and Tools

The main material used was CPO sourced from commercial palm oil processing companies in East Kalimantan. The samples, including freshly pressed CPO, were collected and stored for processing to evaluate the effect of storage on degumming efficacy. The

chemicals used were analytical grade (PA) acetic acid, NaOH (Merck, Germany), phenolphthalein indicator, starch indicator, alcohol (One Med, Indonesia), and $Na_2S_2O_3$ (Merck, Germany).

Method

Degumming phosphoric acid accounts for 85% of the acid degumming process. After heating the CPO to 60 °C, 0.09% phosphoric acid was added. This implies that for every liter of solution (CPO + phosphoric acid), there are 0.09 liters of 85% phosphoric acid. The CPO solution was agitated and cleaned until the pH was neutral. The CPO was heated at 60 °C and sprayed with water (washed) in a 1:1 ratio for water degumming.

Determination of FFA, Peroxide Value and Water Content

This experiment tested the peroxide value using the AOAC (Association of Analytical Communities) titration method, free fatty acid using acidic base titration, and water content using the gravimetric method.

Determination of Alpha Tocopherol

The oil samples were dissolved in ethanol, and the absorbance was measured at 221 nm. The tocopherol content of the oil samples was expressed as mg α -tocopherol/kg oil (ppm).

Determination of Carotenoids

Carotenoids were determined according to the PORIM test method (PORIM, 1995). Oil samples were dissolved in hexane, and the absorbance was measured at 446 nm. The carotenoid content of the oil samples was expressed as mg β -carotene/kg oil (ppm).

Experimental Design and Data Analysis

This experiment was a single-factor experiment (product type), namely CPO, acid-degummed oil, and water-degummed oil. The treatments were replicated five times for each treatment. Data were analyzed using analysis of variance (ANOVA), followed by Tukey's test at $\alpha = 5\%$.

RESULTS AND DISCUSSION

Pre-treatment of CPO by degumming showed significant ($p < 0.05$) positive effects on reducing the FFA and peroxide numbers.

However, it also significantly ($p < 0.05$) reduced the α -tocopherol content. The β -carotene and water content in the degummed

oil remained as CPO. Neither degumming method significantly affected any of the chemical characteristics observed (Table 1).

Table 1. Chemicals characteristics of CPO and degummed oil

Product	Water content (%)	FFA (%) as palmitate	β -Carotene (ppm)	α -Tocopherol (ppm)	Peroxide Number (meq. O ₂ /kg)
CPO	0.24 ± 0.05	1.14 ± 0.09a	53.59 ± 1.19	108.55 ± 0.99a	2.31 ± 0.11a
Acid degumming	0.23 ± 0.02	0.23 ± 0.02b	52.10 ± 1.27	99.53 ± 0.87b	1.95 ± 0.09b
Water degumming	0.22 ± 0.03	0.22 ± 0.04b	53.21 ± 2.88	100.55 ± 1.34b	1.91 ± 0.09b

Note: Data (mean ± SD) were calculated from five replicates each. The data were analyzed using ANOVA. The data within the same column followed by different letters indicate significant differences (Tukey's test, $p < 0.05$).

Water Content and FFA (Free Fatty Acid)

Moisture content is a critical parameter for determining oil quality. A high moisture level indicates the presence of significant water in the oil, which accelerates hydrolytic reactions and promotes the breakdown of triglycerides.

The water content of CPO after treatment via either acid or water degumming did not differ significantly (Table 1). This is because the water content in the oil reflects the accuracy of oil–water separation through the decanting funnel during the washing step.

Acid degumming, which uses phosphoric acid (H₃PO₄) and warm water (~60 °C), is a typical degumming method used in the manufacturing of palm frying oils. Phosphoric acid and warm water are used to remove non-hydratable phosphatides. Phosphatidylethanolamine (PE) is the main constituent of non-hydrated phosphatides. Phosphoric acid transforms it into a hydratable form, whereas hydratable phosphatides, such as phosphatidylcholine (lecithin), can be readily extracted from the oil using cold water (approximately 40 °C). This causes the phospholipids to become lipophobic instead of lipophilic, making them easier to separate from the oil (Dijkstra and Opstal, 1987; Lamas et al., 2016; McClements and Jafari, 2018).

The quality of the oil is lowered by residual water or water that is left in the oil after degumming. The Indonesian CPO standard (SNI 01-2901-2006) (BSN, 2006) requires a maximum moisture and impurity concentration of 0.5 %. The water content of the oil in the current study remained between 0.22% and 0.24%, which is the maximum limit. According to recent research, moisture levels in palm oil following degumming and

refining procedures usually fall between 0.24 and 0.25 percent (Teye et al., 2023; Ominyi and Isaac, 2024). The phosphorus and residual phospholipid content in palm oil are greatly affected by degumming process parameters, such as phosphoric acid dosage, temperature, and time (Nidzam et al., 2022).

Triglycerides, which constitute the majority of oils, are hydrolyzed and oxidized to produce free fatty acids (FFA). Because the reaction converts neutral oil into glycerol and FFA, hydrolysis lowers the oil quality. In particular, the FFA produced have a rotten taste and smell (Ketaren, 2008).

Triglycerides, which constitute the majority of oils, are hydrolyzed and oxidized to produce free fatty acids (FFA). Because the reaction converts neutral oil into glycerol and FFA, hydrolysis lowers the oil quality. Particularly in short-chain fatty acids, the FFA that are produced have a rotten taste and smell (Ketaren, 2008). This illustrates that while there is no discernible difference in the FFA content between the acid and water degumming processes, there is a discernible difference when compared to crude palm oil (CPO) without degumming, where the degumming treatment significantly reduced the FFA content. This suggests that some FFA dissolved in the aqueous phase during the degumming process due to the use of water. The addition of water to the degumming process can hasten the breakdown of oil through enzyme activity. By limiting the time that water and oil come into contact and speeding up phase separation, proper handling throughout the degumming process can stop or lessen hydrolysis. The removal of gums coincided with a decrease in the FFA content in CPO that underwent aqueous degumming. Degumming CPO to remove phospholipids

resulted in a slight decrease in FFA in the oil, from 1.14% in untreated CPO to 0.61% after acid degumming and 0.70% after water treatment.

The degumming process precipitates or eliminates non-triglyceride materials, such as gums, which are often linked to lipase enzymes and water molecules. Triglycerides are broken down into FFA by lipase enzymes. Degumming gums and contaminants inhibit lipase action, significantly lowering the rate of fresh FFA synthesis (Shahidi & Zhong, 2010). This explains why a significantly more noticeable decrease in FFA content is observed following degumming compared to untreated CPO. Sufficient drying to eliminate excess water used in the degumming stage before further processing is another reason for the drop in FFA. By reducing the time that oil and water are in contact and promoting quick separation, proper handling of the washing stage can prevent or lessen hydrolysis.

Beta Carotene and Tocopherol

The β -carotene (ppm) and tocopherol content of CPO, acid degumming, and water degumming are presented in Table 1. The acid degumming approach with phosphoric acid at 60 °C reduced the β -carotene content from 53.59 ppm to 52.10 ppm (3%), whereas the water degumming method reduced it to 53.21 ppm (1%). Nevertheless, the difference in the decrease between the two approaches was not statistically significant according to the analysis of variance. However, the mean values do reveal a decrease, which is consistent with earlier research showing that the degumming process entrains oil fractions containing β -carotene during separation, in addition to removing water (Sulihatimarsyila et al., 2020; Oey et al., 2020). Degumming and more thorough refining procedures result in significant reductions in carotenoid content, according to recent studies (Widigdo et al., 2023; Hidayat et al., 2025). Further losses of β -carotene have been reported during the distillation and purification of red palm oil, suggesting that the carotenoid fraction may be partially “absorbed,” degraded, or removed during these purification steps (Jusman et al., 2023).

Furthermore, the initial α -tocopherol concentration of 108.55 ppm decreased to

99.53 ppm (−8%) and 100.55 ppm (− 7 %) under the acid and water degumming methods, respectively. Analysis of variance indicated that this reduction was statistically significant. The decline in both β -carotene and α -tocopherol levels is influenced by phosphoric acid and the water used during the washing stage (Tucker and Townsend, 2005; Hambly et al. 2021). Washing oil with water can significantly reduce tocopherol content. These results suggest that tocopherol is more readily lost or dissolved during washing than β -carotene.

Peroxide Number (meq O₂/kg)

When unsaturated fatty acids react with oxygen, peroxides are formed (Gunstone, 1984). A higher peroxide value (PV) indicates greater oil oxidation (Yin and Porter, 2011). The peroxide value of an oil indicates the early oxidation stage of fats or oils (Shahidi and Zhong, 2010). Therefore, PV is the main signal of oil deterioration, particularly in the early stages prior to the formation of secondary chemicals such as aldehydes and ketones, which provide rancid flavor and odor (Gotoh and Wada, 2006; Shahidi and Zhong, 2010). Overall, the PV measured in the treatment remained below the maximum peroxide value of 10 meq O₂/kg stipulated by the Indonesian national standard (SNI 3741:2013) for cooking oil (BSN, 2013). The peroxide value dropped after the degumming treatment, from 2.31 meq O₂/kg to 1.95-1.91 meq O₂/kg, although the decline was not statistically significant. Certain contaminants, including physical impurities, phospholipids, and free fatty acids, can be eliminated by washing oil with hot water during the degumming process. However, because the peroxide molecules are already dissolved in the oil phase and are chemically stable, hot-water washing is not very effective in achieving a considerable reduction in the peroxide value.

CONCLUSION

Acid and water degumming effectively lowered free fatty acids (FFA) and removed impurities from crude palm oil (CPO). Both can reduce FFA to the level of 79.8-80.7% and 15.6-17.3% for peroxide number. Although reductions in α -tocopherol were observed,

they remained acceptable and did not affect nutritional value.

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