Chapter 31
Papaya (*Carica papaya* L.) Seed Oil

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Abstract Papaya (*Carica papaya* L.) is available in both the tropical and sub-tropical regions around the world. The seeds, size, shape, color and flavor may vary depending on the varieties of papaya. Papaya bears fruits throughout the years and the large amounts of papaya seeds, consisting of about 15–20% in mass, are usually attached to the interior of the fruits in a row. The papaya seeds are edible; however, the majority of the consumers would consider them as wastes. The seeds have the potential to produce 30–34% of oil, especially rich in oleic acid and triacylglycerol; wherein OOO and POO are among the predominant triacylglycerol. The nutritional and functional properties of papaya seed oil are highly similar to olive oil, which in turn makes papaya seed oil a good prospective source of oil. Soxhlet, solvent, aqueous, enzymatic, ultrasound-assisted and supercritical carbon dioxide extractions are among the methods adopted in obtaining the papaya seed oil. The fatty acid compositions of the papaya seed oil yields are within the similar range despite the different extraction methods. Considering the large quantity of discarded papaya seeds globally, oil extraction from the seeds could play an important role in benefiting the food, cosmetic, pharmaceutical and health industries economically.

Keywords *Carica papaya* L. · Papaya seed oil · Extraction

1 Introduction

Papaya (*Carica papaya* L.), under the family of Caricaceae, is available in both the tropical and sub-tropical regions around the world (Yanty et al. 2014). Various species of papaya are available for consumption, which including Sekaki/Hong Kong, Batek Batu, Formosa, Tainoung, Eksotika, Eksotika II, Hawaii, and Chilean. The seeds, size, shape, color and flavor of papaya may vary depending on the varieties and species of the papaya. The papaya fruit flesh is green in color when harvested

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and gradually becomes yellow to orange or reddish during ripening (Barroso et al. 2016; Yanty et al. 2014).

Papaya bears fruits throughout the year and the large amounts of papaya seeds, consisting about 15–20% in mass, are usually attached to the interior of the fruits in a row (Chielle et al. 2016). Papaya seeds are edible; however, the majority of the consumers would consider them as wastes. The spicy flavor of papaya seeds, attributed by the benzyl isothiocyanate, makes it a substitute for black pepper (Yanty et al. 2014).

The oil obtained from papaya seed can achieve up to 34% (Li et al. 2015; Samaram et al. 2013), with the color ranging from pale to dark yellow, almost odorless and flavorless (Yanty et al. 2014). The nutritional and functional properties of papaya seed oil are highly similar to olive oil, in which the papaya seed oil is especially rich in oleic acid and triacylglycerol; whereby OOO and POO are among the predominant triacylglycerol (Yanty et al. 2014). The edibility of this oil is inconclusive up-to-date and further investigations would be required prior to the commercialization of papaya seed oil for food markets or food industries usage. Nevertheless, the fatty acid composition and triacylglycerol profile of papaya seed oil has in turn, made it a very suitable candidate to be used for cosmetic, pharmaceutical and health industries. This could directly help to reduce, reuse and recycle the high amount of papaya seeds that have been globally labeled as agro waste.

2 Composition of Papaya Seeds

The proximate composition of dry papaya seeds from different cultivars (Sekaki, Batek Batu, Chilean and Formosa) and different drying methods (oven-dried and air-dried) is shown in Table 31.1. The dry papaya seeds contain a high percentage of lipid (28.5%) and protein (27.7%), regardless of the cultivars. Among the different cultivars, papaya seeds from Chilean papaya (*Vasconcellea pubescens*) that grows in colder climates (Briones-Labarca et al. 2015) were significantly low in moisture content but high in fiber, protein and lipid contents. The high lipid content of papaya seeds is especially of economically attractive for the industrial extraction, when compared with other oilseed crops, such as corn (3.1–5.7%) and soybean (18.0–20.0%) (Malacrida et al. 2011).

Table 31.1 Proximate composition (% weight) of dry papaya seed

	Average	Range
Moisture	5.9	3.5–7.2
Lipid	28.5	25.3–30.7
Protein	27.7	24.3–31.8
Ash	5.9	2.4–8.8
Fiber	21.0	17.0–24.4
Carbohydrate	23.1	11.7–32.5

Source: Yanty et al. (2014) and Briones-Labarca et al. (2015)

3 Extraction and Processing of Papaya Seed Oil

Papaya seed oil can be extracted through either the conventional extraction techniques such as solvent extraction, screw press and hydrodistillation, or the non-conventional extraction techniques such as enzyme-assisted, ultrasound-assisted, microwave-assisted, pressurized liquid and supercritical fluid extractions. Selected extraction and processing methods of papaya seed oil are discussed below and the recovery yield of different extraction procedures is shown in Fig. 31.1. The result showed the Soxhlet extraction method recovered the highest yield (30.4%) of papaya seed oil, while screw press extraction method produced the lowest yield (4.2%) as compared to other extraction methods (Puangsri et al. 2005). Besides the extraction methods, the drying process of the papaya seeds prior to the oil extraction does play a role in the levels of oil yielded. The previous study showed the optimum drying temperature that could provide the maximum papaya seed oil yield was at the air temperature of 70 °C and an air velocity of 2.0 m/s (Chielle et al. 2016).

Chemical properties of papaya seed oil obtained from different extraction methods are given in Table 31.2. Iodine value, saponification value, unsaponifiable matter and free fatty acid are among the chemical properties analyzed and discussed. The degree of unsaturation of the oil is determined by the iodine value (Puangsri et al. 2005). Soxhlet and screw press extractions obtained the highest (79.95) and lowest (64.10) iodine value, respectively. As for the saponification value and unsaponifiable matter, screw press and Soxhlet extraction methods recorded the highest

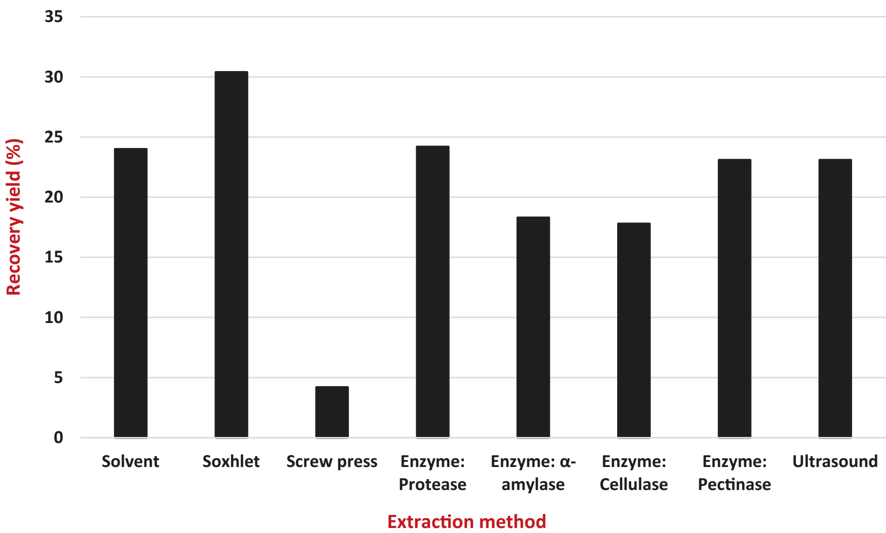

Fig. 31.1 Recovery yield (%) of papaya seed oil obtained by different extraction methods. (Source: Puangsri et al. 2005; Samaram et al. 2013)

Table 31.2 Chemical properties of papaya seed oil obtained from different extraction methods

Extraction method	Iodine value	Saponification value	Unsaponifiable matter (%)	FFA[a] (as % of oleic acid)
Solvent	66.00	154.70	1.39	0.32
Soxhlet	79.95	96.40	1.35	1.27
Screw press	64.10	185.00	4.50	n.d.[b]
Enzyme-assisted				
i. Protease	66.20	154.20	2.15	0.25
ii. α-Amylase	67.60	161.40	2.26	0.23
iii. Cellulase	68.30	158.40	2.58	0.20
iv. Pectinase	69.30	161.70	2.40	0.25
Ultrasound-assisted	71.00	n.d.	1.35	n.d.

Source: Puangsri et al. (2005), Malacrida et al. (2011), Lee et al. (2011), and Samaram et al. (2014)
[a]*FFA* Free fatty acid
[b]*n.d.* Not determined

and lowest readings, respectively. The fatty acid compositions of the papaya seed oil are within the similar range despite the different extraction and processing methods, as given in Table 31.3. Oleic acid is the main fatty acid in papaya seed oil from different extraction methods. Solvent and enzyme (protease) extraction methods have obtained the highest oleic acid (76.8%) among the other extraction methods.

3.1 Solvent Extraction

Solvent extraction is based on the principles of solvent extraction power in combination with the heat and/or agitation (Wang and Weller 2006). Soxhlet, a standard and main reference for lipid extraction that commonly used as a model for the comparison of new extraction alternatives, is the classical example of solvent extraction techniques (Azmir et al. 2013). Soxhlet extraction is suitable for all types of samples except for thermolabile compounds, in view that the extraction and evaporation temperatures do play a significant role in determining the quality of final products (Wang and Weller 2006).

Petroleum ether, *n*-hexane, isopropanol and ethanol are among the solvents used for edible oil extraction. However, petroleum ether is the most commonly used solvent for papaya seed oil extraction. The advantages of solvent extraction are simple, cheap and no filtration requirement after leaching (Wang and Weller 2006). On the other hand, the disadvantages of this extraction method include long extraction time, a large amount of solvent required and also the possibility of thermal decomposition of the target compounds (Wang and Weller 2006).

Table 31.3 Fatty acid composition (%) of papaya seed oil extracted by different methods

	Fatty acid (%)								
Extraction method	Myristic	Palmitic	Palmitoleic	Stearic	Oleic	Linoleic	Linolenic	Arachidic	Eicosenoic
Solvent	0.2	13.9	0.2	4.9	76.8	3.0	0.2	0.4	0.3
Soxhlet	0.2	14.9	0.3	5.2	74.2	3.5	0.2	0.4	0.4
Screw press	0.7	19.7	0.4	6.7	66.7	3.2	0.2	0.4	0.5
Enzyme-assisted									
i. Protease	0.1	12.8	1.8	4.4	76.8	3.2	0.1	0.4	0.3
ii. α-Amylase	0.2	13.3	2.1	4.4	76.0	3.2	0.1	0.4	0.3
iii. Cellulase	0.2	13.4	2.0	4.6	76.5	3.3	0.2	0.4	0.3
iv. Pectinase	0.2	13.6	1.4	4.6	75.9	3.3	0.2	0.4	0.3
Ultrasound-assisted	0.2	15.1	0.3	5.1	74.2	3.5	0.2	0.4	0.4

Source: Puangsri et al. (2005), Samaram et al. (2013), and Lee et al. (2011)

3.2 Enzyme-Assisted Extraction

Enzyme-assisted extraction is based on the addition of specific enzymes during the extraction process to enhance the yield and recovery by breaking the cell wall and hydrolyzing the structural polysaccharides and lipid bodies. Cellulase, α-amylase, protease and pectinase are some examples of enzymes used to support the extraction and yield recovery (Azmir et al. 2013). The advantages of enzyme-assisted extraction include lower extraction temperature, no involvement of explosive solvents and no production of harmful wastes (Puangsri et al. 2005). However, enzyme composition and concentration, the particle size of the sample, solid to water ratio as well as hydrolysis time are among the factors identified which might influence the efficiency of enzyme-assisted extraction (Azmir et al. 2013).

3.3 Ultrasound-Assisted Extraction

Ultrasound, within the range of 20 kHz to 100 MHz, is a special sound wave which beyond human hearing (Azmir et al. 2013). It creates expansion and compression cycles when passes through a medium (Wang and Weller 2006). Ultrasound could improve the mass transfer, induce a greater penetration of the solvent into cellular materials and also facilitate the release of contents through the disruption of biological cell walls (Wang and Weller 2006). This extraction method is recommended for thermolabile compounds that tended to be altered or neglected in the solvent extraction method (Wang and Weller 2006).

The advantages of ultrasound-assisted extraction are simple, inexpensive equipment, reduction of extraction time, temperature, energy and solvent used (Samaram et al. 2013). Nevertheless, there are some factors that might influence the efficiency and effectiveness of ultrasound-assisted extraction, which includes moisture content of the sample, particle size, solvent selection, temperature, pressure, frequency and time of sonication (Azmir et al. 2013).

3.4 Microwave-Assisted Extraction

The utilization of electromagnetic radiations within a frequency from 300 MHz to 300 GHz, to generate heat for the extraction of papaya seed oil, is the principle of microwave-assisted extraction (Wang and Weller 2006). Microwave-assisted extraction is suitable for the extraction of thermosensitive compounds and the advantages of this method include reduction of extraction time and solvent usage while at the same time improved extraction yield (Azmir et al. 2013). Sample particle size, solvent selection and operating conditions are among the factors that influence the efficiency of microwave-assisted extraction (Wang and Weller 2006).

3.5 Supercritical Fluid Extraction

Supercritical, a state that can only be achieved when a substance is exposed to the temperature and pressure that beyond its critical point (Azmir et al. 2013). The supercritical fluid has both the gas-like characteristics of diffusion, viscosity and surface tension as well as the liquid-like characteristics of density and solvation power (Wang and Weller 2006). Carbon dioxide is an ideal solvent for supercritical fluid extraction in view of its critical temperature is close to room temperature (31 °C) and low critical pressure (74 bars) that can easily achieve (Azmir et al. 2013).

Wang and Weller (2006) reported oil extracted with the supercritical fluid method can prevent oxidation of lipids and more protected from the oxidation of unstable polyunsaturated fatty acids (PUFA), as compared to oil extracted with the solvent method. The advantages of supercritical fluid extraction include reduced extraction time, complete extraction, a wider range of solvent selection as well as ideal for thermolabile compounds extraction (Azmir et al. 2013). The choice of supercritical fluids, sample pre-preparation and the extraction conditions are some of the practical issues that will impact the supercritical fluid extraction efficiency (Wang and Weller 2006).

4 Fatty Acid Composition and Acyl Lipids

The fatty acid composition of papaya seed oils extracted from three commercial papaya cultivars (Formosa, Hawaiian and Golden) grown in Brazil is shown in Table 31.4. Regardless of the cultivars, the predominant fatty acids in the papaya seed oil are oleic acid (69.78–72.04%), subsequently followed by palmitic acid (18.20–18.95%), stearic acid (5.07–5.30%) and linolenic acid (3.23–4.84%), respectively. A similar trend is observed by Lee et al. (2011) and Yanty et al. (2014). The oleic acid level of papaya seed oil is comparable with other edible oils, such as olive (71%) and hazelnut (73%) oils (Vingering et al. 2010). It has been reported

Table 31.4 Fatty acid profile (% weight) of papaya seed oil

Fatty acid	Average	Range
Myristic acid	0.21	0.20–0.22
Palmitic acid	18.68	18.20–18.95
Palmitoleic acid	0.28	0.23–0.32
Stearic acid	5.19	5.07–5.30
Oleic acid	70.65	69.78–72.04
Linoleic acid	4.24	3.23–4.84
Arachidic acid	0.38	0.35–0.41
Gadoleic acid	0.34	0.32–0.41

Source: de Melo and de Sousa (2016)

Table 31.5 Triacylglycerol profile (% weight) of papaya seed oil

Triacylglycerol	Average	Range
LOO	3.55	2.54–4.40
LOP	2.27	1.72–2.80
OOO	43.23	41.30–44.60
POO+SOL	30.67	27.70–33.80
OPP	5.81	5.10–6.19
SOO	9.29	8.37–9.80
SOP	3.12	2.41–3.80
Unknown	2.06	0.20–4.80

Source: Samaram et al. (2013)
LOO linoleoyl-dioleoyl glycerol, *LOP* linoleoyl-oleoyl-palmitoyl glycerol, *OOO* trioleoyl glycerol, *POO* palmitoyl-dioleoyl glycerol, *SOL* stearoyl-oleoyl-linoleoyl glycerol, *OPP* oleoyl-dipalmitoyl glycerol, *SOO* stearoyl-dioleoyl glycerol, *SOP* stearoyl-oleoyl-palmitoyl glycerol

that plant oils with a high level of oleic acid have enough oxidative stability in domestic cooking applications like frying (Corbett 2003). Thus, the high-oleic papaya seed oil can potentially be a healthy substitute for partially hydrogenated plant oils.

Triacylglycerols (TAG) represent the major lipid class of papaya seed oil. The TAG composition of papaya seed oil of different cultivars (Sekaki, Batek Batu and Tainoung) and extraction techniques (screw press and solvent extraction) is given in Table 31.5. The predominant TAG molecular species of papaya seed oil are OOO (41.30–44.60%), POO+SOL (27.70–33.80%), SOO (8.37–9.80%) and OPP (5.10–6.89%). The study of Samaram et al. (2013) demonstrated the TAG composition of papaya seed oil significantly affected by extraction techniques, whereby the amounts of OOO, POO+SOL and SOO in ultrasound-assisted solvent-extracted papaya seed oil were significantly lower than solvent-extracted papaya seed oils.

The total phospholipids of papaya seed oil, as measured using the thin layer chromatography silica gel plate, was found to be 0.63%. Three phospholipid components, namely phosphatidylinositol, phosphatidylcholine and phosphatidylethanolamine, have been identified in papaya seed oil. The relative percentages of these components were 34%, 28% and 19%, respectively (Prasad et al. 1987).

5 Minor Bioactive Compounds in Papaya Seed Oil and Their Functions

Minor bioactive compounds of papaya seed oil, including tocopherol, carotenoid, phenolic and flavonoid; are sitting in the unsaponifiable matters upon the oil extraction (Samaram et al. 2014). In addition, sterols, triterpene alcohols, hydrocarbons and the fat-soluble vitamins could be included in the dissolved unsaponifiable

Table 31.6 Minor bioactive compounds compositions of papaya seed oil

Compounds	Value (mg/kg)
Total tocopherols	74.71
α-tocopherol	51.85
β-tocopherol	2.11
γ-tocopherol	1.85
δ-tocopherol	18.89
Total carotenoids	7.05
β-cryptoxanthin	4.29
β-carotene	2.76
Total phenolics[a]	957.60
Total flavonoids[b]	0.60

Source: Malacrida et al. (2011), and Briones-Labarca et al. (2015)
[a]mg of gallic acid equivalent/kg
[b]mg of quercetin equivalent/g

matters as well (Puangsri et al. 2005). Table 31.6 shows the compositions of minor bioactive compounds in the papaya seed oil. Malacrida et al. (2011) reported the low content of tocopherols (74.7 mg/kg) in papaya seed oil as compared to other commercially edible plant oils such as soybean (1797.6 mg/kg), maize (1618.4 mg/kg), and sunflower (634.4 mg/kg) oil. The low content of tocopherols in papaya seed oil might justify the low PUFA content, especially the linoleic and linolenic acids, in the same sample. Both α- and δ-tocopherol are the major tocopherols in the papaya seed oil (Malacrida et al. 2011). The high biological activity and high antioxidant capacity of α- and δ-tocopherol, respectively, are suggested for human consumption (Malacrida et al. 2011).

β-cryptoxanthin is the main carotenoid in papaya seed (Malacrida et al. 2011). The β-carotene content in papaya seed oil is higher than the amount reported for peanut, soybean and corn oils (Malacrida et al. 2011). A similar trend was observed by the same researchers on the total phenolic content of papaya seed oil, whereby the value is much higher than soybean, rice bran, rapeseed, corn and sunflower oils. A study conducted on the effects of the different extraction methods on the yield of total flavonoid content has revealed that high hydrostatic pressure extraction has increased significantly the total flavonoid content as compared to the conventional solvent extraction method (Briones-Labarca et al. 2015).

6 Aroma Profile

The sensory and quality characteristics of edible oils are influenced by their aroma. There have been controversies surrounding the aroma of papaya seed oil. A study by Eckey (1954) reported that papaya seed oil is odorless. However, using an electronic nose (zNose), Yanty et al. (2014) found that papaya seed oil had a distinct aroma profile compared to other seed oils like musk lime, rambutan and honeydew. The author did not report the individual aroma compounds present in papaya seed oil. Further research is needed to better understand the unique aroma properties of papaya seed oil.

7 Oxidative Stability

The oxidative stability index of papaya seed oil, as measured using a Rancimat instrument, was found to be 77.97 h (Malacrida et al. 2011). This value was 6.3–7.8 times longer than the soybean and sunflower oils (Malacrida et al. 2011). The author postulated the high oxidative stability of papaya seed oil is due to its low amounts of PUFA. Another study of de Melo and de Sousa (2016) measured the oxidative stability of papaya seed oil at 65 °C for 25 days. Their study showed papaya seed oil was high in thermo-oxidative stability as the peroxide value recorded at the end of the experiment was lower than value needed for the formation of oxidized compounds.

8 Health-Promoting Traits of Papaya Seed Oil

Limited studies have been conducted on the health-promoting traits of papaya seed oil and its oil constituents to date. This could be due to the lack of studies on the safety assessment and the edibility of this oil. Nevertheless, Castro-Vargas et al. (2016) reported the antibacterial, ovicidal, larvocidal, anti-helminthic, anti-amoebic, anti-inflammatory effects of papaya seed extracts. In addition, Lohiya et al. (2000) found the post-testicular anti-fertility drug potential of papaya seeds in male rabbits. The contraceptive efficacy of papaya seed extracts was also observed in male rats, monkeys and dogs as reported by Castro-Vargas et al. (2016). Benzyl isothiocyanate, a compound that contributed to the spicy flavor of the papaya seeds, has been discovered with cancer preventive property (Yanty et al. 2014). Further investigation on the prospective health benefits of papaya seed oil need to be carried out in view of the high similarity of this oil to olive oil.

9 Edible Applications of Papaya Seed Oil

Papaya seed oil is characterized by high levels of oleic acid (>70%). Plant oils with a high level of oleic acid have sufficient stability to be used in domestic cooking applications like frying (Corbett 2003). The study of Puangsri et al. (2005) suggested the application of papaya seed oil as spray oil for dried fruits, snacks, cereals, crackers and bakery products. This in turn, can enhance the food quality and palatability. Safety assessment of papaya seed oil should be conducted before commercializing for food applications.

10 Other Issues

No publication on the adulteration and authenticity of papaya seed oil is found to date.

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