Potential of red fruit oil (*Pandanus conoideus* Lam.) as an antioxidant active packaging: A review

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Abstract. The active packaging system is a food packaging that is continuously developed to produce safe, healthy, and quality food products for consumers. The addition of antioxidants in packaging is one of the innovations in active packaging technology. Active packaging that contains synthetic antioxidants has now been avoiding as natural antioxidants from natural products produces has been already a growing trend to replace synthetic substances. The use of red fruit oil on the packaging is expected to act as a natural antioxidant. Red fruit (*Pandanus conoideus* Lam.) is a plant that is often found in Papua, Indonesia. By local people, red fruit oil is usually used as medicine. The main compounds of red fruit oil are β-carotene and tocopherol which have potential as natural antioxidants. Red fruit extract does not contain heavy metals and harmful microorganisms, so it is safe when applied to food products. Besides being easily found in Indonesia, red fruit oil also has a more economic value compared to the use of antioxidants from other essential oils such as rosemary oil, sunflower oil, and cinnamon oil. This paper will discuss the potential of the red fruit oil to be used for active packaging to protect and prolong the shelf life of the food product.

1. Introduction

The development of active packaging technology so far has been very rapid, especially for vacuum packaging [1], modified and controlled atmosphere [2, 3], flavor/odor absorbers, and oxygen scavengers [4, 5]. This packaging system is carried out to delay product damage by stopping microbial spoilage, enzymatic and oxidative reactions, minimizing contamination, reducing weight, and ensuring product color and integrity while preserving storage [6]. Active compounds such as antioxidants can be added to the packaging system to increase the oxidative stability of food products [7, 8]. Antioxidants can be included in the active packaging system in various forms such as labels, sachets, immobilization, or coating on the surface of packaging materials, multilayers, and others [9].

Active packaging (AP) containing synthetic antioxidants such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), tertiary butylhydroquinone (TBHQ) and propyl gallate (PG) can protect meat against lipid oxidation [10]. However, consumer demand for the use of natural ingredients for food products has produced a growing trend in the use of natural antioxidants as synthetic substitutes [11]. Therefore, the use of plant extracts and essential oils is a major substitute for synthetic additives in food products [12].

Red fruit extract contains active compounds that have the potential as antioxidants [13-15]. Red fruit extract or red fruit oil is obtained from red fruit (*Pandanus conoideus* Lam) which is an endemic plant of Papua (spread in Indonesia and Papua New Guinea) [16] (Figure 1) which is widely used by
local residents as food, natural coloring, and as traditional medicinal ingredients. Until now the red fruit remains the food of some Papuans, especially those living in the mountains of Jayawijaya [17].

Red fruit is known as a million benefits, because red fruit contains nutrients in high levels, including β-carotene, tocopherol, oleic acid, linoleic acid, decanoic, protein, calcium, vitamins, energy, fats, and fiber [18, 19]. The percentage of antioxidant power that traps free radicals from red fruit extract is greater than vitamin C, which is equal to 81.02 % [19]. In addition, red fruit is also included in the Category 5 GHS (Globally Harmonized System for Chemical Classification Substances and Mixtures) which practically does not contain toxic substances [20]. Therefore, red fruit extract is very well used as a natural antioxidant and safe for consumption.

2. Active packaging with natural antioxidant

Antioxidant active packaging is an active packaging that contains antioxidant substances that can interact with the main chamber and product packaging for limiting or preventing lipid oxidation [21]. In addition to microbial growth, oxidative degradation is a major cause of food spoilage [5, 22]. Oxidation causes a decrease in the nutritional value of food due to the degradation of essential fatty acids, proteins, and vitamins that are fat-soluble [5], oxidation can also produce unpleasant taste and odors and color changes due to the degradation of pigments [12, 23].

According to its mechanism, antioxidant compounds can be classified into two parts, primary antioxidants as free radical scavengers (chain breakers) and secondary (preventive) antioxidants including metal chelators, UV absorbers, singlet oxygen absorbers, and oxygen scavengers. Primary antioxidants react with free radicals to convert them into stable enough products that are not involved in the initiation or further propagation reactions. Meanwhile, secondary antioxidants lie in their capacity to reduce or prevent oxidation [5]. Antioxidants delay or inhibit lipid oxidation at low concentrations [24].

Tocopherol, ascorbic acid, carotenoids, flavonoids, amino acids, phospholipids, and sterols are natural antioxidants in food. Antioxidants inhibit food oxidation by cleaning free radicals, chelating prooxidative metals, cooling singlet oxygen and photosensitizers, and inactivating lipoxygenases. Antioxidants show interactions, such as synergism (tocopherol and ascorbic acid), antagonism (tocopherol and caffeic acid), and simple additions. Synergism occurs when one antioxidant is regenerated by another one, when one antioxidant protects another antioxidant by oxidizing its sacrifice, and when two or more antioxidants show different antioxidant mechanisms [24].

Consumer reluctance to synthetic additives results in the use of natural compounds such as tocopherol, ascorbic acid, and plant extracts in packaging which are generally safe and also provide many health benefits [25]. This natural compound can be used to minimize oxidative processes in meat-based products. Studies using natural antioxidants have been carried out by using plant extracts...
or essential oils such as sunflower oil, rosemary extract, green tea extract, and oregano extract because the use of this plant extract is safer and not harmful to health [26] (Table 1).

### Table 1. Development of natural antioxidants for food packaging.

| Natural Antioxidants | Method | Packaging Material | Food Application | Reference |
|----------------------|--------|--------------------|------------------|-----------|
| Sunflower oil        | - Sunflower oil 0.15% + Vitamin E 0.54% | Corn starch film | Instant noodle seasoning | [27] |
| Rosemary extract     | - Coating, rosemary extract 3%, 10%, 20% | LDPE | Fresh beef | [7] |
|                      | - Spread (coating), 1000 ppm | PE | Meat patties | [9] |
|                      | - Varnish (coating), 4% | PP | Fresh lamb | [28] |
|                      | - Varnish (coating), 0.1-8% | | Fresh beef | [29] |
|                      | - Spread (coating), 1000 ppm | LDPE | Pork Patties | [30] |
| PVPP-WS (Polyvinylpolypyrrolidone washing solution) | - Coating, PVPP extract 3%, 10%, 20% | LDPE | Fresh beef | [7] |
| Green tea extract    | - Casting, 5% | Starch film | Fresh beef | [31] |
|                      | - Coating film, 1% | PET/PE/EVOH/PE | Foal meat | [32] |
|                      | - 0.1%, 0.3%, 0.5% | Grain Proteins | Pork meat | [25] |
|                      | - Encapsulated GTE, 6.4 & 12.8 mg/g of film | PE | Fresh minced meat | [33] |
| Oregano extract      | - Varnish (coating), Oregano essential oil 2% | PET/PE/EVOH/PE | Foal meat | [32] |
|                      | - Varnish (coating), 4% | - | Fresh lamb | [28] |
|                      | - 1% | Whey protein | Painhos, Alheiras | [34] |
|                      | - Varnish (coating), 0.5%, 1%, 2%, 4% | - | Fresh lamb | [35] |
| Strawberry           | - curing, 30% | - | Beef *dendeng* | [36] |
| *Morinda citrifolia* oil (MO) | - 1-3% | Fish gelatin film | - | [21] |
| Citric acid          | - Spraying (coating) | Paper sheet coating + gelatin | Minced beef meat | [37] |
|                      | - Extrusion | Corn starch + LLDPE | Minced beef meat | [38] |

3. **Red fruit (Pandanus conoideus Lam.) oil**

Red fruit oil is a vegetable oil extracted from red fruit (*Pandanus conoideus* Lam). Red fruit extraction can be performed by wet (traditional) and dry (by pressing jack press) extraction methods [18] (Figure 2). The content of red fruit oil is quite high at 11.2 – 30.7 % dry weight [39]. The content of red fruit oil is different for red fruit cultivars that are based, such as Monsmir cultivars 30.72 %, U Sauw 26.88 %, and Tawi 27.39 % [17].
During storage at high temperatures, free fatty acids of red fruit tend to increase. Increased FFA levels of red fruit oil can also be triggered due to an increase in the water content of red fruit oil during storage [41]. Purification of red fruit oil can reduce FFA levels from 20.5 % to 0.28 % and the peroxide number from 4.4 mg O₂/100 g to 0.0 mg O₂/100 g but decreases the β-carotene levels from 123 ppm to 0.66 ppm. The purification of red fruit oil (wet extraction) can be performed with stages of degumming (0.2 % H₃PO₄), neutralization (NaOH 16 °Be), chelation (citric acid 0.005 %), and blanching (4 % active charcoal) [18].

**Table 2.** Chemical properties of red fruit oil [43].

| Parameter                  | Value  |
|----------------------------|--------|
| Fat (g/100 g)              | 99.70  |
| Protein (g/100 g)          | < 0.10 |
| Carbohydrate (g/100 g)     | < 0.10 |
| Water (g/100 g)            | 0.30   |
| Calorific value (kcal/100 g)| 899    |
| Calorific value (KJ/100g)  | 3695   |
From the results of an analysis conducted commercially by the SGS Institut Fresenius GmbH, Berlin, Germany, the chemical content of red fruit oil was obtained (Table 2). It was also found that RFO contained 69.7 % monounsaturated fatty acids (MUFA), 9.7 % polyunsaturated fatty acids (PUFA), and 20.1 % saturated fatty acids (SFA). The main MUFA is oleic acid (64.42 %) and palmitoleic acid (1.15 %) while linoleic acid (omega-6; 9.05 %) and α-linolenic acid (omega-3; 0.66 %) represent the main PUFA in RFO. The ratio of omega-6 and omega-3 in RFO is around 13:1. SFA is dominated by palmitic acid (17.5 %) and stearic acid (1.9 %) [42].

3.1. Nutritional content of red fruit oil

The nutritional content of red fruit oil from the analysis results in Japanese laboratories is presented in Table 3 [43].

| 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 (μg)                | 130    |
| β-Carotene (μg)                | 1.980  |
| β-Cryptoxanthin (μg)           | 1.460  |
| Lutein                         | Not detected |
| Zeaxanthin                     | Not detected |
| Lycopene                       | Not detected |
| α-Tocopherol (mg)              | 21.20  |

The α-tocopherol (vitamin E) content is relatively high (Table 3). In contrast, carotene concentrations are very low. The content of vitamin E in red fruit oil is quite high, this means red fruit oil is very good as a source of natural vitamin E. Besides, red fruit oil does not contain heavy metals and harmful microorganisms [44]. β-Carotene, β-Cryptoxanthin, and α-Tocopherol found in red fruit oil are natural antioxidant compounds [24, 45].

3.1.1 β-Carotene

The most important nutritional component in red fruit is pro-vitamin A in the form of β-carotene. β-carotene is an organic compound with a long carbon chain and is non-polar (Figure 3). Extraction to obtain red fruit oil involves the heat process at the boiling stage. β-carotene is unstable at high temperatures, so red fruit oil can decrease in quality if the temperature and duration of heating used are inappropriate. At a heating temperature of 60 °C, carotenoids have not been damaged, but carotenoid oxidation can run faster at relatively high temperatures [46]. But the presence of β-carotene can protect against thermal oxidation [47].

![Figure 3. Structure of β-Carotene](image-url)
3.1.2 β-Cryptoxanthin

In addition to β-carotene, β-cryptoxanthin is also a type of carotenoid that functions as pro-vitamin A which is converted into vitamin A in the body [48] (Figure 4). Among the types of provitamin A, β-cryptoxanthin is a micronutrient that is in great demand because international clinical trials have proven efficacy as an inhibitor of lung cancer [49]. High pre-diagnostic serum-cryptoxanthin levels are associated with a reduced risk of lung cancer in a cohort study of Chinese men in Shanghai. Studies that have been conducted that β-cryptoxanthin is stronger in inhibiting the growth of lung cancer compared with β-carotene [50].

![Figure 4. Structure of β-Cryptoxanthin.](image)

3.1.3 α-Tocopherol

Tocopherol is a monophenol compound and chromanol derivatives which are very soluble in oil and are therefore the most important antioxidants in fats and vegetable oils (Figure 5). Tocopherol is more often found in vegetable oils than animal fat. Most vegetable oils contain tocopherol at concentrations higher than 500 ppm. Purification processes, especially deodorization, can reduce the tocopherol content in oil [24]. From the analysis, it is known that the α-Tocopherol content of red fruit oil is 3 times more than the α-Tocopherol content in olive oil [49].

![Figure 5. Structure of α-Tocopherol.](image)

α-Tocopherol is a chain-breaking antioxidant to inhibit the propagation step. α-tocopherol donates its phenolic hydrogen atom to the peroxyl radical and converts it to hydroperoxide. Tocopheroxyl radicals that are formed are stable enough to not continue the chain and are instead removed from the cycle by reaction with other peroxyl radicals to form inactive non-radical products. Thus, it can be said that α-tocopherol acts as a free radical scavenger [51].

3.2. The utilization of red fruit oil

Packaged red fruit oil has been marketed to several regions of Indonesia and abroad since 2003 [44]. The price of red fruit oil in 250 mL bottles ranges from $10 - $15, and this is also available at online shop stores in Indonesia. People in Indonesia, especially in Papua, believe that red fruit oil has a variety of benefits, including as a raw material for medicines, food, natural dyes, cosmetics, and waste as food [44]. Some of the benefits of red fruit oil that have been studied are presented in Table 4.
Table 4. The utilization of red fruit oil.

| The utilization of red fruit oil | Technical information | Reference |
|---------------------------------|-----------------------|-----------|
| Decreased oxidative DNA damage | - 50 μM Benzo[a]pyrene + RFO, 500 μM tert-Butylhydroperoxide + RFO, RFO at a dilution of 1:10,000 for 24 h | [42] |
| Anti-Goitrogenic | - 1 mL RFO and 80 μg KIO3/kg ransum | [52] |
| Prevent breast cancer development | - LC50 600 ppm | [53] |
| Prevent colorectal cancer development | - LC50 0.25 μL/mL | [54, 55] |
| Reduce blood glucose levels | - RFO 45 mL | [56] |
| Prevent colorectal cancer development | - 0.5 %, 0.25 % | [57] |
| Prohibited the growth of lung cancer cells | - 500 mg RFO/mL | [43] |
| Natural Antioxidant | - IC50 14.454 ppm | [19, 57] |
| Natural pigments | - heptadecene-(8)-carbonic acid (79.66%), hexadecanoid acid (5.62%), dan furan, tetrahydro-2,2-dimethyl (2.95%) | [46] |
| Recover liver damage | - RFO 6% b/v | [58] |
| Reducing the low-density lipoprotein-cholesterol (LDL-C) in the blood | - Alloxan induction + RFO 0.12 mL | [59] |

4. Potential application of red fruit oil in food packaging

The addition of antioxidant compounds to the food packaging system is intended for food products that are sensitive to oxidation reactions [12]. Meat, poultry, and seafood are foods that are sensitive to oxidation reactions [10]. This is due to the high content of unsaturated fatty acids in these food products, which causes lipid oxidation reactions [60]. Lipid oxidation is a complex chemical process that involves developing bad taste, reducing acceptance of meat and meat products by reducing color, texture, and nutritional value, and can ultimately trigger health hazards and economic losses due to lower product quality [61]. Lipid oxidation can be considered as a major cause of quality degradation in meat and meat products [60].

Antioxidants can be added to packaging systems in various forms such as labels, sachets, immobilization or coating on the surface of packaging materials, multilayers, and others [9]. Red fruit oil can be added directly to the meat and processed meat products such as sausages. However, the aesthetic value of the product should be considered that the red fruit oil has a strong red color. If red fruit oil is added to a packaging polymer, further research is needed to find out the right amount of red fruit oil to be added to the packaging polymer. Therefore, it can function as an antioxidant in inhibiting the occurrence of lipid oxidation reactions during food product storage.
5. Conclusions
There are many natural antioxidants found in plants as a substitute for synthetic antioxidants which are known to be harmful to health when used in excessive doses. Red fruit oil can be an alternative as a natural antioxidant because it contains quite high antioxidant compounds. In addition, the availability is quite large, the extraction process is simple, and can be performed traditionally or in a modern way. The application of red fruit oil can be focused on packaging meat, poultry, seafood products to maintain product quality and extend product shelf life.

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