The Pharma Innovation Journal 2023; 12(5): 2667-2676

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(5): 2667-2676

www.thepharmajournal.com
Received: 23-03-2023
Accepted: 27-04-2023

Sreya Prakash
Department of Food Technology and Nutrition, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Dr. Shweta Sharma
Assistant Professor, Department of Food Technology and Nutrition, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Corresponding Author:
Dr. Shweta Sharma
Department of Food Technology and Nutrition, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

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

Sreya Prakash and Dr. Shweta Sharma

DOI: https://doi.org/10.22271/tpi.2023.v12.i5af.20250

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, fluidised 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) [64]. 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].

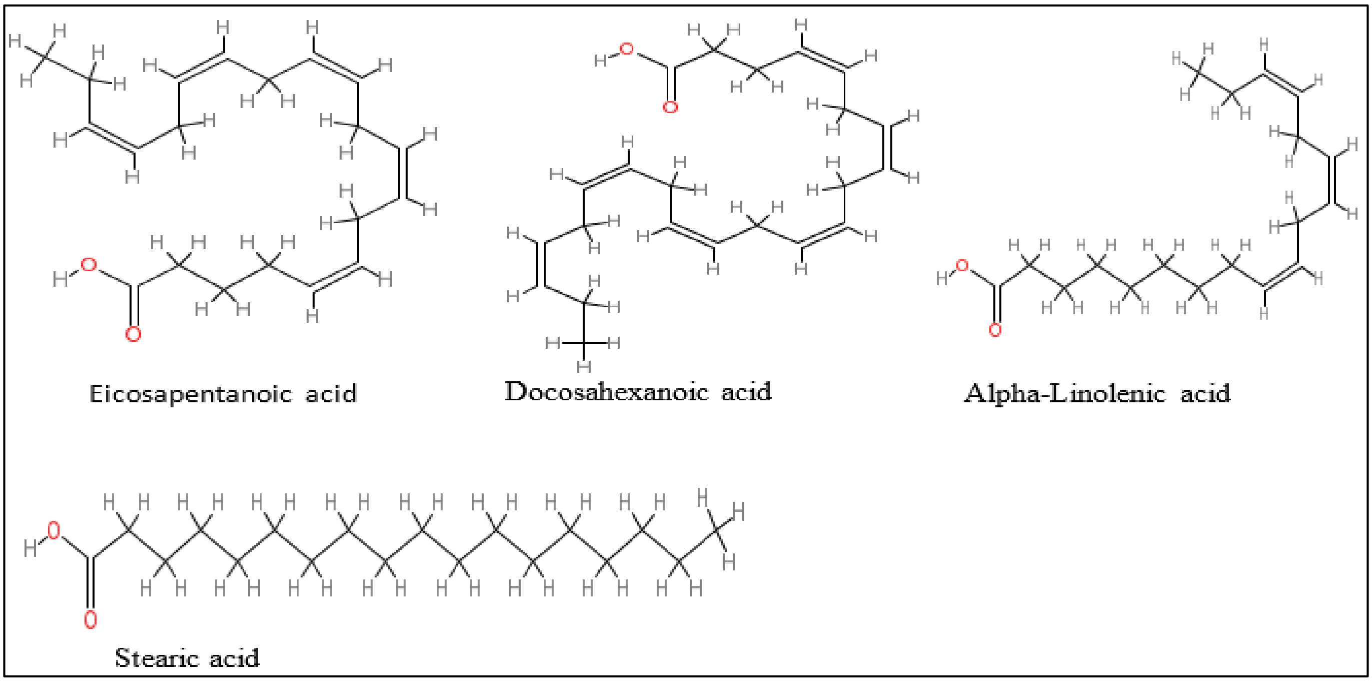

Fig 1: Structural representation of omega-3 PUFAs

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, archidonic 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) [75]. 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].

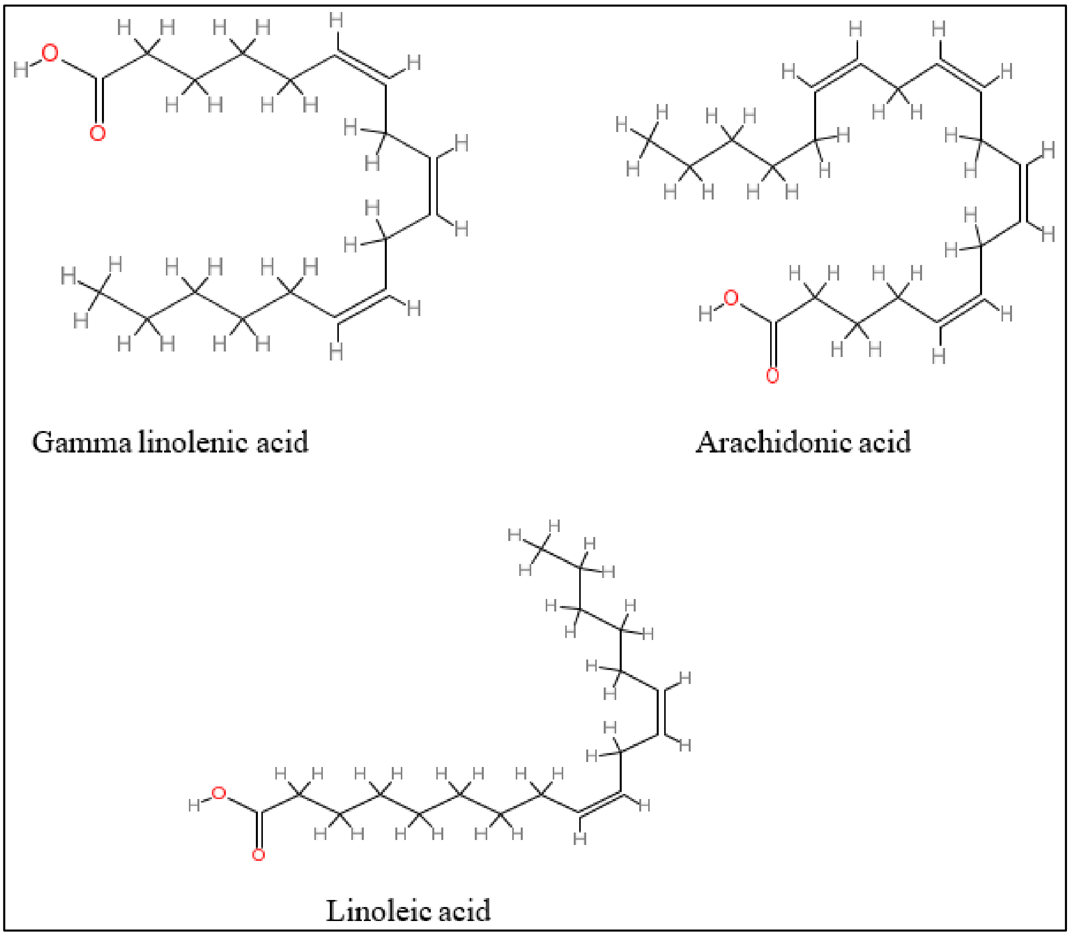

Fig 2: Structural representation of omega-6 PUFAs

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) [61]. 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).

Table 1: Fatty acid composition of oil seeds

Oil	Oil content	Linolenic	Linoleic	Oleic	Stearic	Palmitic	Reference
Chia oil	32.3-38.6	60.7-65.0	19.8-20.8	7.3-8.2	3.1-3.7	6.3-7.1	(Ixtaina *et al.*, 2011) [35]
Grape seed oil	10.45-16.73	0.16-0.35	66.0-75.3	19.19-23.29	3.14-4.96	8.52-10.01	Tangolar *et al.*, (2009) [65]
Pumpkin seed oil	10.9-30.9	0.14-0.30	42.73-55.33	29.20-6.44	4.15-5.67	9.39-12.48	Nederal *et al.*, (2014) [51]
Camelina seed oil	28.1-48.0	27.1-38.9	13.5-19.0	14.0-17.40	1.4-2.7	5.3-6.43	Abramovic and Abram, (2005) [1]
Pomegranate seed oil	17.59-24.69	0.16-9.94	31.49-38.61	24.76-31.26	8.10-10.42	18.16-22.63	Melgarejo *et al.*, (1995) [79]
Flaxseed oil	35.05-41.30	39.90-52.37	12.25-14.19	17.97-21.26	4.59-5.50	4.72-6.69	Gutte *et al.*, (2015) [31]; Guimarães *et al.*, (2013)
Mustard oil	40.65-49.00	0.41-11.30	25.31-41.92	38.21-40.72	2.78-5.76	4.51-9.58	Dorni *et al.*, (2018); Chowdhury *et al.*, (1970)

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) [35]. 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) [53]. 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) [12] 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 (Matthäus, 2008) [48]. 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) [39].

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, protiens, polyunsaturated fatty acids like omega-3, 6, and 9, lutein, carotenes, vitamins such carotenoids, chlorophyll, tocopherols, trace minerals and phytosterols (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 lipidosis, 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), is that it 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

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

Health benefits of PUFAs

Polyunsaturated fatty acids (PUFAs) are known to play a vital role in maintain 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 beacaue both cannot be produced inside the body and required to be consume 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].

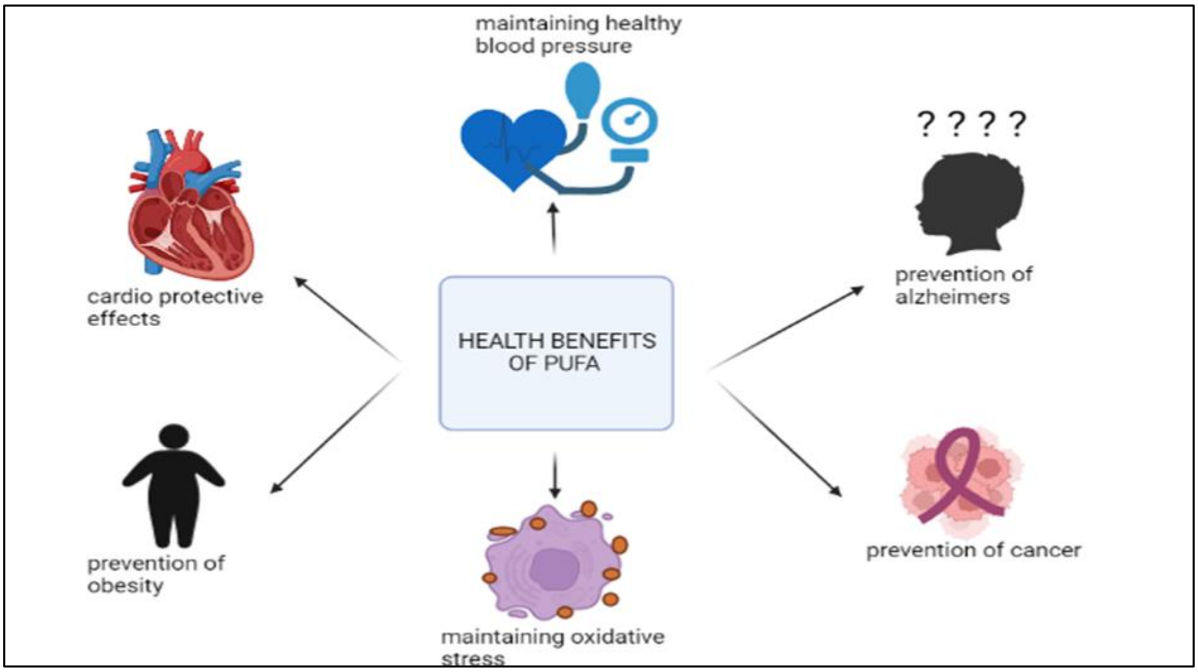

Fig 3: Health benefits of polyunsaturated fatty acids

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 verweight (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.

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 archidonic acid and n-3 LCPUFA to 33 weeks gestation resulted in decreased body fat formation in new-borns (Wargo *et al.*, 2005) [29]. 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 studied 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 3: Clinical trials on obesity

RCT type	Age/ type of pathology	No of Participants	PUFA dose	Outcomes	Reference
parallel double-blind intervention to age adjusted for gestation of 12 months	Pre-term infants, age < 33 weeks	60	n-3 LCPUFA and arachidonic acid	decreased body fat formation in newborns developing,	Wargo *et al.*, (2005) [29]
Randomized, double-blind, parallel research lasting 31 weeks	Pregnant women	93	n-3 LCPUFA intake of 200 mg DHA	reduced body mass index and weight in offspring	Bergman *et al.*, (2007) [8]
4-month double-blind, randomised parallel study	low fish intake mothers fron Danish	122	0.79 g DHA + 0.62 g EPA	There was no change in the offspring's length, weight, or head circumference increases.	Lauritzen *et al.*, (2005) [43]
2-month parallel, double-blind intervention	Postmenopausal women with type 2 diabetes	26	0.72g DHA, 1.08 g EPA	Neither weight loss nor fat mass decrease differs.	Kabir *et al.*, (2007) [8]
10-week dietary intervention with open-label parallel double-blind 2 to 5-week	Athlete's exercising (non-competitive) at least 3 h/ week	33	0.8 g DHA, 1.6 g EPA	Greater decrease in % body fat	Fontani *et al.*, (2005) [25]
Double-blind, randomised, controlled, parallel research lasting 3 months	Obese adults	65	0.36 g EPA, 1.6 g DHA	Fish oil and exercise have separate effects on body fat mass reduction.	Hill *et al.*, (2007) [33]
Double-blind, randomised, controlled, parallel research lasting 24 week	Overweight or obese hyperinsulinemic women	93	2.9 g DHA, 1.3 g EPA	No difference in weight loss	Krebs *et al.*, (2006) [40]

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) [59]. 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 4: Clinical trials on cardiovascular disease

Trials	Patient characteristics	No of Participants	Pufa dose	Outcomes	Reference
DART	Men after the occurrence of myocardial infarction	2033	350 mg EPA	29% reduction in total mortality rates	Burr *et al.*, (1989) [13]
RCT	Healthy subjects	310	EPA = 900 g/d EPA = 1800 mg/d	BP decreased after 1800 mg/d of EPA	Alsaleh *et al.* (2014) [2]
JELIS	Hypercholesterolemic Men and women with high cholesterol (69%) who are currently taking statins both with and	18,645	1,800 mg of EPA	19% reduction in major cardiovascular events	Yokoyama *et al.*, (2007) [73]

	without coronary heart disease				
RCT	Healthy subjects	40	EPA of1500 mg/d, DHA of 1050 mg/d	Decrease of CVD risk factors and BP.	Nilsson *et al.* (2012) [52]
Randomised trials of interventions	cardiovascular health in those who are at high risk for CVD	110	EPA of 2720 mg/d + DHA of 440 mg/d	An improvement in the lipid profile and omega-3 index	Shaikh *et al.* (2014)

Conclusion

The current review intended to highlight the different types of oil seeds which are a rich source of polyunsaturated fatty acids. Unsaturated fatty acids that have numerous double bonds in their chemical structure are known as polyunsaturated 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 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.

Reference

1. Abramovič H, Abram V. Physico-chemical properties, composition and oxidative stability of camelina sativa oil. Food Technology and Biotechnology. 2005;43(1):63-70.
2. AlSaleh A, Maniou Z, Lewis FJ, Hall WL, Sanders TAB, O'Dell SD. Interaction between a CSK gene variant and fish oil intake influences blood pressure in healthy adults. Journal of Nutrition. 2014;144(3):267-272. https://doi.org/10.3945/jn.113.185108
3. Ayerza HR. Oil content and fatty acid composition of chia (*Salvia hispanica* L.) from five northwestern locations in Argentina. Journal of the American Oil Chemists' Society. 1995;72(9):1079-1081. https://doi.org/10.1007/BF02660727
4. Ayerza HR, Coates W. Protein content, oil content and fatty acid profiles as potential criteria to determine the origin of commercially grown chia (*Salvia hispanica* L.). Industrial Crops and Products. 2011;34(2):1366 -1371. https://doi.org/10.1016/j.indcrop.2010.12.007
5. Badr SEA, Shaaban M, Elkholy YM, Helal MH, Hamza AS, Masoud MS, El Safty MM. Chemical composition and biological activity of ripe pumpkin fruits (*Cucurbita pepo* L.) cultivated in Egyptian habitats. Natural Product Research. 2011;25(16):1524-1539. https://doi.org/10.1080/14786410903312991
6. Bazinet RP, Layé S. Polyunsaturated fatty acids and their metabolites in brain function and disease. Nature Reviews Neuroscience. 2014;15(12):771-785. https://doi.org/10.1038/nrn3820
7. Belayneh HD, Wehling RL, Cahoon E, Ciftci ON. Extraction of omega-3-rich oil from *Camelina sativa* seed using supercritical carbon dioxide. Journal of Supercritical Fluids. 2015;104:153-159. https://doi.org/10.1016/j.supflu.2015.06.002
8. Bergman RN, Kim SP, Hsu IR, Catalano KJ, Chiu JD. Kabir M, *et al*. Abdominal Obesity: Role in the Pathophysiology of Metabolic Disease and Cardiovascular Risk. American Journal of Medicine, 120(2 SUPPL); c2007. p. 3-8. https://doi.org/10.1016/j.amjmed.2006.11.012
9. Bernacchia R, Preti R, Vinci G. Chemical Composition and Health Benefits of Flaxseed. Austin Journal of Nutrition and Food Sciences. 2014;2(8):1-9.
10. Berti M, Gesch R, Eynck C, Anderson J, Cermak S. Camelina uses, genetics, genomics, production, and management. Industrial Crops and Products. 2016;94: 690-710. https://doi.org/10.1016/j.indcrop.2016.09.034
11. Bloomer RJ, Larson DE, Fisher-Wellman KH, Galpin AJ, Schilling BK. Effect of eicosapentaenoic and docosahexaenoic acid on resting and exercise-induced inflammatory and oxidative stress biomarkers: A randomized, placebo controlled, cross-over study. Lipids in Health and Disease. 2009;8:1-12. https://doi.org/10.1186/1476-511X-8-36
12. Brenna JT, Salem N, Sinclair AJ, Cunnane SC. α-Linolenic acid supplementation and conversion to n-3 long-chain polyunsaturated fatty acids in humans. Prostaglandins Leukotrienes and Essential Fatty Acids. 2009;80(2-3):85-91. https://doi.org/10.1016/j.plefa.2009.01.004
13. Burr ML, Gilbert JF, Holliday RM, Elwood PC, Fehily AM, Rogers S, *et al.* Effects of Changes in Fat, Fish, and Fibre Intakes on Death and Myocardial Reinfarction: Diet and Reinfarction Trial (Dart). The Lancet. 1989;334(8666):757-761. https://doi.org/10.1016/S0140-6736(89)90828-3
14. Calder PC. Omega-3 fatty acids and inflammatory processes: From molecules to man. Biochemical Society Transactions. 2017;45(5):1105-1115. https://doi.org/10.1042/BST20160474
15. Calder PC, Yaqoob P. Omega-3 polyunsaturated fatty acids and human health outcomes. Bio Factors. 2009;35(3):266-272. https://doi.org/10.1002/biof.42
16. Carmo CS, Serra AT, Duarte CMM. Engineering Foods for Bioactives Stability and Delivery; c2017. https://doi.org/10.1007/978-1-4939-6595-3
17. Chowdhury K, Banu L, Khan S, Latif A.. Studies on the Fatty Acid Composition of Edible Oil. Bangladesh Journal of Scientific and Industrial Research. 1970;42(3):311-316. https://doi.org/10.3329/bjsir.v42i3.669
18. Cole GM, Ma QL, Frautschy SA. Omega-3 fatty acids and dementia. Prostaglandins Leukotrienes and Essential Fatty Acids. 2009;81(2-3):213-221. https://doi.org/10.1016/j.plefa.2009.05.015
19. Crews C, Hough P, Godward J, Brereton P, Lees M, Guiet S, *et al*. Study of the main constituents of some authentic walnut oils. Journal of Agricultural and Food Chemistry. 2005;53(12):4853-4860. https://doi.org/10.1021/jf0478354
20. Djoussé L, Gaziano JM, Buring JE, Lee IM. Dietary omega-3 fatty acids and fish consumption and risk of type 2 diabetes. American Journal of Clinical Nutrition.

2011;93(1):143-150. https://doi.org/10.3945/ajcn.110.005603
21. Dobrzyńska M, Przysławski J. The effect of camelina oil (α-linolenic acid) and canola oil (oleic acid) on lipid profile, blood pressure, and anthropometric parameters in postmenopausal women. Archives of Medical Science, LDL; c2020. https://doi.org/10.5114/aoms.2020.94033
22. Dorni C, Sharma P, Saikia G, Longvah T. Fatty acid profile of edible oils and fats consumed in India. Food Chemistry. 2018 May 238:9-15. https://doi.org/10.1016/j.foodchem.2017.05.072
23. El-Sayed, E., & Ibrahim K. Effect of the types of dietary fats and non-dietary oils on bone metabolism. Critical Reviews in Food Science and Nutrition. 2017;57(4):653-658. https://doi.org/10.1080/10408398.2014.914889
24. Fasina OO, Hallman H, Craig-Schmidt, M., & Clements, C. Predicting temperature-dependence viscosity of vegetable oils from fatty acid composition. JAOCS, Journal of the American Oil Chemists' Society. 2006;83(10):899-903. https://doi.org/10.1007/s11746-006-5044-8
25. Fontani G, Corradeschi F, Felici A, Alfatti F, Bugarini R, Fiaschi AI, *et al.* Blood profiles, body fat and mood state in healthy subjects on different diets supplemented with Omega-3 polyunsaturated fatty acids. European Journal of Clinical Investigation. 2005;35(8):499-507. https://doi.org/10.1111/j.1365-2362.2005.01540.x
26. Nava-Arzaluz G, Pinon-Segundo M, Ganem-Rondero EA, Lechuga-Ballesteros D. Single Emulsion-Solvent Evaporation Technique and Modifications for the Preparation of Pharmaceutical Polymeric Nanoparticles. Recent Patents on Drug Delivery & Formulation. 2012;6(3):209-223. https://doi.org/10.2174/187221112802652633
27. Garavaglia J, Markoski MM, Oliveira A, Marcadenti A. Grape seed oil compounds: Biological and chemical actions for health. Nutrition and Metabolic Insights. 2016;9:59-64. https://doi.org/10.4137/NMI.S32910
28. Gossell-Williams M, Davis A, O'Connor N. Inhibition of Testosterone-Induced Hyperplasia of the Prostate of Sprague-Dawley. J Med Food. 2006;9(2):284-286.
29. Groh-Wargo S, Jacobs J, Auestad N, O'Connor DL, Moore JJ, Lerner E. Body composition in preterm infants who are fed long-chain polyunsaturated fatty acids: A prospective, randomized, controlled trial. Pediatric Research. 2005;57(5 I):712-718. https://doi.org/10.1203/01.PDR.0000156509.29310.55
30. Guimarães R, De CA, Macedo MLR, Munhoz CL, Filiu W, Viana LH, *et al*. Sesame and flaxseed oil: Nutritional quality and effects on serum lipids and glucose in rats. Food Science and Technology. 2013;33(1):209-217. https://doi.org/10.1590/S0101-20612013005000029
31. Gutte KB, Sahoo AK, Ranveer RC. Effect of ultrasonic treatment on extraction and fatty acid profile of flaxseed oil. OCL-Oilseeds and Fats. 2015;22:6. https://doi.org/10.1051/ocl/2015038
32. Health Effects of Overweight and Obesity in 195 Countries over 25 Years. New England Journal of Medicine. 2017;377(1):13-27. https://doi.org/10.1056/nejmoa1614362
33. Hill AM, Buckley JD, Murphy KJ, Howe PRC. Combining fish-oil supplements with regular aerobic exercise improves body composition and cardiovascular disease risk factors. American Journal of Clinical Nutrition. 2007;85(5):1267-1274. https://doi.org/10.1093/ajcn/85.5.1267
34. Hong H, Kim CS, Maeng S. Effects of pumpkin seed oil and saw palmetto oil in Korean men with symptomatic benign prostatic hyperplasia. Nutrition Research and Practice. 2009;3(4):323. https://doi.org/10.4162/nrp.2009.3.4.323
35. Ixtaina VY, Martínez ML, Spotorno V, Mateo CM, Maestri DM, Diehl BWK, *et al.* Characterization of chia seed oils obtained by pressing and solvent extraction. Journal of Food Composition and Analysis. 2011;24(2):166-174. https://doi.org/10.1016/j.jfca.2010.08.006
36. Jurić S, Jurić M, Siddique MAB, Fathi M. Vegetable Oils Rich in Polyunsaturated Fatty Acids: Nanoencapsulation Methods and Stability Enhancement. Food Reviews International. 2022;38(1):32-69. https://doi.org/10.1080/87559129.2020.1717524
37. Jyothi Sri S, Seethadevi A, Suria Prabha K, Muthuprasanna P, Pavitra P. Microencapsulation: A review. International Journal of Pharma and Bio Sciences. 2012;3(1):P509-P531. https://doi.org/10.56726/irjmets26546
38. Kabir M, Skurnik G, Naour N, Pechtner V, Meugnier E, Rome S, *et al.* Treatment for 2 mo with n-3 polyunsaturated fatty acids reduces adiposity and some atherogenic factors but does not improve insulin sensitivity in women with type 2 diabetes: A randomized controlled study. American Journal of Clinical Nutrition. 2007;86(6):1670-1679. https://doi.org/10.1093/ajcn/86.6.1670
39. Khanna S, Roy S, Ryu H, Bahadduri P, Swaan PW, Ratan RR, *et al.* Molecular Basis of Vitamin E Action. Journal of Biological Chemistry. 2003;278(44):43508-43515. https://doi.org/10.1074/jbc.m307075200
40. Krebs JD, Browning LM, McLean NK, Rothwell JL, Mishra GD, Moore CS, *et al.* Additive benefits of long-chain n-3 polyunsaturated fatty acids and weight-loss in the management of cardiovascular disease risk in overweight hyperinsulinaemic women. International Journal of Obesity. 2006;30(10):1535-1544. https://doi.org/10.1038/sj.ijo.0803309
41. Lalia AZ, Dasari S, Robinson MM, Abid H, Morse DM, Klaus KA, Lanza IR. Aging-09-1096. 2017;94.
42. Lansky EP, Jiang W, Mo H, Bravo L, Froom P, Yu W, *et al.* Possible synergistic prostate cancer suppression by anatomically discrete pomegranate fractions. Investigational New Drugs. 2005;23(1):11-20. https://doi.org/10.1023/B:DRUG.0000047101.02178.07
43. Lauritzen L, Hoppe C, Straarup EM, Michaelsen KF. Maternal fish oil supplementation in lactation and growth during the first 2.5 years of life. Pediatric Research. 2005;58(2):235-242. https://doi.org/10.1203/01.PDR.0000169978.92437.58
44. Lee JM, Lee H, Kang SB, Park WJ. Fatty acid desaturases, polyunsaturated fatty acid regulation, and biotechnological advances. Nutrients. 2016;8(1):1-13. https://doi.org/10.3390/nu8010023
45. Li C, Jones PM, Persaud, SJ. Role of the endocannabinoid system in food intake, energy homeostasis and regulation of the endocrine pancreas. Pharmacology and Therapeutics. 2011;129(3):307-320.

https://doi.org/10.1016/j.pharmthera.2010.10.006
46. Liu B, Yan W. Quantitative polyunsaturated fatty acid analysis of chia seed oil by high-performance liquid chromatography. Journal of Chromatographic Science. 2021;59(2):120-127. https://doi.org/10.1093/chromsci/bmaa084
47. Loukhmas S, Kerak E, Elgadi S, Ettalibi F, El Antari A, Harrak H. Oil Content, Fatty Acid Composition, Physicochemical Properties, and Antioxidant Activity of Seed Oils of Ten Moroccan Pomegranate Cultivars. Journal of Food Quality; c2021. https://doi.org/10.1155/2021/6617863
48. Matthäus B. Virgin grape seed oil: Is it really a nutritional highlight? European Journal of Lipid Science and Technology. 2008;110(7):645-650. https://doi.org/10.1002/ejlt.200700276
49. Mocellin MC, Camargo C, De Q, Fabre ME, De S, Trindade EBS, De M. Fish oil effects on quality of life, body weight and free fat mass change in gastrointestinal cancer patients undergoing chemotherapy: A triple blind, randomized clinical trial. Journal of Functional Foods. 2017;31:113-122. https://doi.org/10.1016/j.jff.2017.01.041
50. Mozaffarian D, Benjamin EJ, Go AS, Arnett DK, Blaha MJ, Cushman M, *et al.* Heart disease and stroke statistics-2016 update a report from the American Heart Association. In Circulation. 2016;133:4. https://doi.org/10.1161/CIR.0000000000000350
51. Nederal S, Petrović M, Vincek D, Pukec D, Škevin D, Kraljić K, *et al*. Variance of quality parameters and fatty acid composition in pumpkin seed oil during three crop seasons. Industrial Crops and Products. 2014;60:15-21. https://doi.org/10.1016/j.indcrop.2014.05.044
52. Nilsson A, Radeborg K, Salo I, Björck I. Effects of supplementation with n-3 polyunsaturated fatty acids on cognitive performance and cardiometabolic risk markers in healthy 51 to 72 years old subjects: a randomized controlled cross-over study. Nutrition Journal. 2012;11:1-9. https://doi.org/10.1186/1475-2891-11-99
53. Olivos-Lugo BL, Valdivia-López MÁ, Tecante A. Thermal and physicochemical properties and nutritional value of the protein fraction of Mexican chia seed (*Salvia hispanica* L.). Food Science and Technology International. 2010;16(1):89-96. https://doi.org/10.1177/1082013209353087
54. Orsavova J, Misurcova L, Vavra Ambrozova J, Vicha R, Mlcek J. Fatty acids composition of vegetable oils and its contribution to dietary energy intake and dependence of cardiovascular mortality on dietary intake of fatty acids. International Journal of Molecular Sciences. 2015;16(6):12871-12890. https://doi.org/10.3390/ijms160612871
55. Prasad K. Flaxseed and cardiovascular health. Journal of Cardiovascular Pharmacology. 2009;54(5):369-377. https://doi.org/10.1097/FJC.0b013e3181af04e5
56. Prommaban A, Kuanchoom R, Seepuan N, Chaiyana W. Seed Oil from Aqueous Enzymatic Extraction; c2021.
57. Rangel-Huerta OD, Gil A. Omega 3 fatty acids in cardiovascular disease risk factors: An updated systematic review of randomised clinical trials. Clinical Nutrition. 2018;37(1):72-77. https://doi.org/10.1016/j.clnu.2017.05.015
58. Rodriguez-Leyva D, Bassett CMC, McCullough R, Pierce GN. The cardiovascular effects of flaxseed and its omega-3 fatty acid, alpha-linolenic acid. Canadian Journal of Cardiology. 2010;26(9):489-496. https://doi.org/10.1016/S0828-282X(10)70455-4
59. Ruxton CHS, Reed SC, Simpson MJA, Millington KJ. The health benefits of omega-3 polyunsaturated fatty acids: A review of the evidence. Journal of Human Nutrition and Dietetics. 2004;17(5):449-459. https://doi.org/10.1111/j.1365-277X.2004.00552.x
60. Saini RK, Keum YS. Omega-3 and omega-6 polyunsaturated fatty acids: Dietary sources, metabolism, and significance: A review. In Life Sciences. 2018;203:2017. Elsevier Inc. https://doi.org/10.1016/j.lfs.2018.04.049
61. Sanders TAB. Polyunsaturated fatty acids in the food chain in Europe. American Journal of Clinical Nutrition. 2000;71(1 Suppl.):176-178. https://doi.org/10.1093/ajcn/71.1.176s
62. Shaban A, Sahu, RP). Pumpkin Seed Oil: An Alternative Medicine. International Journal of Pharmacognosy and Phytochemical Research. 2017;9:2. https://doi.org/10.25258/phyto.v9i2.8066
63. Shahidi F, Ambigaipalan, P. The annual review of food science and technology: omega-3 polyunsaturated fatty acids and their health benefits. Annu. Rev. Food Sci. Technol. 2018 Jan;9:16-17.
64. Takezaki T, Inoue M, Kataoka H, Ikeda S, Yoshida M, Ohashi Y, *et al.* Diet and lung cancer risk from a 14-year population-based prospective study in Japan: With special reference to fish consumption. Nutrition and Cancer. 2003;45(2):160-167. https://doi.org/10.1207/S15327914NC4502_04
65. Tangolar SG, Özoğul Y, Tangolar S, Torun A. Evaluation of fatty acid profiles and mineral content of grape seed oil of some grape genotypes. International Journal of Food Sciences and Nutrition. 2009;60(1):32-39. https://doi.org/10.1080/09637480701581551
66. Tortosa-Caparrós E, Navas-Carrillo D, Marín F, Orenes-Piñero E. Anti-inflammatory effects of omega 3 and omega 6 polyunsaturated fatty acids in cardiovascular disease and metabolic syndrome. Critical Reviews in Food Science and Nutrition. 2017;57(16):3421-3429. https://doi.org/10.1080/10408398.2015.1126549
67. Tripathi R, Agrawal SB. Interactive effect of supplemental ultraviolet B and elevated ozone on seed yield and oil quality of two cultivars of linseed (*Linum usitatissimum* L.) carried out in open top chambers. Journal of the Science of Food and Agriculture. 2013;93(5):1016-1025. https://doi.org/10.1002/jsfa.5838
68. Vollmann J, Steinkellner S, Glauninger J. Variation in resistance of Camelina (*Camelina sativa* [L.] Crtz.) to downy mildew (*Peronospora camelinae* Gäum.). Journal of Phytopathology. 2001;149(3-4):129-133. https://doi.org/10.1046/j.1439-0434.2001.00599.x
69. Vuksan V, Whitham D, Sievenpiper JL, Jenkins AL, Rogovik AL, Bazinet RP, *et al.* Supplementation of Conventional Therapy With the Novel Grain Salba (*Salvia hispanica* L.) Improves Major and Emerging Cardiovascular Risk Factors in Type 2 Diabetes. Diabetes Care. 2007;30(11):2804 LP-2810. https://doi.org/10.2337/dc07-1144.Clinical
70. Wang Z, Bin, Xin SS, Ding LN, Ding WY, Hou YL, *et al.* The Potential Role of Probiotics in Controlling

Overweight/Obesity and Associated Metabolic Parameters in Adults: A Systematic Review and Meta-Analysis. Evidence-Based Complementary and Alternative Medicine; c2019. https://doi.org/10.1155/2019/3862971

71. Yamasaki M, Kitagawa T, Koyanagi N, Chujo H, Maeda H, Kohno-Murase J, *et al.* Dietary effect of pomegranate seed oil on immune function and lipid metabolism in mice. Nutrition. 2006;22(1):54-59. https://doi.org/10.1016/j.nut.2005.03.009
72. Yamashima T, Ota T, Mizukoshi E, Nakamura H, Yamamoto Y, Kikuchi M, *et al.* Intake of ω-6 Polyunsaturated Fatty Acid-Rich Vegetable Oils and Risk of Lifestyle Diseases. Advances in Nutrition. 2020;11(6):1489-1509. https://doi.org/10.1093/advances/nmaa072
73. Yokoyama M, Origasa H, Matsuzaki M, Matsuzawa Y, Saito Y, Ishikawa Y, *et al.* Effects of eicosapentaenoic acid on major coronary events in hypercholesterolemia patients (JELIS): A randomised open-label, blinded endpoint analysis. Lancet. 2007;369(9567):1090-1098. https://doi.org/10.1016/S0140-6736(07)60527-3
74. Zhang X, Kundoor V, Khalifa S, Zeman D, Fahmy H, Dwivedi C. Chemopreventive effects of sarcophine-diol on skin tumor development in CD-1 mice. Cancer Letters. 2007;253(1):53-59. https://doi.org/10.1016/j.canlet.2007.01.009
75. Zheng JS, Hu XJ, Zhao YM, Yang J, Li D. Intake of fish and marine n-3 polyunsaturated fatty acids and risk of breast cancer: Meta-analysis of data from 21 independent prospective cohort studies. BMJ (Online). 2013;347(7917):1-10. https://doi.org/10.1136/bmj.f3706
76. Afshin A, Sur PJ, Fay KA, Cornaby L, Ferrara G, Salama JS, *et al*. Health effects of dietary risks in 195 countries, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. The Lancet. 2019;393:1958-72.
77. Tortosa-Caparrós E, Navas-Carrillo D, Marín F, Orenes-Piñero E. Anti-inflammatory effects of omega 3 and omega 6 polyunsaturated fatty acids in cardiovascular disease and metabolic syndrome. Critical Reviews in Food Science and Nutrition. 2016;57:3421-3429.
78. MacLean CH, Mojica WA, Morton SC, Pencharz J, Garland RH, *et al.* Effects of omega-3 fatty acids on lipids and glycemic control in type II diabetes and the metabolic syndrome and on inflammatory bowel disease, rheumatoid arthritis, renal disease, systemic lupus erythematosus, and osteoporosis: summary. Evid. Rep. Technol. Assess. (Summ.). 2004;89:1-4
79. Melgarejo P, Salazar DM, Amorós A, Artés F. Total lipids content and fatty acid composition of seed oils from six pomegranate cultivars. Journal of the Science of Food and Agriculture. 1995;69(2):253-256. https://doi.org/10.1002/jsfa.2740690216
80. Hora JJ, Maydew ER, Lansky EP, Dwivedi C. Chemopreventive effects of pomegranate seed oil on skin tumor development in CD1 mice. Journal of medicinal food. 2003;6:157-161.
81. Shaikh NA, Yantha J, Shaikh S, Rowe W, Laidlaw M, Cockerline C, *et al*. Efficacy of a unique omega-3 formulation on the correction of nutritional deficiency and its effects on cardiovascular disease risk factors in a randomized controlled VASCAZEN®REVEAL Trial. Molecular and Cellular Biochemistry. 2014;396(1-2):9-22. https://doi.org/10.1007/s11010-014-2132-1