

COMPREHENSIVE UTILIZATION OF RED FRUIT (*Pandanus conoideus Lam.*) OIL AS ANTIOXIDANTS: FOOD APPLICATION AND HEALTH BENEFITS

Daphne Tan¹
Angelica Putri Alfonsus¹
Nicholas Kelvin Utama²
Cicilia Tinardi¹
Angeline Nathania¹
Timothy Sastra¹
Juanida Astina^{1*}

¹Food Science and Nutrition, Indonesia International Institute for Life Sciences, Jakarta, 13210, Indonesia
²Food Technology, Indonesia International Institute for Life Sciences, Jakarta, 13210, Indonesia

ABSTRACT

Oxidative stress has been commonly associated with numerous diseases, including cardiovascular disease, and cancer. As a protective measure against oxidative stress, antioxidants can be utilized as one of the schemes due to their ability to neutralize reactive oxygen species (ROS). However, synthetic antioxidants have been considered to have many safety issues over time. As such, there has been a growing trend towards using natural antioxidants due to their low toxicity and health benefits. One of the prominent natural sources of antioxidants is red fruit oil. Red fruit oil (*Pandanus conoideus Lam*) contains essential vitamins and minerals as well as high amounts of antioxidants, with α -tocopherol being the most abundant. Besides the components mentioned, red fruit oil also includes a variety of fatty acids, a majority being oleic acid and other unsaturated fatty acids such as linoleic acid and alpha-linoleic acid. With a vast number of antioxidants, red fruit oil can improve the shelf life of food products and offer a wide range of health benefits. Nevertheless, many limitations can be observed, such as its underutilization, which leads to a lack of research in specific areas. As such, this paper discusses the current study of red fruit oil, its health benefits, and its application in the food industry, as well as presents potential future research that can be conducted

Keywords: antioxidant; food industry; health benefits; *Pandanus conoideus Lam.*; red fruit oil

ABSTRAK

Stres oksidatif kerap diasosiasikan dengan berbagai penyakit, termasuk penyakit kardiovaskular, dan kanker. Antioksidan dapat digunakan sebagai salah satu tindakan protektif terhadap stres oksidatif dikarenakan kemampuannya dalam menetralkan radikal bebas. Namun, seiring waktu, antioksidan sintetik dianggap memiliki banyak isu keamanan pangan. Oleh karena itu, terdapat perkembangan tren terhadap penggunaan antioksidan natural karena tingkat toksisitas yang rendah serta manfaat kesehatannya. Salah satu sumber antioksidan natural adalah minyak buah merah. Minyak buah merah (*Pandanus conoideus Lam*) mengandung vitamin dan mineral esensial serta kadar antioksidan yang tinggi, sebagian besar terdiri dari α -tokoferol. Selain itu, minyak buah merah juga mengandung berbagai macam asam lemak, dengan asam oleat dan asam lemak tak jenuh seperti asam alfa-linolenat. Dengan kadar antioksidannya, minyak buah merah dapat memperpanjang umur simpan produk makanan disertai dengan manfaat kesehatan. Namun, banyak keterbatasan ditemukan di studi literatur, seperti kurangnya pemanfaatan minyak buah merah, mengakibatkan kurangnya studi di area-area yang lebih spesifik. Oleh karena itu, jurnal ini membahas literatur kini mengenai minyak buah merah, khasiatnya, dan aplikasinya pada industri makanan, serta potensinya pada studi lanjutan yang dapat dilakukan.

Kata kunci: antioksidan; industri makanan; manfaat kesehatan; *Pandanus conoideus Lam.*; minyak buah merah

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***Corresponding author:**
Juanida Astina

Email:
juanida.astina@i3l.ac.id

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INTRODUCTION

Oxidative damage has been involved in the origin of many diseases, including cardiovascular diseases, neuronal degeneration, and cancer. As such, protection against the harmful effects of oxidative damage or stress is essential and can be achieved by utilizing antioxidants (Sharifi-Rad et al., 2020). Antioxidants are compounds that can neutralize free radicals and reactive oxygen species (ROS) within the cell, which can be categorized into two primary groups: synthetic and natural. Synthetic antioxidants have been commonly used in contrast to natural ones due to their low cost, wide availability, higher stability, and performance. However, safety issues have been mentioned over time, including skin allergies, gastrointestinal tract problems, and increased cancer risk (Lourenço, Moldão-Martins and Alves, 2019).

On the other hand, natural antioxidants are substances that exist naturally in food, hence may have lower toxic effects. As such, the global trend towards using natural substances in food as a source of antioxidants and functional ingredients has been progressively increasing in recent years (Dziki et al., 2014). Additionally, a study by Caleja et al. (2017), suggested that using natural sources of antioxidants may become a driver for consumers who are progressively concerned about choosing healthy foods. In this direction, one of the prominent natural sources of antioxidants that have been discovered to contain many healthy benefits, including reduction of oxidative stress, yet not fully explored.

Red fruit (*Pandanus conoideus Lam.*), commonly known as buah merah in Indonesia, is an endemic plant from Papua Province, Indonesia and Papua New Guinea. For local inhabitants, red fruit is used as medicine for degenerative diseases, including cancer, stroke, and arteriosclerosis. According to Rohman

and Windarsih (2017), red fruit oil contains essential vitamins and minerals, such as carotenoids and vitamin E, and also high doses of essential fatty acids, such as oleic acid and linoleic acid. The carotenoids has a long series of conjugated double bonds that are able to neutralize the free radicals whereas the vitamin E comprises of chromanol ring equipped with hydroxyl group that could reduce the free radical (Masaki, 2010; Miller, Li and Liu, 2014). As such, it is a prominent functional food oil that can serve as a potential natural antioxidant, fulfilling the interest of utilizing natural sources as antioxidants due to their associated health benefits (Rahaman et al., 2023). In this review, the beneficial properties of red fruit oil, as well as the current utilization of red fruit oil in the food industry, will be discussed to raise awareness relating to this functional food as a good source of natural antioxidants and highlight further the potential red fruit oil may offer to the food industry as well as the public.

RECENT FINDINGS

Research on red fruit oil has mainly focused on its effect on preventing degenerative diseases, such as lowering blood glucose or reducing oxidative stress in rats. A study by Khairani, Wijayanti, and Gunawan (2023) investigated the impact of red fruit oil on creatine levels, microalbumin, and renal histopathology in rats, concluding that a dose of 5.4 mL of red fruit oil per kg of BW is effective in reducing blood glucose levels and repairing damage to the kidneys of rats. Furthermore, the research status on antioxidant content, fatty acid profile, vitamins, and minerals is more prevalent in this particular era. The study of this red fruit may explore its role in promoting cardiovascular health, supporting the immune system, or managing oxidative stress-related conditions and potential anti-inflammatory effects (Rist et al., 2021). This includes in vitro and in vivo

studies to elucidate the mechanisms underlying its bioactivity.

Even so, some human data or materials are currently utilized, one of which was a study conducted by Sinaga (2017), in which he performed research on human athletes, concluding that red fruit oil can increase endurance and delay the fatigue induced by maximal physical activity. This indicates that despite the research on the possible effects of red fruit oil being mainly conducted on rats, more human data needs to be gathered and encouraged to validate current research or studies on red fruit oil.

The utilization of red fruit oil as a potential natural food additive is also currently being conducted to evaluate its feasibility for application in the industry and the public. The extraction itself mostly utilizes the solvent extraction method, particularly 1:1 v/v chloroform:methanol, due to its efficiency in oil extraction. However, yield appeared to be a limitation (Letviany, 2015). Nevertheless, Sarungallo et al. (2020) found that steam pressure at 100-120 °C before extraction increased yield, with higher temperature resulting in higher yield, yet decreased antioxidant content, including carotenoids and tocopherols. Alternatively, the ultrasonic-assisted extraction (UAE) method could also be conducted, as done by Susanti et al. (2022). They found that UAE conditions of 67 °C extraction temperature, 0.5 pulse duty cycle per second, and 1:2.5 g mL⁻¹ sample to water ratio increased extraction output by 53.02% compared to wet rendering, along with maintaining the phenolic compounds' stability, making it a promising technique for RFO extraction.

ANTIOXIDANT ACTIVITY

Red fruit oil (RFO) is abundant in antioxidants and active components such as α -carotene, β -carotene, α -tocopherol, vitamin C, and unsaturated fatty acids, especially linoleic, oleic acids (Inayatillah, Guhir, and Ramadhani, 2022). The antioxidant molecules work by donating an electron to a rampaging free radical to neutralize the capacity to further damage the cells in the termination step of lipid oxidation. They mainly delay or even inhibit cellular damage using their free radical scavenging properties, preventing unsaturated fatty acids from oxidative reactions (Rao, 2016). The effectiveness of these antioxidants is influenced by several factors, namely light, heat, oxygen, and extreme environmental conditions, as these may influence the stability and tenacity of these compounds. Hence, the potential and effectiveness of these antioxidants could be measured by determining the samples' antioxidant activity (Christodoulou et al., 2022).

Table 1. Antioxidant activity (IC₅₀) of RFO from various studies

Concentration (ppm)	Analytical method	References
IC ₅₀ 53.47	DPPH	Rohman et al. (2010)
IC ₅₀ 14.454	DPPH	Sangkala et al. (2014)
IC ₅₀ 48.85	DPPH	Jufri et al. (2022)
IC ₅₀ 121.51	DPPH	Ranggawati, Arief, and Wulandari (2022)

Table 1. shows the antioxidant activity of RFO. IC₅₀ or half-maximal inhibitory concentration value refers to a concentration measurement of any compound required for 50% or half inhibition of a particular biological or process, in which a high IC₅₀ value indicates low antioxidant activity (Ugwu and Conradie, 2023). The antioxidant activity of the study conducted by Sangkala et al. (2014) shows the lowest concentration, indicating that only 14.454 ppm of RFO is needed to scavenge 50% of the radicals present in the reaction. Furthermore, according to Yun-Sang, Michelle, and Iqbal (2023), a compound is classified as having a very strong antioxidant effect if it has an IC₅₀ value of less than 50 ppm. Thus, it could be concluded from the research conducted that Table 1 shows that RFO can be classified as a strong or very strong antioxidant.

The 2,2-diphenyl-1-picrylhydrazyl (DPPH) is a popular, rapid, easy, and affordable method that could be used for the measurement of antioxidant properties in the samples, which utilizes free radicals to assess the potential of a substance to serve as a free-radical scavenger (Baliyan et al., 2022). The free radical in the sample was stable at room temperature, thus, the antioxidant that is tested will perform a reduction process, which resulted in the colorless ethanol solution that would then be measured using spectrophotometry at the wavelength of 515-520 nm (Garcia et al., 2012).

PROPERTIES OF RFO

The properties of RFO have drawn the interest of many studies, with its antioxidant content being a particular point of interest. A majority of the antioxidants in RFO, as shown in **Table 2.**, are α -tocopherol (21.2mg/100g) as well as small amounts of carotenoids in the form of α -carotene (130 μ g/100g), β -carotene (1.98 μ g/100g), and β -cryptoxanthin (1.46 μ g/100g), giving the oil its distinct bright red-orange color (Swapnil et al., 2021).

Table 2. Nutritional content of red fruit oil extract per 100 g sample. Adapted from Sirait, Warsiki, and Setyaningsih (2021) as cited from Surono et al. (2008)

Parameter	Value
Moisture (g)	0.70
Energy (kcal)	868
Protein	0
Lipid (g)	94.20
Carbohydrate (g)	5.10
Ash	0
Sodium (mg)	3
α -carotene (μ g)	130
β -carotene (μ g)	1.980
β -cryptoxanthin (μ g)	1.460
α -Tocopherol (mg)	21.20

These lipid-soluble antioxidants act synergistically to quench reactive oxygen species, prevent lipid peroxidation, and support redox homeostasis through provitamin A activity and direct radical scavenging (Terao, 2023). Moreover, they have been widely known to protect against various lifestyle-related diseases, with β -cryptoxanthin in particular showing better bioavailability compared to α -carotene and β -carotene. β -cryptoxanthin, in particular, has drawn the attention of many for its reported efficacy in protecting against lung cancers and improving lung function post-smoking (Rodriguez-Amaya, 2015). The oils extracted from red fruit itself are made up of a variety of fatty acids, a majority being unsaturated, with oleic acid being the majority at around 68.80% the total lipid composition, with some other sources suggesting up to 79% (Rohman & Windarsih, 2017). Meanwhile, polyunsaturated fatty acids make up 9.7% of the lipid composition, mainly divided into linoleic acid or omega-6 at 9.05% and α -linolenic acid or omega-3 at 0.66%, suggesting an estimated omega-6 to omega-3 ratio of 13:1 (Renyaan, 2020; Sirait, Warsiki, & Setyaningsih, 2021).

In addition to the other unsaturated fatty acids, RFO contains saturated fatty acids such as palmitic acid (17.48%) and trace amounts of stearic and myristic acid. The considerable amount of polyunsaturated fatty acids, especially with the high omega-6 to omega-3 ratio, which implies an increased oxidative metabolite production, necessitates higher antioxidant capacity to preserve redox balance (Prisacar, 2016; Sarajlic et al., 2023).

RFO also contains various volatile compounds that contribute to its aroma; however, studies surrounding the subject have yielded different results. One study by Arumsari, Riyanto, and Rohman (2013) shows the major compounds are 9-octadecenoic acid and 8-octadecenoic acid, however, another study by Rohman, Sugeng, and Man (2012) suggests the major compounds are 1,3-dimethylbenzene, N-glycyl-L-alanine, trichloromethane, and ethane. Another component of interest in red fruit oil is its phenolic compounds, typically composed of phenolic acids and flavonoids; however, no paper has yet attempted to characterize the phenolic compound composition (Susanti, Rohman, and Setyaningsih, 2022).

HEALTH BENEFITS

The health benefits of RFO are simply undeniable since it consists of many bioactive compounds and nutrients that may improve human health. As seen in **Table 3.**, one of the main components of RFO is 69.7% monounsaturated fatty acids (MUFA), 9.7% polyunsaturated fatty acids (PUFA), and 20.1% saturated fatty acids (SFA), which may decrease oxidative DNA damage in endothelial cells (Xia et al., 2018). The study examined the effect of induction

of RFO in human EA.hy 926 cells with RFO for 30 minutes, and the results showed that it may promote Nitric Oxide production and eNOS phosphorylation in endothelial cells, which may reduce oxidative stress. Furthermore, the study also found that RFO could reduce oxidative stress by promoting vasodilation that was observed in male C57BL/6J mice with RFO concentration as low as 1:100,000 dilution.

Aside from its benefit in preventing cancer cell development, RFO may also maintain skin health as proven by a study conducted by Dumaria et al. (2018) where the study utilized guinea pigs to assess the increase of skin melanin. There were three treatments, which included guinea pigs that applied a basic cream containing 4% hydroquinone and 10% RFO cream, then further exposed to UVB with a total dose of 390 mJ/cm² given for 2 weeks. The result showed that a cream formulated with red fruit extract was found to effectively inhibit the increase of skin melanin in guinea pigs exposed to UVB, comparable to the efficacy of a 4% hydroquinone cream.

Moreover, RFO possesses anti-goitrogen properties, as explained by Wasito (2014), where 70 Sprague-Dawley white mice were divided into 2 groups, of which 45 mice were given goitrogenic feed and 25 mice as the control group. After 45 days, 5 mice from each group were taken randomly for necropsy, and the success rate was assessed through histopathological examination of the thyroid gland. The results of the assessment showed that supplementation of 1-2 ml/mouse/day RFO extract with or without KIO₃ fortification for 30, 60, and 90 days has potential as an anti-goiter herbal medicine.

Table 3. Health Benefits of Red Fruit Oil

Subject of Research	Key Findings	References
Human EA.hy 926 endothelial cells	RFO is found to stimulate the phosphorylation of eNOS at serine 1177, leading to increased NO production. This resulted in a reduction in oxidative stress.	(Xia et al., 2018)
Thoracic aortas (male C57BL/6J mice)	RFO treatment results in vasodilation, which reduces oxidative stress.	
<i>Cavia porcellus</i> was exposed to UVB, basic cream, 4% hydroquinone, or 10% red fruit cream	10% red fruit extract cream prevents an increase in the amount of melanin in guinea pig skin exposed to UVB as effectively as exposed with 4% hydroquinone	(Dumaria et al., 2018)
70 adult female Sprague Dawley white rats were divided into 2 groups: a group of 45 white rats fed goitrogenic food and a control group of 25 rats.	1-2 ml of red fruit extract supplementation with/without KIO3 fortification for 30, 60, and 90 days has potency as an anti-goitrogenic herbal medicine	(Wasito, 2014)

APPLICATION IN THE FOOD INDUSTRY

RFO could be incorporated into a variety of aspects in the food industry, with **Table 4.** highlighting the applications specifically due to its antioxidant properties. Mandacan et al. (2019) utilized RFO as the antioxidant to scavenge free radicals in palm oil, and its antioxidant activity was determined using the DPPH analysis. Results showed that the IC50 of palm oil with RFO is 60.972 ppm on the 5th day. Following that, on the 15th day, the IC50 became 70.022. Despite that, all IC50 values are within the range of 50-100 ppm, which indicates that the antioxidant activity of RFO-added palm oil is within the “strong” category, even after 15 days of storage. Another study by Puspita et al. (2019) assessed the total carotenoid content of palm oil with the addition of 1%, 5%, and 10% RFO, with the highest carotenoid content peaking at day 15, after which prolonged storage beyond that time will reduce the carotenoid content. Hence, from this research, it is said that the addition of RFO is effective in prolonging shelf life up to 15 days.

Aside from meat-based and lipid-based products, RFO’s application in a tea-based functional drink was also explored, in this case by Sonatha (2018). To

improve the solubility of RFO in a water-based beverage, an emulsion with carboxymethyl cellulose (CMC) was used. The addition of 6% RFO-CMC is found to significantly improve the carotenoid content and phenolic content of the drink, in which both have a linear relationship with antioxidant activity (Fitriansyah, Fidrianny, and Ruslan, 2017). Hence, the addition improved the antioxidant activity of the drink, while also contributing to the prolonged shelf life of the product.

Table 4. Current Research Application of RFO in the Food Industry

Product	Key Findings	References
Palm Oil	Increase in antioxidant activity (AA).	(Mandacan, Puspita and Nusawakan, 2019)
Palm Oil	Proportional relationship between amount of RFO added with the carotenoid content.	(Mandacan, Puspita and Nusawakan, 2019)
Java tea-based functional drink	6% emulsion mixture of RFO and CMC resulted in optimum increase in total carotenoid and phenolic content.	(Sonatha, 2018)

LIMITATIONS

As of now, there has been no research on the long-term antioxidant activity and stability of RFO to be applied in commercial food products. Furthermore, more research is needed to assess the antioxidant properties of RFO after different processing methods to determine its feasibility for application in different food formats. Regardless, overall, there is not much available research applying RFO as antioxidants to food products

CONCLUSION

The Papuan Red fruit (*Pandanus conoideus Lam*) oil (RFO) has been widely used as medicine due to its bioactive compounds, including antioxidants. This review dives more into the potential of RFO as a natural antioxidant. With notable antioxidant content and properties from β -carotene and β -cryptoxanthin, RFO has been found to possess numerous health benefits, including the reduction of oxidative stress, inhibiting the growth of cancer cells, and anti-goitrogenic properties. Despite that, the current application of RFO in food products is still limited due to the sensory attributes and stability. Hence, further research is needed to overcome such limitations to improve its applicability in the food industry as a highly promising natural antioxidant.

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