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A comprehensive review on papaya seed oil extraction and recent applications in food industry

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Abstract
The study has been carried out to explore papaya seed oil extraction techniques which are the new source of edible oil in the food industry. Given the global trend towards the utilisation of solid waste and agricultural leftovers, oil extraction could give economic value to a large number of seeds that are generally wasted. In conventional extraction technology there are many shortcomings, like high consumption of energy, more consumption of harmful chemicals. These have forced the food and chemical industries to find new separation "green" techniques which typically use less solvent and energy, such as microwave extraction, supercritical fluid extraction, ultrasound extraction, ultrafiltration, flash distillation, the controlled pressure drop process and subcritical water extraction. Separation under extreme or non-classical conditions is currently a dynamically developing area in applied research and industry. The bioactive compounds present in papaya seeds make its essential oil a promising food for therapeutic benefits. There are traditional and non-traditional methods for extracting oil from papaya seeds. Traditional extraction methods such as soxhlet extraction and solvent extraction as well as non-traditional extraction methods such as enzyme-assisted, ultrasound-assisted, microwave-assisted, and supercritical fluid extractions have been studied. Plants are used to extract vegetable oils, which are then employed in a variety of industrial and food products. This review summarizes the methods and technologies that can be used for the efficient extraction of papaya seed oil, along with its nutritional importance and applications in the food sector.

Keywords: *Carica papaya* L, papaya seed oil, extraction

1. Introduction
The *Carica papaya* is a member of the *Caricaceae* family (Yanty *et al*., 2014) [26]. It was first cultivated in Central America and now spread throughout the world tropical and subtropical climates. Papaya fruits are valuable both as food, including concentrates and mixed beverages and in traditional medicine. The report states that global papaya production increased from over 13.74 million metric tones in 2019 to just under 14 million metric tones in 2020. Papaya has high nutritional value as well as medicinal value. Its roots, leaves, peels, fruits, and seeds have nutritional and therapeutic properties. Papaya fruit is elongated and club-shaped up to 6 to 20 inches (15-50 cm) long and 4 to 8 inches thick. Weight of papaya fruit is up to 1 to 2 kilograms sometimes much more (Li *et al*., 2015) [9]. There are 50 types of papaya varieties that have been identified. However, due to uncontrolled pollination, pure breeding of papaya varieties is decreasing (Samaram *et al*., 2014) [20]. The skin is waxy and fairly tough. In ripening process it becomes light or deep yellow in color. It is juicy, some type quite musky. The numerous spherical, wrinkled black seeds are adhered to the walls of the expansive central chamber.

As shown in Fig 1, the papaya fruits have a 60% pulp present, which is useful for juices, jams, jelly and pepin production (Tan *et al*., 2020) [23]. The papaya seed accounts for approximately 20% of the weight of the fresh fruits, which are agricultural waste but processed by the food industry, they are edible. Overall, the papaya has 12% peel, which is also agricultural waste (Li *et al*., 2015) [9]. The roots and leaves of papaya can be used as diuretics, anthelmintics, and to cure bilious disorders. It contain proteolytic enzyme that soothes the stomach and aids in digestion its liquid extract has been used to shrinonsils (Natural Product Radiance, n.d.).

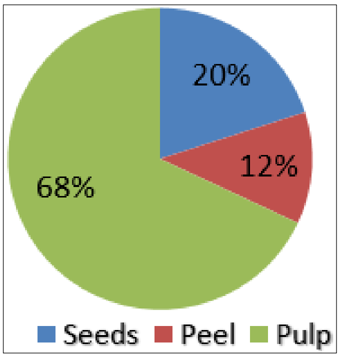

Fig 1: Anatomical composition (%) of papaya fruits

As shown in Fig 1, the papaya fruits have a 60% pulp present, which is useful for juices, jams, jelly and pepin production (Tan *et al*., 2020) [23]. The papaya seed accounts for approximately 20% of the weight of the fresh fruits, which are agricultural waste but processed by the food industry, they are edible. Overall, the papaya has 12% peel, which is also agricultural waste (Li *et al*., 2015) [9]. The roots and leaves of papaya can be used as diuretics, anthelmintics, and to cure bilious disorders. It contain proteolytic enzyme that soothes the stomach and aids in digestion its liquid extract has been used to shrinonsils (*Natural Product Radiance*, n.d.).

1.1 Papaya seed

The papaya seed accounts for approximately 20% of the weight of the fresh fruits. It contains high lipid and protein content, which are new sources of edible oil in the future (Zhang *et al*., 2019) [28]. Papaya seed have antibacterial properties which are effective against the trophozoites of Trichomonas vaginalis. High levels of lipophilic phytochemicals and unsaturated fatty acids can be found in papaya seed oil. These characteristics encourage the creation of numerous techniques for obtaining papaya seed oil. The waste of papaya seed which is used to processing and despite edible (Samaram *et al*., 2014) [20] In food industry papaya seed utilized as the substitute for black paper (Samaram *et al*., 2013) [19].

Table 1: Proximate composition (% weight) of dry papaya seed

Chemical components	Average	Range
Moisture	5.9	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) [26]

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 were significantly low in moisture content but high in fiber, protein and lipid contents (Jamett, 2015) [7]. 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%) (Roberta MALACRIDA *et al*., 2011) [18].

As indicated in fig. 2, there are both traditional and nontraditional methods of oil extraction. Traditional techniques, which have been around for a while, including Soxhlet extraction, takes long time and require a lot of solvents (Luque De Castro & Garcõ Âa-Ayuso, n.d.). Non traditional methods include ultrasound-assisted extraction, microwave-assisted extraction and supercritical fluid extraction. These methods may be able to operate at high pressures and/or temperatures, considerably reducing the extraction time. Additionally, papaya seeds have several useful components that may serve as growth stimulants, antibacterial and anti parasitic agents, as well as anti-material and anti-fungal isolates. Papaya seeds can be utilized as a functional feed ingredient to lower feed costs and improve animal health.

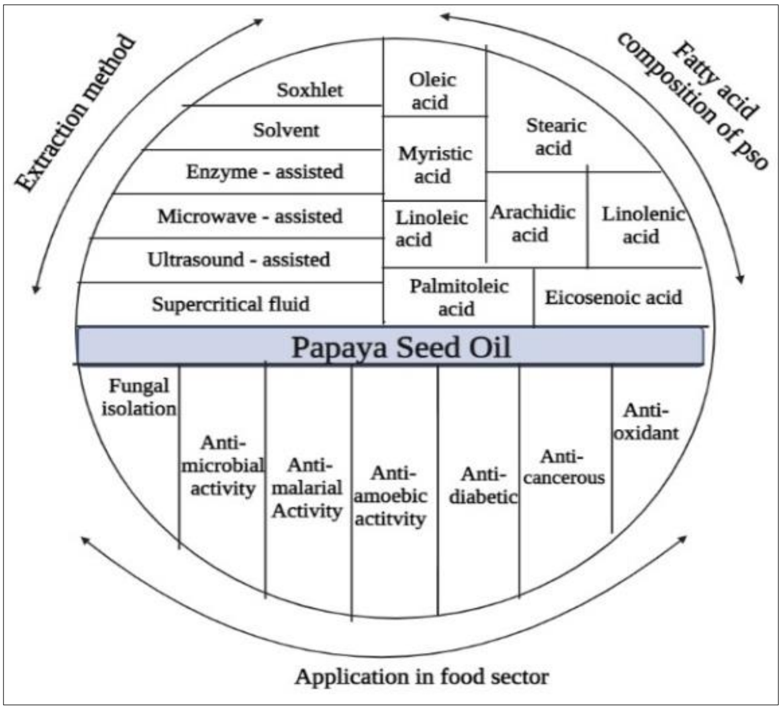

Fig 2: Extraction of papaya seed oil and its recent applications in food sector

2. Extraction techniques of papaya seed oil

An excellent quality papaya seed oil can be produced using the right oil recovery technology. Oil has been extracted from papaya seeds using a variety of methods. The following are approaches that are described in depth. Traditional extraction methods such as solvent extraction, soxhlet extraction, as well as non-traditional extraction methods such as enzyme-assisted, enzyme-assisted, microwave-assisted, and supercritical fluid extractions are discussed. In figure 3, several methods are shown for extracting oil from papaya seeds.

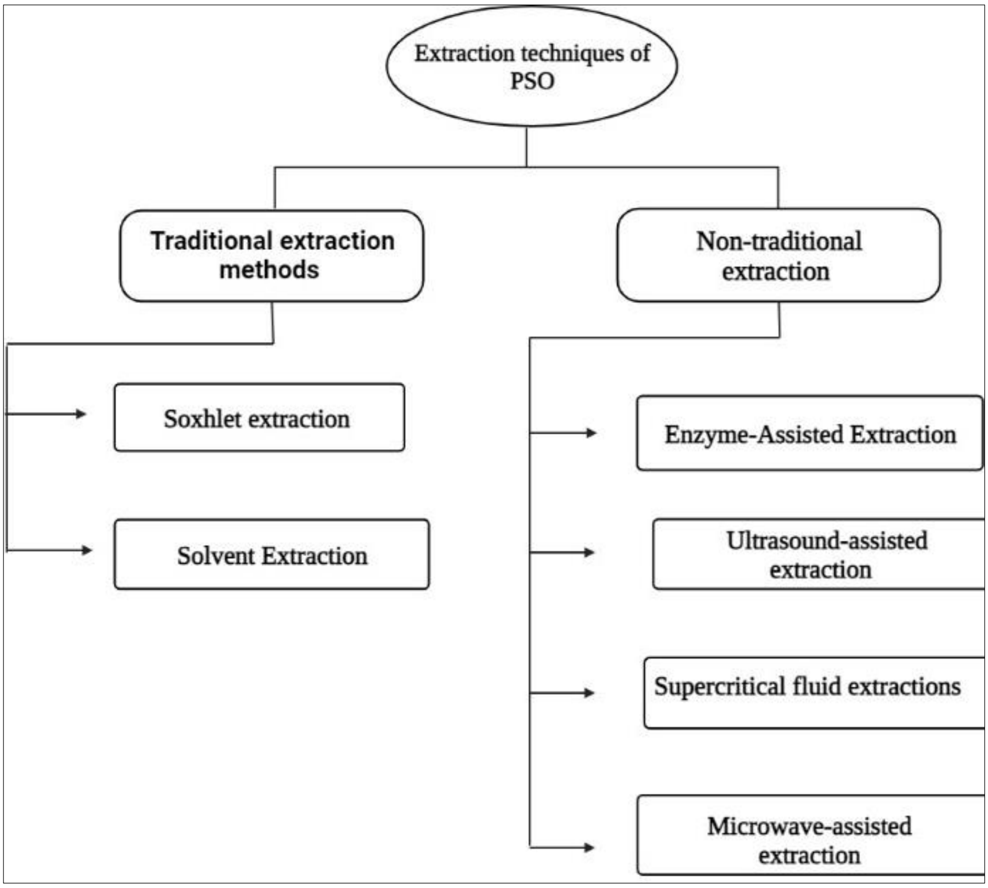

Fig 3: Different methods for extraction of papaya seed oil

2.1 Soxhlet extraction (SE)

Soxhlet extraction (SE) is the most common method used to extract oils on a laboratory scale, across the global. Organic and non-polar solvents are generally used for extraction. Extraction with hexane as a solvent is the most widely applied method for papaya seed oil. Oil is extracted from oilseeds and oleaginous fruits with the semi-continuous traditional method known as soxhlet extraction. It serves as a benchmark method for determining food lipid content and serves as the primary reference method for evaluating various oil extraction options (Tan *et al*., 2020) [23]. In the conventional implementation of SE, the sample is placed in a thimble that is gradually filled with condensed fresh extractant (the term applied to refer to the solvent required for extraction) from a distillation flask. After the liquid reaches an overflow level, a siphon aspirates it from the thimble and unloads it into the distillation flask again. As a result, the extracted analytes are carried into the bulk liquid. Repeat the process until the extraction is complete. As a result of this performance, soxhlet is considered a hybrid continuous-discontinuous technique. In as much as the extractant acts stepwise, the assembly can be considered a batch system. However, since the extractant is recirculated through the sample, the system also has a continuous characteristic (López-Bascón-Bascon & Luque de Castro, 2019) [11].

2.2 Solvent extraction (SE)

Solvent extraction is based on the principles of solvent extraction power in combination with the heat and agitation (Wang & Weller, 2006) [25]. This technique is also known as solvent extraction or maceration extraction (Senrayan & Venkatachalam, 2018) [29]. The benefits of solvent extraction are simple, reasonably-priced and no filtration requirement after leaching on the alternative hand, the hazards of this extraction approach consist of lengthy extraction time, a big quantity of solvent required and additionally the opportunity of thermal decomposition of the goal compounds. By using this method, one component of a mixture dissolves in a particular liquid, and the other component is separated as a residue. Solvent extraction, also known as maceration extraction, is a simple technique for plant oil isolation (Samaram *et al*., 2013) [19].

For solvent extraction, 150 g of crushed seeds were put in a cellulose paper cone and extracted for 8 hours in a 5-L Soxhlet extractor with light petroleum ether (bp 40-60C). Using a rotary evaporator Model N-1 (Eyela, Tokyo Rikakikai Company, Ltd, Tokyo, Japan), the solvent was evaporated to recover the oil. The solvent residue was then removed by drying the oil at 60 °C for one hour and flushing it with 99.9% nitrogen (Puangsri *et al*., 2005) [17].

Samaram studied Ultrasound-assisted extraction(UAE) and solvent extraction of papaya seed oil crystallization and thermal behavior, saturation degree, color and oxidative stability, which was published in 2014. Solvent is diffused over the plant cell wall into oil-bearing cells to extract the oil. The extraction solvents used have a significant impact on the oil production. Solvents having low latent heat of vaporization, easy recovery, and high solubility to the lipids bound inside the plant matrix are preferred in general. They soaked the seed powder with the solvent for one week, followed by oil recovery using evaporation. The study found that extraction of papaya seed oil with the most polar solvent (ethanol) produced the least amount of papaya seed oil compared to less polar solvents.

2.3 Enzyme-assisted extraction (EAE)

The advantages of enzyme-assisted extraction (EAE) includes lower extraction temperature, no involvement of explosive solvents and no production of harmful wastes In comparison to standard techniques, this technology increased pectin extraction yield and was used at low process temperatures, reducing energy usage. The enzymatic extraction was then also compared to the traditional acid-based extraction. The extraction yield obtained using enzymatic preparations was larger than that obtained using acidic extraction (Cheng *et al*., 2015) [5]. In 2014, A study was conducted by Yusoff on Aqueous enzyme assisted oil extraction from oilseeds and emulsion de-emulsifying methods, Their study demonstrated the effect of enzyme specificity on the cellular composition of papaya seed. The existence of higher amount of pectin in the cellular composition of papaya seed suggests that the oil is liberated more rapidly from the cellular matrix by breaking down the pectin, which is achieved by the action of enzyme pectinase. 15 g of ground papaya seeds were weighed into separate 250 mL conical flasks, and 150 mL of distilled water was added, resulting in a ratio of 1: 10 (w/v), which is thought to be the ideal ratio for the oil extraction process (Dominguez *et al*. 1995) [30]. The samples were carefully simmered for five minutes, then quickly cooled to room temperature in an ice water bath (Tano-Debrah & Ohta 1995) [31]. Protease was added to the suspension (which was left unaltered and had a pH of 5.8), and it was incubated at 45 °C for 24 hours while being constantly stirred at 120 rpm. Under identical conditions, the a-amylase, pectinase, and cellulase processes were repeated. Following the incubation process, the flasks were removed and 100 mL of boiling distilled water was added to each flask to halt the activity of the enzymes. Using a Beckman centrifuge model J2-12M/E, oil from enzymatic extraction was recovered by centrifugation at 9820 g of the aqueous mixture. The emulsion and residue must be separated at 20C for 20 minutes. The emulsion was decanted, and the water was gently heated out to get the oil (Puangsri *et al*., 2005) [17]. Using the initial yield produced by the Soxhlet technique, the oil was collected and expressed as a percentage recovery before being stored at -20C for analysis. Each enzyme assisted extraction study considers operational conditions such as temperature of reaction, time of extraction, pH of system, enzyme concentration, and particle size of sample. Figure 4 illustrates the enzyme assisted extraction method for natural products. In all studies, it has been demonstrated that enzyme assisted extraction increases yield and product quality while also reducing extraction time and solvent volume.

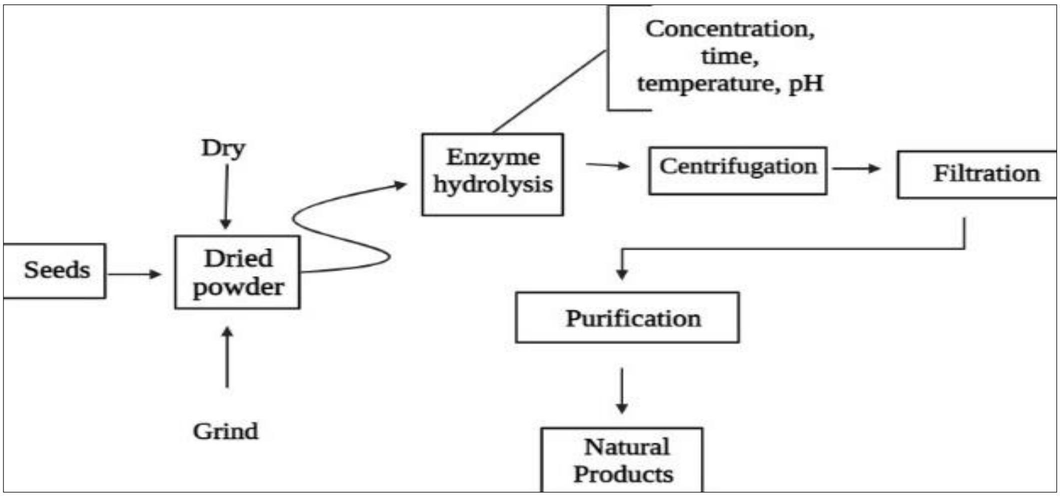

Fig 4: Enzyme-Assisted Aqueous Extraction

2.4 Supercritical fluid extraction (SFE)

Supercritical, that can only be accomplished whilst a substance is exposed to the temperature and pressure that beyond its critical point (Azmir *et al*., 2013) [3]. The supercritical fluid has every the gas-like properties of diffusion, viscosity and ground tension and also liquid-like properties of density and salvation power (Wang & Weller, 2006) [25]. Carbon dioxide is an important chemical for supercritical fluid extraction so its essential temperature is equal to room temperature (31 °C), it has an irregular essential strain (74 bars) that can be achieved without issue (Azmir *et al*., 2013) [3].

Supercritical fluid extraction (SFE) has gained lots of importance in being a rapid, selective, and efficient method. Further, it is a clean technique as it does not leave any harmful residue in the extracted oil and is safe for the environment. The works on supercritical fluid extraction (CO2) of PSO has reported a higher oil yield, punicic acid, and tocopherol contents (Liu *et al*., 2009) [10]. In a study by Abbasi, Rezaei, and Rashidi (2008) [37], a higher phenolic content was observed in SFE extracted PSO compared to stirring, soxhlet, microwave, and ultrasonic extractions. However, the higher capital and investment costs 118 hinder the commercialization of SFE. The efficacy of SFE depends on the choice of solvent, preparation of the materials, and extraction conditions. The temperature and pressure used for

SFE are important parameters that vary depending on the requirement of higher extraction yield or selectivity of particular compounds (Lang & Wai, 2001) [32]. Upon the investigations of the extraction of PSO with SFE, It was suggested that the oil yield increased with higher antioxidant contents at elevated pressures and temperature (G. Liu *et al*., 2009) [10].

Wang and Weller (2006) [25] have reported that oil extracted using the supercritical fluid method prevents lipid oxidation and is more resistant to polyunsaturated fatty acid oxidation. Some of the practical issues that will influence the effectiveness of supercritical fluid extraction include the choice of supercritical fluids, sample preparation, and extraction conditions.

2.5 Microwave- assisted extraction (MAE)

A unique technique for extracting soluble compounds into a fluid from a variety of materials using microwave energy is known as "microwave-assisted extraction" (Cheng *et al*., 2015) [5].

In this setting, Paré *et al*. created, tested, and published a technique called "microwave-assisted solvent extraction" in the middle of the 1990s with the US EPA. The US EPA authorized this method as Method 3546 under SW-846 after it underwent rigorous evaluation and validation procedures.

The variables of time 50 s and power 360 W, 480 W, and 600 W, was used to conduct microwave-assisted extraction (MAE) The solvent-to-solid ratio was kept Z constant. The rotary evaporator will be used to dry the crude extract (Buchi R-210, Flawil, Switzerland). It was determined what the extraction yield would be.

Wang and Weller published in 2006, a scientific article outlining recent advances in the extraction of nutraceuticals from plants. The use of electromagnetic radiation with a frequency ranging from 300 MHz to 300 GHz to induce heat for the extraction of papaya seed oil is known as microwave-assisted extraction. Microwave-assisted extraction is suited for the extraction of thermo sensitive chemicals, and it has the advantages of reducing extraction time and solvent usage while improving extraction yield. Microwave-assisted extraction efficiency is influenced by a number of parameters, including sample particle size, solvent choice, and operation conditions.

2.6 Ultrasound-assisted extraction (UAE)

Heat and mass transfer can be accelerated with ultrasound-assisted extraction, which has proven successful in the past. When plant material interacts with ultrasound waves, its physical and chemical properties are altered. As a result of disrupting the cell walls of plants, the gravitational effect facilitates the release of extractable compounds. UAE is a clean method that does not require the use of large amounts of solvent and reduces the extraction time. It has been demonstrated by Luque-Garci that ultrasounds are an effective technology for extracting plants. In the chemical and food industries, ultrasound is well known to have a significant impact on the rate of various processes. Ultrasound has been used to extract natural products that would normally take hours or days to extract using conventional methods.

Ultrasound, in the range of 20 kHz to 100 MHz, is a unique sound wave which is beyond human hearing (Azmir *et al*., 2013) [3]. It creates expansion and compression cycles when passing through a medium (Wang & Weller, 2006) [25]. This extraction technique is suggested for thermo labile compounds that tended to be altered or omitted within side the solvent extraction technique (Wang & Weller, 2006) [25]. The advantages of ultrasound-assisted extraction are simple, less expensive equipment, discount of extraction time, temperature, strength and solvent used (Samaram *et al*., 2013) [19]. Nevertheless, there are a few elements that could have an impact on 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].

Table 2: PSO extraction condition and its key findings

Extraction methods	Condition of extraction	Key findings	References
Microwave-Assisted	• Microwaves are electromagnetic radiations with a frequency from 0.3 to 300 GHz. Domestic and industrial microwaves generally operate at 2.45 GHz, and occasionally at 0.915 GHz in the USA and at 0.896 GHz in Europe	• Reduced extraction time • Reduced solvent usage • Improved extraction yield	(Tan *et al*., 2020) [23] (Hasbay & Galanakis, 2018) [6]
Solvent extraction	• Petroleum ether, n-hexane, isopropanol and ethanol are among the solvents used for edible oil extraction • Extraction and evaporation temperatures do play a significant role in determining the quality of final products	• Simple, cheap and no filtration requirement after leaching	(Samaram *et al*., 2013) [19]
Supercritical Fluid Extractions	• The supercritical fluid possesses both the density and solvation power of a liquid as well as the diffusion, viscosity, and surface tension of a gas	• Reduced extraction time, complete extraction, a wider range of solvent selection	(Azmir *et al*., 2013) [3]
Ultrasound-Assisted	• Ultrasound is a unique sound wave that is audible to humans only at frequencies between 20 kHz and 100 MHz.	• Recommended forthermolabile compounds	(Wang & Weller, 2006) [25]
Enzyme-Assisted Aqueous Extraction	• Cellulase, α-amylase, protease and pectinase are some enzymes used to support the extraction.	• Lower extraction temperature no involvement of explosive solvents	(Puangsri *et al*., 2005) [17]

3. Applications of Papaya Seed Oil in Food

Oleic acid concentrations in papaya seed oil are high (>70%). Plant oils with a high oleic acid content are stable enough to be used for home cooking tasks like frying (Corbett 2003) [33]. Papaya seed oil may be used as a spray oil for dried fruits, snacks, cereals, crackers, and bakery goods (Puangsri *et al*., 2005) [17]. This in turn may improve the flavor and quality of the dish. Before selling papaya seed oil for use in food applications, a safety assessment should be done.

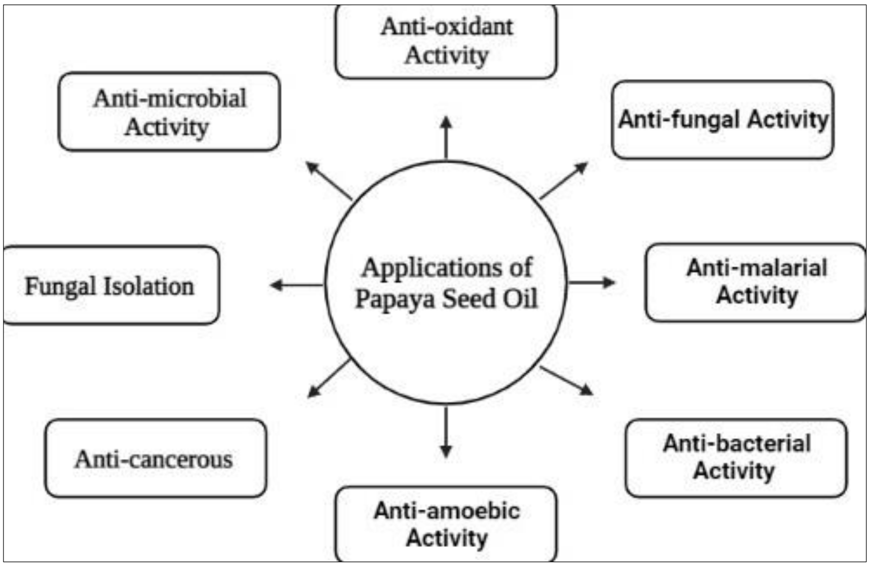

Fig 5: Application of papaya seed oil in food industry

3.1 Antioxidant activity
Consumers can benefit from antioxidants by preventing the production of free radicals. The results of the DPPH, FRAP, and TPC tests confirm that papaya seeds contain antioxidants (Omar *et al*., 2020) [15]. High antibacterial activity against V. cholerae and limited antimicrobial activity against C. albicans were found in papaya seed extract. It had been claimed that phytate had antioxidant properties (Masfufatun *et al*., 2019) [13]. As unripe seeds are used in place of mature *Carica papaya* seeds to treat illnesses, unripe seeds contain greater quantities of phytin (Afolabi & Ofobrukweta, 2011) [2].

3.2 Antimicrobial activity
Papaya seeds have antimicrobial action against *Trichomonas vaginalis trophozoites*. The study warns against toxicity when utilising papaya seed for urogenital conditions like trichomoniasis (Calzada *et al*., 2007) [4]. The papaya seed and pulp are bacteriostatic against a number of enteropathogens, including *Bacillus subtilis, Enterobacter cloacae, Escherichia coli, Salmonella typhi, Staphylococcus aureus, Proteus vulgaris, Pseudomonas aeruginosa,* and *Klebsiella pneumoniae,* according to research using the agar cup plate method (*Natural Product Radiance,* n.d.).

3.3 Fungal isolation
A bronchial asthma patient was found to have *Aspergillus flavus*. The isolate was kept alive for 7 days at 28. 2 °C on a 2% Potato Dextrose Agar (PDA) agar medium with 0.05 g/L chloramphenicol was added as an antibacterial agent (Mahmoud *et al*., 2011) [12]. with minor modification. The isolate was identified microscopically according to Moubasher (1993) [34].

3.4 Antifungal activity
Few studies have examined the antifungal effects of papaya seed extracts on contagious yeasts. According to Singh and Ali (2011) [38], C. albicans can't develop when exposed to a methanolic extract of papaya seeds or the 2,3,4-Trihydroxytoluen chemical that was isolated from the methanolic extract. Additionally, it has been observed that BITC has antifungal properties against the fungi *Sclerotinia sclerotiorum* and *Gibberella moniliformis* (Kurt *et al*. 2011; Azaiez *et al*. 2013) [35-36]. Since BITC was shown to be the primary chemical in the isolated EO, it is possible to use papaya seeds as a natural source of BITC. The EO has antifungal action against Candida species such as *C. albicans, C. krusei, C. parapsilosis, C. tropical, and C. glabrata,* as shown by the inhibition zone diameters, MICs, and MFCs of the EO. The EO also prevented the growth of C. albicans, a yeast strain that is resistant to FLZ, showing that it can stop the growth of some yeast strains that are resistant to the current antifungal medications. The mechanism of action of BITC on pathogenic yeasts is unknown at this time. To transform BITC into potent antifungal drugs for therapeutic application, more research is required.

3.5 Antimalarial activity
Significant antimalarial activity is seen in the papaya fruit's rind petroleum ether extract. The rind of this plant, which is widely distributed across the tropics and whose active ingredient may be extracted and used for antimalarial activity, may have enormous commercial potential (*Natural Product Radiance*, n.d.).

3.6 Antibacterial activity
Several enteropathogens, including bacillus subtilis, enterobacter cloacae, escherichia coli, salmonella typhi, staphylococcus, proteas vulgaris, pseudomonas aeruginosa, and klebsiella pneumonia, have been reported to be resistant to the bacteriostatic action of papaya seeds. The gram-negative bacteria tested were more sensitive to the extract than the gram-positive bacteria.

3.7 Anti-amoebic activity
Mature papaya seeds' cold-macerated aqueous extract has anti-amoebic activity against *Entamoeba species Histolytica* (Kumar Assistant Professor *et al*., 2017) [8].

3.8 Anti-cancerous
Papaya seeds are an all-natural method of birth control for both males and females. It has historically been used to temporarily reduce male fertility. It's interesting that papaya seeds have no known side effects yet pharmacological contraceptives frequently have them. Papaya seeds may have

anticancer effects against cancer of the prostate gland, a crucial component of the male reproductive system, because it appears that they have activity for the male reproductive system. We proposed that papaya seeds may be an effective nutraceutical for preventing and/or treating prostate cancer in males because they can effectively limit the proliferation of prostate cancer cells (Udoh *et al*., 2005) [24]. White and black seeds extracts from papaya were tested for their anticancer activities using PC-3 prostate cancer cells to investigate how they affected the proliferation of prostate cancer cells (Panzarini *et al*., 2014) [16].

Table 3: Application in food industry

Application	Description	Reference
Meat Tenderizer	Papaya seeds contain enzymes, such as papain and chymopapain, that can help break down proteins in meat, making it more tender. Papaya seed powder can be used as a meat tenderizer in the food industry.	(Sugiharto, 2020) [21]
Salad Dressings	Papaya seed oil, which is extracted from the seeds, is rich in healthy fatty acids and can be used in salad dressings as a healthy alternative to traditional oils.	(Yao & Xu, 2021) [27]
Seasoning	Papaya seeds can be dried and ground into a powder that can be used as a seasoning in various dishes. The powder has a slightly peppery flavor and can be used in place of black pepper.	(Sunmola & David, 2011) [22]
Beverages	Papaya seeds can be used in smoothies and other beverages as a natural source of protein and fiber. The seeds can be ground and added to the drink or used to make a seed milk.	(Adesola *et al*., 2019) [1]
Preservative	Papaya seeds have antimicrobial properties that make them a natural preservative. They can be added to food products to help extend their shelf life.	(Adesola *et al*., 2019) [1]

4. Conclusion

In conclusion, the study highlights the potential of papaya seed oil as a new source of edible oil in the food industry. Given the increasing global trend towards utilizing solid waste and agricultural leftovers, the extraction of oil from papaya seeds could provide economic value to seeds that are generally wasted. The conventional extraction technology has many shortcomings, and hence, the food and chemical industries are exploring new separation "green" techniques that typically use less solvent and energy. The bioactive compounds present in papaya seeds make its essential oil a promising food for therapeutic benefits. The study has reviewed both traditional and non-traditional methods of papaya seed oil extraction and highlighted their efficiency, nutritional importance and applications in the food sector.

Products made from papaya seeds have been shown to be nutritious, have a variety of sources of all nutrients, and have a number of health benefits. People's health effects. It is for this reason that papaya seeds are commonly thrown away despite their potential use in growing plants that are considered safe for consumption and extremely nutritious. This could lead to the development of a revolutionary form of medicine. New, fast extraction techniques, including supercritical fluid extraction, accelerated solvent extraction and microwave-assisted solvent extraction, among others, have rendered conventional soxhlet as an old-fashioned, time-consuming method. Incorporating auxiliary energies such as microwaves has updated the technique, enabling it to be competitive with its recent counterparts in terms of features that enable it to be advantageous.

4.1 Funding Statement

Not Applicable

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