Plants based rich sources of polyunsaturated fatty acids: A comprehensive review

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Abstract
Many oil seeds contain the necessary fatty acids i.e polyunsaturated fatty acids (PUFAs) like omega-3 and omega-6. These PUFAs are oxidation-prone. Before being applied to or added as a value to food products, PUFAs need to be protected, hence this is accomplished by microencapsulation. This review provides a comprehensive overview of different types of PUFA rich oil seeds and their benefits in human health. Health benefit of pufa include obesity which have become a global health crisis. Clinical studies on obesity, cardiovascular disease, and inflammatory disorders have all shown that omega 3 fatty acids have effects on anti-inflammatory characteristics that can reduce or lower the risk of heart diseases. One of the newest technique to prevent oxidation of PUFAs is microencapsulation. One strategy for maintaining the integrity of delicate chemicals is microencapsulation. It is also a way to create materials with new beneficial features. The method of microencapsulation involves encasing microscopic particles in a polymeric shell. This review also describes different techniques of microencapsulation of PUFAs which includes single and double emulsion technique, spray drying, phase separation coacervation technique, fluidized bed coating, and solvent evaporation.

Keywords: Polyunsaturated fatty acids, obesity, cardiovascular diseases

Introduction
Oils and fats are considered to be the fundamental (or basic) food components because they play a good role in contributing positively to the food product's taste, flavour, and quality (Jurić et al., 2022) [36]. According to the double bonds present in fats and oils can be mainly of two types, Monounsaturated which contains one bond and polyunsaturated which contains more than one double bonds. The unsaturated fatty acid classes are further divided into groups using the omega series. Omega-3 and omega-6 are the only two required fatty acids for humans whereas omega-9 is not an essential fatty acids (Calder and Yaqoob, 2009) [15]. Vegetable oils are one of the major and important component of human diets, which comprises 25% of average caloric intake (Fasina et al., 2006) [24]. Currently widely consumed cooking oils are omega-6 fatty acid rich vegetable oils which includes canola oils and soybean oils (Yamashima et al., 2020) [72], linoleic acids (LA) and Linolenic (ALA) are the two basic polyunsaturated fatty acids represented as 18:2, n-6 and 18:3, n-6 respectively. Docosahexaenoic acid is one of the main sources of PUFAs (DHA, 22:6, N-3). Most terrestrial sources are found in green vegetables, nuts, and seeds. Current research has demonstrated the value of PUFA in protecting against cancer, coronary heart disease, diabetes, obesity, and other illnesses of the cardiovascular system. Moreover, it encompasses renal illness, hypertension, autoimmune, inflammatory, and thrombotic diseases (Orsavova et al., 2015) [54]. As obesity continues to be a growing health issue, especially for young people there have been and still are several investigations into the causes of obesity (Li et al., 2011). This review focuses on the benefits of pufa, the sources of pufas from oil seeds, and the impact of pufa on obesity. Finally this review provides different techniques of microencapsulation which can be used to prevent oxidation of pufa.

Different types of fatty acids and their benefits
Omega 3 fatty acids: α-linolenic acid, eicosapentaenoic acid, stearidonic acid and docosahexaenoic acid, represented as ALA; 18:3 PUFA, EPA; 20:5 PUFA, SDA; 18:4 PUFA, DHA; 22:6 PUFA are some examples of omega-3 PUFA (given in Fig 1). Oils that include certain fatty acids (FAs) or portions of these fatty acids mostly come from specific plant sources or are altered in plants.
The livers of white lean fish, fatty fish, and mammals contain the long-chain (LC) omega-3 fatty acids that are entaenoic acid and docosapentaenoic acid (Shahidi and Ambigaipalan, 2018) [63].

Health effects: The Western world has a high mortality rate for cardiovascular diseases and related conditions due to the intake of a high-fat diet. PUFAs' effects on major cardiovascular conditions which include stroke, irregular heartbeat, atrial fibrillation, congenital heart disease, subclinical atherosclerosis, coronary heart disease, myocardial infarction and valvular disease, heart failure, sudden cardiac death and peripheral arterial disease have been the focus of numerous studies (Mozaffarian et al. 2016) [50]. Regarding the function of omega-3 PUFAs in the management of diabetes, there are some areas of disagreement. According to Djoussé et al. (2011), eating more omega-3 PUFAs (i.e. 0.2g of fish/day) increases the risk of type 2 diabetes. It has been established that omega-3 PUFAs have an effect on a number of malignancies, including prostate, colon, stomach, lung, pancreatic, breast and skin cancers (Takezaki et al. 2003) [62]. Moreover, studies have demonstrated that omega-3 PUFAs enhance the tolerability and effectiveness of chemotherapy (Mocellin et al. 2017) [49]. Reduced intakes of omega-3 PUFAs are linked to an increased risk of dementia, particularly for Alzheimer's disease, according to several epidemiological studies. According to MacLean et al. (2004), there is enough clinical proof that omega-3 fatty acids can prevent Alzheimer's disease. In the brain, particularly in the synaptosomes, cerebral cortex, synaptic vesicles and mitochondria, docosahexanoic acid is the main constituent of membrane phospholipids. Many reviews have also examined how omega-3s affect dementia (Cole et al. 2009) [18].

Omega 6 fatty acids
Canola, sunflower, soybean and corn oils are substantial sources of omega-6 fatty acids in the form of linoleic acid, with minimal amounts of n-3 FAs in most crop seeds and vegetable oils (ALA). In comparison to n-6 FAs, the intake of n-3 FAs is typically insufficient due to their constrained sources. Types of omega 6 PUFAs include linoleic acid, arachidonic acid and gamma linoleic acid (given in Fig 2) (Bazinet and laye, 2014) [6].

Health effects: According to several studies, people who take gamma linolenic acid (GLA) for six months or longer may have reduced symptoms of nerve discomfort if they have diabetic neuropathy. GLA may work better for those with good blood sugar control than for those with poor blood sugar control (Saini and Keum, 2018) [60]. Another study on breast cancer discovered that taking gamma linolenic acid improved the effectiveness of the medicine tamoxifen, which is used to treat estrogen-sensitive breast cancer, in comparison to taking simply tamoxifen (Zheng et al., 2013) [79]. Elevated blood pressure (hypertension), preliminary study suggests that GLA consumed with omega-3 fatty acids like EPA and DHA, may help in lowering the blood pressure. GLA consumed in combination with omega-3 fatty acids also reduces the same (Tortosa-Caparrós et al., 2016). Osteoporosis, numerous studies have shown that persons who do not get enough EPA and GLA—two necessary fatty acids—are more prone to lose bone than those who do. Women with osteoporosis over the age of 65 who consumed GLA and EPA supplements, experienced less bone loss over the course of three years than those who received a placebo. In addition, several of these ladies had an increase in bone density (Sayed and Ibrahim, 2015) [23].

Fig 1: Structural representation of omega-3 PUFAs
PUFAs rich oil seeds
Although fish oil is the main dietary source of long chain omega-3 polyunsaturated fatty acids (PUFA), the current intake of omega-3 fatty acids is far below the recommended rates due to the low acceptance of oily fish. Therefore the consumption of this becomes very important (Sanders, 2000)\(^6\). To find an alternative there are also many other edible vegetable oils which provide high amount of omega-3 fatty acids needed for health. These can be chia seed oil, grape seed oil, camelina seed oil, pumpkin seed oil, pomegranate seed oil, flaxseed oil and linseed oil. All these oils possess high percentage of different fatty acids like linolenic acid, linoleic acid, stearic acid, oleic acid and palmitic acid (Given in table 1). PUFA rich oilseeds have health benefits like reducing the cardiovascular effects, inflammatory diseases, atherosclerosis, hypertension and prevention of some forms of cancer which makes these oils an excellent dietary intake by humans (given in table 2).

![gamma linolenic acid](image1)
![arachidonic acid](image2)
![linoleic acid](image3)

Table 1: Fatty acid composition of oil seeds

<table>
<thead>
<tr>
<th>Oil</th>
<th>Oil content</th>
<th>Linolenic</th>
<th>Linoleic</th>
<th>Oleic</th>
<th>Stearic</th>
<th>Palmitic</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chia oil</td>
<td>32.3-38.6</td>
<td>60.7-65.0</td>
<td>19.8-20.8</td>
<td>7.3-8.2</td>
<td>3.1-3.7</td>
<td>6.3-7.1</td>
<td>(Ixtaina et al., 2011)</td>
</tr>
<tr>
<td>Grape seed oil</td>
<td>10.45-16.73</td>
<td>0.16-0.35</td>
<td>66.0-75.3</td>
<td>19.19-23.29</td>
<td>3.14-4.96</td>
<td>8.52-10.01</td>
<td>Tangolar et al., (2009)</td>
</tr>
<tr>
<td>Pumpkin seed oil</td>
<td>10.9-30.9</td>
<td>0.14-0.30</td>
<td>42.73-55.33</td>
<td>29.20-6.44</td>
<td>4.15-5.67</td>
<td>9.39-12.48</td>
<td>Nederal et al., (2014)</td>
</tr>
<tr>
<td>Camelina seed oil</td>
<td>28.1-48.0</td>
<td>27.1-38.9</td>
<td>13.5-19.0</td>
<td>14.0-17.40</td>
<td>1.4-2.7</td>
<td>5.3-6.43</td>
<td>Abramovic and Abram, (2005)</td>
</tr>
<tr>
<td>Mustard oil</td>
<td>40.65-49.00</td>
<td>0.41-11.30</td>
<td>25.31-41.92</td>
<td>38.21-40.72</td>
<td>2.78-5.76</td>
<td>4.51-9.58</td>
<td>Dorni et al., (2018); Chowdhury et al., (1970)</td>
</tr>
</tbody>
</table>

Chia seed oil
It is an annual herbaceous flowering plant that blooms in the summer and is a member of the Lamiaceae family. Chia seeds have a significant potential for nutrition because of their structure. The composition is determined by the genetic make-up and the effects of the habitats in which the plants were raised (Ayerza and Coates, 2011)\(^4\). Chia seeds have a total of 37-45% carbs, 31-34% fat, 16-26% protein, and 23-35% dietary fibre. They also include antioxidants, minerals (like phosphorus, calcium, potassium, and magnesium), and vitamins (like niacin, thiamine, folic acid, riboflavin, and vitamin A) (Ixtaina et al., 2011)\(^3\). Prolamins make up the majority of the 16 to 26% of proteins in chia seeds, which also contain glutelins, globulins, and albumins (Lugo et al., 2010)\(^3\). Seven exogenous amino acids, which are regarded as essential, are among the 18 amino acids that are present in...
chia seeds. The study by Lugo et al., 2010 (53), revealed that the Glutamic acid, the primary amino acid in chia seeds, is essential for the healthy functioning of the brain. Chia seeds have minerals in them. They contain 4 times of potassium, 6 times as much calcium, and 11 times of phosphorus as cow’s milk (Ayerza, 1995) [3]. They are reported to have anti-inflammatory effects, manage lipid metabolism, protect the cardiovascular system (Brenna et al., 2009) [25] have anti-oxidative qualities, and improve athletic performance. Chia seed’s anticoagulant and anti-inflammatory properties may help type II diabetics avoid strokes and heart attacks (Vuksan et al., 2007) [69].

Grape seed oil
Around 60 million tonnes of grapes are produced globally; the top four producers are France, Italy, the United States, and China. About 6 to 11 million tonnes of grape marc are produced during the making of wine or juice from this total number of grapes grown worldwide. While the grape marc and, in particular, the seeds, were once primarily used as waste, many alternative uses are now recognised (Matthaus, 2008). Grape seed oil is studied as a potential source of specialized lipids, and its use in cooking is on the rise. One of the vegetable oils with a high level of unsaturated fatty acids is grape seed oil. In terms of the total fatty acid content, unsaturated fatty acids account for around 90% of all fatty acids. Linoleic acid makes up more than 70% of the oil, and the remaining 15% is primarily constituted of oleic acid. Grapeseed oil's predominant fatty acid (72.2%) was linoleic acid. Similar high levels of linoleic acid can be found in sunflower and safflower seed oils. Grape seed oils had a total unsaturated fatty acid content of 88.6% (Crews et al., 2005) [19]. The important fatty acids linoleic and linolenic acid are converted into eicosanoids, also known as hormone-like compounds, by extending the carbon chain and adding more double bonds. These eicosanoids regulate a variety of bodily functions and act as the body's mediators and effectors in a number of metabolic processes (Matthaus, 2008) [40]. Vitamin E, flavonoids, and phenolic compounds are examples of antioxidants with established antioxidant potential that may change the state of oxidative stress. These substances are intrinsic to the composition of oil GSO. The primary chemical component of GSO discovered in the literature is tocotrienol. By controlling specific signal transmission, tocotrienols can prevent the effect of glutamate-induced neuronal cell death (Khanna et al., 2003) [51].

Pumpkin seed oil
The proportional distribution of oleic, linoleic, palmitic, and stearic fatty acids is 43.8%, 33.1%, 13.4%, and 7.8%, respectively. These four predominant fatty acids make for 98.1% of all the fatty acids in the dark green pumpkin seed oil. Pumpkin seed oil is used as a nutritional supplement because it is a natural source of essential fatty acids, proteins, polyunsaturated fatty acids like omega-3, 6, and 9, lutein, carotenes, vitamins such carotenoids, chlorophyll, tocopherols, trace minerals and phytoestrogens (Williams et al., 2006). Several studies have suggested that pumpkin seed extract's antioxidant capabilities may enhance fertility, guard against heart disease, reduces high blood pressure, and arteriosclerosis and also supports the metabolism of fats that have been accumulated in the body (Shaban et al., 2017) [62]. Investigations on how pumpkin seed oil may affect hair growth have also been conducted. It's interesting to note that research by Cho et al., assessed how pumpkin seed oil affected male androgenetic alopecia patients' hair growth. Lower urinary tract symptoms brought on by a prostatic condition have been treated with phytochemicals (phytosterols) as an alternative or integrative therapy (Hong et al., 2009) [34].

Camelina seed oil
Technically known as Camelina sativa, is a dicotyledonous oil-seeded plant which belongs to the Brassicaceae family (Berti et al., 2016) [10]. It is possible to separate the camelina oil's composition into two categories: saponifiable (tocopherols and sterols) and unsaponifiable (fatty acids). Numerous studies have revealed that the omega-3 fatty acid i.e linolenic acid is the main constituent of camelina oil. Minor lipid components of camelina oil include sterols and tocopherols (vitamin E) (Belayneh et al., 2015) [7]. Due to its high omega-3 concentration, camelina oil is important in human nutrition. Given that consuming large amounts of erucic acid is regarded to be the cause of heart lipospis, camelina oil's low erucic acid content is advantageous when used in human diets (Vollmann et al., 2001) [68]. It is well known that camelina can lower cholesterol and triglycerides in the blood. Additionally, Camelina oil can be utilized as a nutraceutical in a variety of ways in the human diet due to the composition of its fatty acids, including salads, cooking, margarine with an enhanced amount of omega-3 fatty acids, mayonnaise, salad dressings, and ice cream (Abramovic and Abram, 2005) [1].

Pomegranate Seed Oil
PSO manufactures 12-20% of the total weight of seeds. Punicic acid (PA), the main fatty acid among them and one that is present in PSO, is thought to be a good source of those fatty acids. Eleostearic acid and catalpic acid (C18:3 9cis, 11trans, 13trans) are two additional isomers of conjugated linolenic acids (CLnAs) (Lansky et al., 2005) [45]. Many studies have shown the many health advantages of conjugated linoleic acids (CLAs) and linolenic acids (LnAs), it is that they shares a strong structural similarity with PA. Several studies have revealed that PA has beneficial benefits, including those that are anti-inflammatory, immunomodulatory, anti-cancer, anti-estrogenic, and have favorable effects on lipid profiles (Yamasaki et al., 2006) [71]. PSO has a strong impact on cancerous cells. Hora et al., (2003) [80] looked into PSO's ability to suppress the growth of skin tumours in CD1 mice. They came to the conclusion that PSO (5%) considerably reduced the occurrence of tumours (P 0.05). PSO offers a variety of medicinal benefits, including those against osteoporosis, pancreatitis, hepatitis, improving insulin secretion, neuroprotection, and the alleviation of menopausal symptoms (Hora et al., 2003) [80].

Flaxseed oil
Recently, flaxseed oil (linseed) were identified as an alternative plant source of omega-3 fatty acids. It is the richest source of a lignan called secoisolariciresinol diglucoside (SDG) (Prasad, 2009) [55]. About 30% of flaxseed's total lipid content is composed of 19% oleic acid, α-linolenic acid (ALA), 17% linoleic acid (LA), 5% palmitic acid and 3% stearic acid (Bernacchia et al., 2014) [9]. Many research have demonstrated the ability or effect of increased intake of omega-3 fatty acid can lower blood pressure in people who...
have been diagnosed with hypertension. Moreover, a diet high in monounsaturated and polyunsaturated fats, especially omega-3 fatty acids from flaxseed, and low in saturated fats can lower the risk of heart disease (Rodriguez-Leyva et al., 2010) [58].

### Table 2: Health effects of PUFA rich oils obtained from different oilseeds

<table>
<thead>
<tr>
<th>Seeds</th>
<th>PUFAs</th>
<th>Health effects</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chia seed oil</td>
<td>Alpha linolenic, linolenic</td>
<td>Cardiovascular effects, inflammatory diseases, atherosclerosis, hypertension</td>
<td>Bingbing Liu and Weidong Yan (2020)</td>
</tr>
<tr>
<td></td>
<td>acid</td>
<td>lower risk for heart disease, Diabetes, Prevention of some forms of cancer</td>
<td>Tripathi and Agarwal, (2012)</td>
</tr>
<tr>
<td>Linseed oil</td>
<td>Alpha linolenic acid</td>
<td>Antimicrobial features, Antioxidant capacity, anti-inflammatory effect</td>
<td>Garavaglia et al.,(2016) [27]</td>
</tr>
<tr>
<td>Grape seed oil</td>
<td>Linoleic acid</td>
<td>Anti-Tyrosinase Activity, Anti-Aging Activity, Antioxidant Activities</td>
<td>Prommaban et al., (2021) [56]</td>
</tr>
<tr>
<td>Pumpkin oil</td>
<td>Linoleic acid and oleic acid</td>
<td>Anti-inflammatory, immunomodulatory, anti-cancer, pancreatitis, Hepatoprotective</td>
<td>Loukhmas et al., (2021) [47]</td>
</tr>
<tr>
<td>Pomegranate seed oil</td>
<td>linoleic acid, oleic acid</td>
<td>Anti-inflammatory, immunomodulatory, anti-cancer, pancreatitis, Hepatoprotective</td>
<td>Loukhmas et al., (2021) [47]</td>
</tr>
<tr>
<td>Camelina seed oil</td>
<td>Alpha-linolenic acid,</td>
<td>decreased low-density lipoprotein cholesterol, cardiovascular disease</td>
<td>Dobrzyńska et al., (2020) [21]</td>
</tr>
<tr>
<td></td>
<td>Linoleic acid</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Health benefits of PUFAs

Polyunsaturated fatty acids (PUFAs) are known to play a vital role in maintaining blood pressure, lowering the risk of cardiovascular diseases, prevention of some forms of cancer, obesity and oxidative stress (Lee et al., 2016) [44]. Among PUFAs, ω-3 and ω-6 fatty acids are recognized as important and crucial fatty acids because both cannot be produced inside the body and required to be consumed through diets. Requirement of the omega-3 and omega-6 fatty acids in the body can be achieved through consumption of the plant’s oilseeds like chia, grape seed oil, pomegranate seed oil and flaxseed oil (Calder et al., 2017) [14]. The growth of the agribusiness, the rising popularity of processed foods, grain-fed fish and animals, the filtration of vegetable oils, and the increased use of oilseeds in food production have boosted the intake of omega-6 fatty acids, which is good for human health benefits (Fig 3) (Saini and Keum, 2018) [60].

#### Obesity

China has surpassed the United States as the nation with the biggest number of affected people globally, with over 61% of total population which include both adults and children being obese or overweight (Wang et al., 2019) [70]. According to a study, bad diets were responsible for one-fifth of all fatalities worldwide (11 million deaths), and in 2017, more than 2% of all deaths globally were attributable to insufficient n-3 PUFA intake. Interestingly, compared to the rest of the world, East Asia has a lower average consumption of polyunsaturated fatty acids (PUFAs), which mainly include omega-3 PUFAs, but high-income countries in the Asia Pacific region have higher average intakes (Afshin et al., 2019) [76]. N-3 PUFAs contain α-linolenic acid (ALA), eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA) and docosapentaenoic acid (DPA) (Lalia et al., 2017) [41]. Lack of a proper balanced diet and exercise causes obese condition in human, which can be altered by the intake of PUFAs. These intake results in re-establishment of TCA cycle homeostasis by influencing mitochondrial activity, particularly the transcription and translation.

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*Fig 3: Health benefits of polyunsaturated fatty acids*
Randomised controlled trials: Randomized controlled trials have been examined the effects of increasing n-3 LCPUFA intake on body composition in humans (Table 3). In the study conducted by Wargo et al., came to conclusion of feeding pre-term infants with PUFA dose of arachidonic acid and n-3 LCPUFA to 33 weeks gestation resulted in decreased body fat formation in new-borns (Wargo et al., 2005) [20]. On the other hand Bergmann et al., determined that supplementing pregnant women with LCPUFA and 200mg DHA intake have reduced the body mass index and weight (Bergman et al., 2007) [8]. Further Fontani et al. showed the effects of intake of n3 LCPUFA supplementation of 1.6g EPA and 0.8g of DHA to non-competitive athlete’s resulted in greater decrease in body fat (Fontani et al., 2005) [25]. All these studies have given conflicting results with the study of Kabir et al., where the study showed the intake of EPA and DHA in postmenopausal women with diabetes type 2 resulted in neither weight loss nor fat mass decrease (Kabir et al., 2007) [38]. Same as with the study of lauritzen et al. showed no effects on body weight of offsprings (Lauritzen et al., 2005) [43]. Thus there are relatively some studies in humans which have examined and determined the effects of intake of n3 LCPUFA reducing body weight showing the vital role of intake of PUFA.

<table>
<thead>
<tr>
<th>RCT type</th>
<th>Age/ type of pathology</th>
<th>No of Participants</th>
<th>PUFA dose</th>
<th>Outcomes</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>parallel double-blind intervention to age adjusted for gestation of 12 months</td>
<td>Pre-term infants, age &lt; 33 weeks</td>
<td>60</td>
<td>n-3 LCPUFA and arachidonic acid</td>
<td>decreased body fat formation in newborns developing.</td>
<td>Wargo et al., (2005) [20]</td>
</tr>
<tr>
<td>Randomized, double-blind, parallel research lasting 31 weeks</td>
<td>Pregnant women</td>
<td>93</td>
<td>n-3 LCPUFA intake of 200 mg DHA</td>
<td>reduced body mass index and weight in offspring</td>
<td>Bergman et al., (2007) [8]</td>
</tr>
<tr>
<td>4-month double-blind, randomised parallel study</td>
<td>low fish intake mothers from Danish</td>
<td>122</td>
<td>0.79 g DHA + 0.62 g EPA</td>
<td>There was no change in the offspring’s length, weight, or head circumference increases.</td>
<td>Lauritzen et al., (2005) [43]</td>
</tr>
<tr>
<td>2-month parallel, double-blind intervention</td>
<td>Postmenopausal women with type 2 diabetes</td>
<td>26</td>
<td>0.72g DHA, 1.08 g EPA</td>
<td>Neither weight loss nor fat mass decrease differs.</td>
<td>Kabir et al., (2007) [9]</td>
</tr>
<tr>
<td>10-week dietary intervention with open-label parallel double-blind 2 to 5-week</td>
<td>Athlete’s exercising (non-competitive) at least 3 h/week</td>
<td>33</td>
<td>0.8 g DHA, 1.6 g EPA</td>
<td>Greater decrease in % body fat</td>
<td>Fontani et al., (2005) [20]</td>
</tr>
<tr>
<td>Double-blind, randomised, controlled, parallel research lasting 3 months</td>
<td>Obese adults</td>
<td>65</td>
<td>0.36 g EPA, 1.6 g DHA</td>
<td>Fish oil and exercise have separate effects on body fat mass reduction.</td>
<td>Hill et al., (2007) [33]</td>
</tr>
<tr>
<td>Double-blind, randomised, controlled, parallel research lasting 24 week</td>
<td>Overweight or obese hyperinsulinemic women</td>
<td>93</td>
<td>2.9 g DHA, 1.3 g EPA</td>
<td>No difference in weight loss</td>
<td>Krebs et al., (2006) [40]</td>
</tr>
</tbody>
</table>

Cardiovascular disease
Polyunsaturated fatty acids (PUFA) and omega-6 PUFA have frequently been the focus of public health about diet and cardiovascular diseases. (Ruxton et al., 2004) [90]. Even among seemingly healthy subjects, cardiovascular diseases (CVD) are still the major cause of death in developed countries, making them a serious clinical problem that still has to be effectively controlled. It has been demonstrated that LC-PUFAs like EPA or docosahexaenoic acid (DHA) in the diet at various stages of life which has a favorable impact on the lipid profile, such as lowering plasma triacylglycerol (TAG) and lowering the risk of CVD (Rangel-Huerta et al., 2018) [57].

Randomised controlled trials: Different trials have been studied and showed the benefit of omega 3 PUFA in reducing mortality in patients who suffered with cardiovascular diseases (Table 4). DART (diet and reinfarction trial) randomised 2033 men with myocardial infarction with 350mg of EPA daily, resulted in 29% reduction in major cardiovascular events (Bur et al., 1989) [13]. The JELIS (Japan EPA lipid intervention study) trial examined the supplementation of omega 3 PUFA where 18,645 patients suffering from hypercholesterolemia were treated with 1800 mg EPA which showed 19% reduction in mortality (Yokoyama et al., 2007) [73]. Further Alsaleh et al. showed decreased blood pressure after supplementing 1800mg per day of EPA to 310 healthy subjects (Alsaleh et al., 2014) [2]. Shaikh et al. determined an improvement in omega 3 level and lipid profile in 110 patients with cardiovascular health in those who are at high risk for CVD with the dose of 2720mg per day of EPA and 440mg per day of DHA (Shaikh et al., 2014). In all these cases on clinical trials there is a visible rate of reduction in the mortality of patients suffering from CVD.

<table>
<thead>
<tr>
<th>Trials</th>
<th>Patient characteristics</th>
<th>No of Participants</th>
<th>Pufa dose</th>
<th>Outcomes</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>DART</td>
<td>Men after the occurrence of myocardial infarction</td>
<td>2033</td>
<td>350 mg EPA</td>
<td>29% reduction in total mortality rates</td>
<td>Burr et al., (1989) [13]</td>
</tr>
<tr>
<td>RCT</td>
<td>Healthy subjects</td>
<td>310</td>
<td>EPA = 900 g/d EPA = 1800 mg/d</td>
<td>BP decreased after 1800 mg/d of EPA</td>
<td>Alsaleh et al. (2014) [2]</td>
</tr>
<tr>
<td>JELIS</td>
<td>Hypercholesterolemic Men and women with high cholesterol (69%) who are currently taking statins both with and without EPA</td>
<td>18,645</td>
<td>1,800 mg EPA</td>
<td>19% reduction in major cardiovascular events</td>
<td>Yokoyama et al., (2007) [73]</td>
</tr>
</tbody>
</table>
## Conclusion

The current review intended to highlight the different types of oil seeds which are a rich source of polysaturated fatty acids. Unsaturated fatty acids that have numerous double bonds in their chemical structure are known as polysaturated fatty acids (PUFAs). Omega-3 fatty acids are crucial for heart health, inflammation reduction, and cognitive function, while omega-6 fatty acids play a role in regulating metabolism and supporting skin health. Foods high in PUFAs include fatty fish, such as salmon, as well as plant-based oils like flaxseed and soybean oil. However, it is important to include fatty fish, such as salmon, as well as plant-based oils like flaxseed and soybean oil. It is important to maintain a balanced intake of both omega-3 and omega-6 fatty acids to support overall health. When compared to grape seed oil, camelina seed oil the content of linolenic acid is high in chia oil. Some of the health benefits of PUFAs include reducing inflammation, lowering the risk of heart disease, obesity, improving brain health, and boosting the immune system. PUFAs also play a role in reducing symptoms of depression and anxiety, maintaining healthy skin and hair, and reducing the risk of certain cancers.

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