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# Blended Microalgae and Vegetable Oil: Composition, Nutritional and Health Consequences

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**Abstract**

Vegetable oils have a crucial role in the human diet, which increases palatability and enhances the calorie load of the dish. Most conventional vegetable oils have broader applications in food processing, but growing health concerns suggest their vast demand and usefulness in terms of the optimum balance of fatty acids. It was also shown that most vegetable oils contain polyunsaturated fatty acid, an omega-3 fatty acid in Alpha-Linolenic Acid (ALA). Still, algae are only the vegetative source containing Eicosapentaenoic Acid (EPA) & Docosahexaenoic Acid (DHA) fatty acids. The quality of blended oil depends on its fatty acid ratio, physical properties, chemical properties, oxidative stability, carotenoids, tocopherol, and polyphenolic compounds. In the recent past blending, oils gain massive popularity due to their various benefits. Replacing the fat/lipid with blended oils as a cooking medium can be considered the best step for well-being and fitness.

**Keywords:** Alpha-Linolenic Acid, Blended Vegetable oils, Docosahexaenoic Acid, Microalgae

## 1. Introduction

Vegetable oils vary significantly in their fatty acid composition. The difference lies primarily in their MUFAs and PUFAs ω-3 & ω-6 ratios, which exhibit wholesome food. The use of these oils helps in reducing LDL cholesterol and promotes HDL cholesterol (Saboo et al., 2019).

There has been a challenge that more PUFAs ω-3 & ω-6 mixture in the fatty acid composition is susceptible to rancidity and ultimately decreases shelf life due to reduction in oxidative stability under a change in environmental conditions. Most of the drying techniques can be employed to increase the stability of PUFA rich oils. Techniques like spray drying, spray granulation, freeze-drying, MW drying. However, each technique has its limitations in that spray drying of oils is exposed at a higher temperature which can trigger the reaction of the oxidation process. Another technique, spray granulation, requires more time than the spray drying process but produces more capsulations to protect the core of powdered oil. Whereas, freeze-drying due to having a highly porous structure increases the rate of diffusion of oxygen which in turn decreases the stability of powdered oil (I Re, 1998; Anwar & Kunz, 2011; Quispe-Condori et al., 2011; Carneiro et al., 2013; Pattnaik & Mishra, 2020). A novel process technique was developed by encapsulation through evaporation and microwave drying to improve the oxidative stability and shelf life rather than non-encapsulated blended oils. By converting into oil powder by encapsulation using microwave drying reduces the drying time and positively impacts the powdered oil flowing properties; solubility also increases significantly. Encapsulated oils were mainly used in the bakery and ice-cream industries (Pattnaik & Mishra, 2020). Another such technique is an ultrasonic emulsion of mono/double-layer followed by spray drying to improve the stability against oxidation. Emulsions like Whey Protein Concentrate (WPC) with modified starch show the highest encapsulation efficiency (Vélez-Erazo et al., 2021). Studies to be done on non-encapsulated blended oils where the balance in fatty acid composition need to increase the stability, functional and physicochemical properties for the oils used as a cooking medium for most Indian foods.

## 2. Materials and Methods

The present study was carried out based on the literature review microalgae oil is the only source of Docosahexaenoic Acid (DHA) among all vegetable oils where most of the oils it is present in form of Linolenic Acid (LA) & Alpha Linolenic Acid (ALA). The metabolic conversion of this LA & ALA i.e., long chain fatty acids (n-6 & n-3) into DHA conversion is restricted. Hence, blending of these oils will help to maintain the balanced fatty acid profile as per suggestions by WHO. The data presented in this work was collected using scientific data taken from google scholar, various articles, reputed books, and various websites.

## 3. Results and Discussion

### 3.1 Alpha-Linolenic Acid (ALA) Vs. Long-Chain Fatty Acids and their sources

Among the PUFAs, Alpha-Linolenic Acid (ALA) 18:3n-3 is essential in the human diet. It has a wide range of functions that act as a substrate to synthesise longer-chain, more conversion to EPA, and limited conversion to DHA (Burdge, 2006).

A list of some foods high in Alpha-Linolenic Acids (ALAs) is disported in Table 1. Food rich in ALA is green leaves, avocados, hemp seeds, chia seeds, navy beans, whole wheat bread, oatmeal, edamame, and oils used as a cooking medium like soyabean oil, flaxseed oil, rapeseed oil, canola oil and Corn Oil. Conversion of LA/ALAs synthesis to longer chain fatty acids (EPA, DPA and DHA) depends on various factors like age, gender, physiological nature (pregnancy), which DHA appears to be limited compared with EPA and DPA (Burdge & Calder, 2005).

### 3.2 Conversion of N-3 and N-6 PUFA into Long-Chain Fatty Acids

Predominately most of the vegetable oils (Flaxseed, Rapeseed, Soy, Safflower) contains n-3/n-6 long-chain Poly Unsaturated Fatty Acids (PUFA), which corresponds to its parent compounds like α-Linolenic Acid (ALA)-18:3n-3 and Linolenic Acid (LA)- 18:2n-6. Human organisms have an inadequate energy source and a precursor of metabolites for long chains (Knapp, 1992). This ALA and LA conversion to Eicosapentaenoic Acid (EPA) – 20:5n-3 is adequate, but its modification to Docosahexaenoic acid (DHA)- 22:6n-3 is very much restricted. Our modern diet's dietary consumption of n-6 PUFA is more when compared to n-3 PUFA (Gerster, 1998). Metabolism of ALA and LA conversion into long-chain PUFA, as shown in Figure 1, uses common enzymes; thus, both the families of fatty acids (n-3 and n-6) compete for desaturation chain elongation. However, ALA (n-3) has a slight advantage over LA (n-6) due to the enzyme desaturase preference for ALA over LA. ALA is generally at a competitive disadvantage because of the high dietary intake of LA (Kompauer et al., 2008).

### 3.3 Bioavailability of EPA and DHA Status

Most studies have concluded that plant food diets, especially vegetable oils provide only ALA and LA but scarcely of conversion to EPA and, most notably, to DHA. Further high amounts of ALA and LA incorporated in the diets that cannot achieve long-chain metabolites of the desired compounds comparable to those of EPA and DHA direct intakes. Table 2 shows the biological effects of increased EPA and DHA in long-chain fatty acids with the input of ALA-rich vegetable oils or marine/fish oils.

Long-chain fatty acids, especially omega-3 fatty acids, are more prone to oxidation (Ottestad et al., 2016). The best way to contend the omega fatty acids was to microencapsulation spray drying using whey protein isolate and gum arabica as complex coacervates (Eratte et al., 2014). To promote stable PUFAs, the most convenient and least expensive method is ionic gelation of Salvia Hispanic chia seed oil encapsulation using sodium alginate to promote health benefits (Us-Medina et al., 2017). Another significant recent development to increase the bioavailability of lipids is to make nano-sizing of EPA and DHA-rich fish oil enables to deliver for oral therapies depends on the droplet size for paracellular absorption (Dey et al., 2019).

### 3.4 EPA and DHA Rich Microalgae Oil (Vegetative Source) An Alternative Source to Fish Oil

Demand for algal oil consumption is increasing because fish oil production is insufficient to scatter the needs of EPA and DHA and their use in the marine industry. It is a known fact that fishes rely on marine microalgae for their feed, and thus, it is the primary source for EPA and DHA in fish oils (Winwood, 2015). An exception to microalgae, the only concern with consumption from vegetative sources is that alpha-linolenic acid conversion to EPA and DHA is restricted in humans and varies from male to female. Most species like Schizochytrium in algal oil production are used for various categories in foods like dairy products, Spreadable fats and dressings, Breakfast cereals, Food Supplements, bakery products, cereal bars, cooking fats and non-alcoholic beverages. The maximum DHA levels range from 80-600 mg/100g (Commission Information Decision, 2014). Some microalgae families like Chlorella, Dunaliella, Spirulina, and Phorphyridium find their way to get highly nutritious food supplements, carotenoids, and functional foods (Milledge, 2012). Different strains for algal oil production Botryococcusbraunii were used for high throughput using photobioreactor array (Kim et al., 2014). Genera Schizochytrium, Thraustochytrium, Scenedesmus dimorphus, Chlorella protothecoides, Pavlova lutheri uses algal oils as a source of EPA and DHA. Also, natural antioxidants (Tocopherol and Carotenoids) help prevent the biological oxidation of ω-3 fatty acids compared with fish oil and other vegetable oils (Armenta &Valentine, 2013). Gradually the availability of fisheries is being narrowed, which made a compulsion to get other sources that remove the burden on the fishing and get new sources of EPA and DHA. The purview of the researcher is to use algal oils in the food products to supplement the EPA and DHA-rich sources, and an additional advantage is that it is susceptible to oxidation.

**3.5 Need of Blended Oils**

The contribution of Fats and Oils plays a vital role in many of the food formulations, salad dressing, cooking, baking, and frying, where it acts as a heat transfer medium to develop flavour and texture. Most vegetable oils lack essential fatty acid profiles (n-3 and n-6) in their natural forms and cannot be synthesised by the human body. Essential fatty acids are needed to maintain cellular integrity and the smooth functioning of metabolic pathways. Therefore, these elemental forms need to be taken from the diet (Simopoulos, 2002). The blending of oils helps to improve and enhance nutritional value, fatty acid profiles, and oxidative stability (Chopra, 2018). The blending of oils nowadays has more commercial viability, thus helping to provide a balanced fatty acid profile, increasing nutritional and functional properties, and susceptibility against oxidation.

National Institute of Nutrition (NIN) suggests that "Fat/Lipid from various sources is better than a single kind." fatty acid profiles in oils vary in different proportions, including SFAs, MUFAs, and PUFAs: ω-3 and ω-6. As per (WHO, 2015) intake of total fat/lipid should not exceed 30 % of total calorie intake. As per the guidelines to prevent heart diseases, the upper limit for SFAs is 8-10 % of total calories, PUFAs: ω-3 and ω-6 to be 5-8 % of total calories MUFAs would contribute the difference. The desirable ratio SFA: MUFA: PUFA is about 1:1.5:1, ω-6: ω-3 is about 5-10:1, TPUFA/TSFA is 0.8-1 whereas for ω-6/ω-3 is 5-10 as per WHO recommended values.

Vegetable oils individually are not a perfect source for complete nutritional characteristics as well as for functional properties. Most vegetable oils lack the essential fatty acids n-6 and n-3, which are incredibly beneficial in cell integrity, regulating lipid metabolism, preventing cardiovascular diseases and carcinogenic diseases like cancer, etc., maintaining the ratios recommended by WHO are beneficial. Unstable ratios lead to obesity, diabetes, atherosclerosis, high blood pressure, and cancer (Simopoulos, 2016). Various blends of vegetable oils to maintain the balanced fatty acid profile apart from decreased cholesterol levels in blood and triacylglycerol as recommended ratios by WHO in which individual vegetable oils were lacking (Sharma & Lokesh, 2013). Table 3 and Table 4 represents fatty acid profiles for some of the commonly consumed individual and Blended vegetable oils and their comparison of the ratio of TSFA:TMUFA: TPUFA and ω-6: ω-3 with WHO specified values.

Table 4 shows various vegetable oils used for blending rather than individual oils to maintain stability in oxidation and improve the textural properties. Using individual vegetable oils may have low nutritional properties, diminish physical and chemical characteristics, and low oxidative stability if they contain many essential fatty acids. For understanding, some of the individual vegetable oils like Palm Oil, Mustard oil, Olive oil, Sesame oil, etc., have low levels of essential fatty acids (ω-6, ω-3). Soyabean Oil, Safflower Oil, etc., have moderate amounts of Alpha-Linolenic Acid but have low oxidation stability. Therefore, to have a balanced fatty acid profile, improve the chemical and physical characteristics, high stability against oxidation, enhance the functionality in human health, and have commercially viable for industrial point of view. The only way to take advantage is by using blended vegetable oils to benefit from each oil.

### 3.6 Effect of Blending on Various Physico-Chemical Properties of Oils

#### Impact of Blending on Physical Properties of Vegetable Oils

The blending of vegetable oils affects various physical properties like viscosity, density, colour, organoleptic characteristics, smoke point, cloud point, melting point. For example, Siddique et al., 2010 found that the viscosity of palm olein (79.70 cP at 23°C) is higher when compared with Soyabean oil, Sunflower oil, Canola oil, and its blends. These are due to change in triacylglycerol. The viscosity of oils decreases with the unsaturation of fatty acids and depends on the molecular structure, affecting deep-fat frying (Kim et al., 2010).

Lower values of density, viscosity and melting point are highly desirable to consumers and ultimately helps in the commercialisation of oils. High melting point (Palm olein) oils may be blended with other oils to decrease values substantially. It varies due to the different compositions and characteristics of triglycerides (Fasina et al., 2008). Odour in the oil changes during frying and is more evidence that shows notes of inherent traits. The blending of palm olein and mustard had dark red colour, harsh and intense odour notes. Odour profiles of blended vegetable oils were prominent even after several times of frying (Ravi et al., 2005).

Colour change has a significant impact on consumer acceptance and due to oxidation intensity of the oil colour gradually increases, which is an undesirable phenomenon. For some of the blends, it was found that colour Index (CI) values for the blends increase when compared with the individual values (Abdel-Razek et al., 2011). Therefore, for some of the blend oils, it will have a lighter note as it depends on the individual blends that among all the oils, palm olein has a higher CI (Tarmizi & Ismail, 2014), and therefore during frying, the phenols present in it tends to cause the darker colour when compared with other vegetable oils (Pantzaris, 1997), and this causes the degradation of compounds leading to the formation of hydroxides, hydroperoxides, ketones and conjugated dienoic acids (Koh et al., 2011;Farhoosh et al., 2009; Lalas et al. 2006). Various other reasons for colour change will also depend on the product type, i.e., browning pigments tend to change the oil's colour.

The smoke point of oils directly correlates with the Free Fatty Acid (FFA) content. At the same time, the presence of monoacylglycerols and other volatile compounds present will decrease the smoke point of oils (Matthaus, 2006). For fresh oils, the minimum smoke point should be greater than 215°C, and the continuously fried oils minimum of 180°C is desirable. Low molecular weight constituents present in oils also alters the smoke point values. Blended vegetable oils during continuous heating found that smoke point values were above the range of acceptable values (Tarmizi & Ismail, 2014) and shows that blended oils have a particular advantage over individual oils.

### 3.7 Effect of Blending on Chemical and Oxidative Stability Properties of Vegetable Oils

Vegetable oils tend to cause degradation of compounds by either oxidation, hydrolysis, and polymerisation during frying. The presence of oxygen leads to the formation of low molecular weight compounds, volatile and non-volatile compounds, which are undesirable to use as frying oil and, in turn, cause various cardiovascular diseases to humans and are highly carcinogenic (Alireza et al., 2010).

Compared with saturated fatty acids, unsaturated fatty acids are more prone to oxidation due to more double bonds that tend to oxidise rapidly in the presence of oxygen. Still, studies show that saturated fatty acids can cause severe health effects in humans. Still, this problem can only be solved by maintaining the balanced fatty acid profile by blending oils. In addition, higher levels of bioactive lipids and natural antioxidants help improve the nutrition and stability of oils (Aladedunye & Przybylski, 2013).

Trans fats are formed during the hydrogenation of oils to increase the saturation content of fatty acids to improve the shelf life, and this type of refining needs to be avoided (Dinc et al., 2014; Khatoon, 2000; Wirkowska-Wojdyla et al., 2016). Among the oils, palm olein and canola oils contain more excellent stability and good texture during frying, but they will have a considerable impact on the diet of humans (Al-Khusaibi et al., 2012). Some vegetable oil blends like olive oil should be used not exceeding 20% to concern stability. In contrast, the ratio can be adjusted for other oils depending upon oils' fatty acid profile (De Leonardis & Macciola, 2012). It is essential to know the property of oils before blending to attain stability, balanced fatty acid profile, nutrition, and increase oils' functional properties. However, some blends can be used to adulterate the superior oils like olive oil that can be detected using markers and the Solid Phase Extraction method (Azadmard-Damirchi, 2010).

Stability of blended oils such as palm oil with different oils like corn oil, sesame oil, and rice bran oil was evaluated for hydrolytic stability and oxidative stability during frying of potato for various interval frequencies found that palm oil with corn oil shows more excellent stability in terms of hydrolytic as well as oxidative stability (Azimah et al., 2017). Balancing the fatty acid profile by blending walnut oil-rich linoleic acid and almond oil is an excellent source of monounsaturated fatty acid and contains bioactive compounds. Blending such oils helps increase stability compared with individual oil (Pan et al., 2020). Especially oils rich in EPA and DHA, like fish oils/marine source oils, are more prone to oxidation. This type of oil blended with pumpkin oil has more antioxidants followed by encapsulation, decreasing the oxidation activity (Ogrodowska et al., 2020). Kinetic properties of the blended linseed oil represent high oxidation stability, Gibbs free energy index, but temperature-related parameters were reduced (Golmakani et al., 2020)

Ternary blends (rice bran oil, flaxseed oil and peanut oil) of vegetable oils were used to increase the stability of oils and to prevent the oxidation compared to the individual Rice Bran Oil; this is due to an increase in the antioxidant activity and exhibits endothermic oxidation process (Pattnaik & Mishra, 2021). In addition, a similar study was performed to increase the antioxidant activity and phytochemical using flaxseed oil blended, tomato seed oil with rice bran oil, enhancing the oxidative stability (Ghosh et al., 2019). Furthermore, other such ternary blends of vegetable oils optimise the omega-6 to the omega-3 ratio by olive, sunflower, and cress oils with higher oxidative stability and antioxidant activity (Nehdi et al., 2019).

The blending of oils helps get the natural form of antioxidants like tocopherol, a thermally labile compound, but when it reacts with lignin type of compound that is a much more stable compound, its degradation properties decrease. For example, sunflower oil contains many tocopherols and, when blended with sesame oil containing lignans, increases the stability (Ghosh et al., 2019).

Health consequences of various vegetable oil blends and their application in commercialisation for food industries

When taken in blended, the health benefits of oils will have more advantages than by individual oils alone (Reena & Lokesh, 2007). As per WHO guidelines for oil consumption, it is a known fact that none of the individual oils will suffice the day-to-day requirement for the individual. Therefore, we need to understand the various blends to overcome multiple diseases, enhance the nutritional content, and helps increase the functionality and metabolic pathway. When the unsaturation content of the fatty acid is high in oils, chances of lipid oxidation increase, and selection of oils need to be seen that antioxidant properties, bioactive lipids present will tend to decrease the rate of oxidation (Gulla & Waghray, 2011). Recent studies on the health benefits of blended vegetable oils have been given in Table 5.

Essential fatty acids like ω-6 and ω-3 are required in our diet to meet various metabolic functions in humans and prevent certain diseases like cancer, cardiovascular diseases (CVD's), and arthritis (Tortosa-Caparros et al., 2017). It is a well-known fact that in most vegetable oils, the essential fatty acids are present in the form α-Linolenic Acid (ALA). Still, the conversion of this depends on individual to long-chain fatty acids.

The food industry has slowly decreased saturated fats in most processed foods, but this change will impact a vast because solid fats play a vital role in foods' acceptability and increase the shelf-life (Vieira et al., 2015). Solid-fat content in the food materials is helpful to decide the texture of some plant foods such as chocolate, meat, and dairy products. More importantly, it imparts melt-away, creaminess, and lubrication. Mainly, margarine and spreads help in converting solid fat to liquid oil in the mouth. In the bakery industry, solid fats help enhance the incorporation of air into the products during processing to inhibit the gluten formation from getting flaky textures and producing fluffy textures like cookies. However, replacing saturated with unsaturated fats is also a problem due to its rapid oxidation, decreasing the shelf life of the food product.

It has been a long time since decreasing saturated fats: consumption trend or using different foods. Before using more saturated fats from plant sources in the 1950s, the use of animal fats such as tallow, butter, and lard abruptly increased. Later some nutritionists realised that consuming animal fats would lead to heart diseases due to high amounts of cholesterol. Because of this food industry drastically reduced the use of animal fat in many the processed foods. Animal fat can be replaced with vegetable oil sources like coconut oil, palm kernel oil, and palm olein. These are commonly named tropical oils, with solid fat content desirable for foods because of their high saturation. Later, some more studies have been conducted in the early 1980s on these tropical oils and found that these oils aids in getting cardiovascular disease (CVD), so that food industries shifted to partially hydrogenated vegetable oils. The use of partially hydrogenated vegetable oil has the slight advantage of being solidified at room temperature. Unsaturation can be removed by hydrogenation (Fennema, 2008). However, partial hydrogenation leads to trans fats in the food products, which is undesirable, and LDL cholesterol increases. Therefore, the inclusion of trans fats on the package has been mandated from 2006 onwards to reduce hydrogenated oils in foods. In 2013, FDA removed "generally recognised as safe" recognition for partially hydrogenated vegetable oils to further decrease the trans fats in foods (Kritchevsky, 1998).

Nutritional quality and thermal stability of blended palm oil with macadamia oil helps to increase the monounsaturated fatty acids as macadamia oil is a rich source and used for stable frying medium oil (Koohikamali and Alam et al., 2019).

From the past years (the 1950s, 1980s) to the present, there has been an alternate change from animal fats to tropical oils and partially hydrogenated vegetable oils. However, these partially hydrogenated vegetable oils still need a severe replacement due to trans fats in foods. The only alternative can be blending vegetable oils to get all the desirable properties of interest. Blending helps to enhance nutritional terms, and the food industries who want replacement with hydrogenated fats and blending of vegetable oils are the likely candidates to do so.

## 4. Conclusion

Most of the Indian food practices involve deep-fat frying at higher temperatures. The blending of oil improves frying quality by increasing smoke point, and as a result, the toxic compound will be reduced while fats are degraded, thus increasing thermal stability. Physicochemical properties for blended oil enhance the flavour, colour, and spreadability of oils. The blending of oils results in a decrease in free fatty acids, iodine value, peroxide value. It provides oxidative stability and contributes to longer shelf life by delaying rancidity.

There is a vast demand for essential fatty acids like EPA and DHA that only vegetative source it contains was microalgal oils as dietary supplements and in foods. The use of algal oils can be quite an alternative source for fish oils, and demand for this also increases proportionally due to limitations in the production of fish oils. There is a need to have some newer technologies to combat the higher yield of production where the land is unsuitable for agriculture use. This type of oil can help us prevent various disorders and enhance the nutritional balance of fatty acid profile by concentrating on the oxidation stability of this oil to make use of these algal oils in a wide range of food products.

## Abbrevations

| | |
|---|---|
| ALA | Alpha-Linolenic Acid |
| CVDs | Cardiovascular Diseases |
| DHA | Docosahexaenoic Acid |
| DPA | Docosapentaenoic Acid |
| EPA | Eicosapentaenoic Acid |
| FFA | Free Fatty Acid |
| FDA | Food and Drug Administration |
| HDL | High-Density Lipoprotein |
| LA | Linolenic Acid |

LDL Low-Density Lipoproteins

MUFAs Monounsaturated Fatty Acids

ω-3 Omega-3

ω-6 Omega-6

PUFAs Polyunsaturated Fatty Acids

SFAs Saturated Fatty Acids

TSFA: TMUFA: TPUFA Total Saturated Fatty Acid: Total Monounsaturated Fatty Acid: Polyunsaturated Fatty Acid

WHO World Health Organisation

**Tables**

Table 1. Food Products and Alpha-Linolenic Acids (ALAs) Contents

| S. No. | Source | Amount of ALA per 100g |
|---|---|---|
| 01 | Flaxseed Oil | 53368mg |
| 02 | Chia Seeds | 17830mg |
| 03 | Hemp Seeds | 8684mg |
| 04 | Canola Oil | 9137mg |
| 05 | Soyabean Oil | 6789mg |
| 06 | Edamame (Green Soyabeans) | 358mg |
| 07 | Navy Beans | 177mg |
| 08 | Avocados | 111mg |
| 09 | Whole Wheat Bread | 137mg |
| 10 | Oatmeal | 18mg |
| 11 | Eggs (Raw) | 36mg |

(Adapted from Papanikolaou et al., 2014)

Table 2. Effect of EPA & DHA from Vegetable Oils/Marine/Fish Oils

| Supplement of ALA/Long-chain PUFA in the form | Observations | Comments | Reference |
|---|---|---|---|
| Flax Seed Oil | Conversion of ALA & LA to long chain-<br>2-Fold (EPA)+ No change (DHA) | LDL cholesterol increases in marine oils compared with plant-based oils | Kestin et al., 1990 |
| Safflower Oil | Conversion of ALA & LA to long chain-<br>2-Fold (EPA)+ No change (DHA) | | |
| Fish Oil | 7-Fold (EPA)+ 2-Fold (DHA) | | |
| Flax Seed Oil (35mg) | Decrease in triglycerides | No significant change in LDL & HDL cholesterol | Layne et al., 1996 |
| Fish Oil (35mg) | A decrease in triglycerides is more significant | | |
| Safflower Oil | Failed on inflammatory treatment compared with marine oil | Improves T-cells mediated immune response | Meydani et al., 1996 |
| Flax Seed Oil | | | |
| Sunflower Oil | Decrease in triglycerides, no other increase in lipid profile | Plant-based not equivalent to marine-based in decrease triglycerides | Harris, 1997 |
| Flax Seed Oil | | | |
| Soy Oil (12g) | Increase in triglycerides | No significant change in LDL & HDL cholesterol | Silva et al., 2005 |
| Fish Oil (12g) | Decrease in triglycerides | | |

Table 3. The Most Consumed Individual Vegetable Oils and their Fatty Acids Profile (Dorni et al., 2018)

| Individual Vegetable Oils | Fatty Acid Composition (%) | | | | | Essential Fatty Acid (%) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Total Saturated Fatty Acids (TSFA)** | **Total Monounsaturated Fatty Acids (TMUFA)** | **Total Polyunsaturated Fatty Acids (TPUFA)** | **TPUFA/ TSFA** | **Ratio TSFA: TMUFA : TPUFA comparing with Recommended by WHO (1:1.5:1)** | **ω-6** | **ω-3** | **ω-6/ ω-3** | **Ratio ω-6: ω-3 comparing with Recommended by WHO (5-10:1)** |
| Coconut Oil | 90.84 | 7.24 | 1.90 | 0.02 | 3.18: 0.25: 0.07 | 1.90 | ND | - | 8.50: 0.00 |
| Corn Oil | 16.6 | 33.67 | 49.74 | 3.00 | 0.58: 1.18: 1.74 | 48.97 | 0.76 | 64.43 | 8.37: 0.13 |
| Cottonseed Oil | 28.17 | 19.66 | 52.16 | 1.85 | 0.99: 0.69: 1.83 | 51.81 | 0.35 | 146.70 | 8.44: 0.06 |
| Gingelly Oil | 16.45 | 41.21 | 42.34 | 2.57 | 0.58: 1.44: 1.48 | 41.92 | 0.41 | 102.24 | 8.42: 0.08 |
| Groundnut Oil | 19.27 | 53.77 | 26.96 | 1.40 | 0.67: 1.88: 0.94 | 26.96 | ND | - | 8.50: 0.00 |
| Mustard Oil | 5.73 | 66.98 | 27.28 | 4.76 | 0.20: 2.34: 0.95 | 15.58 | 11.70 | 1.33 | 4.85: 3.65 |
| Palmolein | 44.84 | 43.62 | 11.54 | 0.26 | 1.57: 1.53: 0.40 | 11.23 | 0.30 | 37.43 | 8.28: 0.22 |
| Rice Bran Oil | 23.63 | 43.71 | 32.66 | 1.38 | 0.83: 1.53: 1.14 | 32.04 | 0.59 | 54.30 | 8.35: 0.15 |
| Safflower Oil | 9.19 | 14.04 | 76.78 | 8.39 | 0.32: 0.49: 2.69 | 76.58 | 0.13 | 631.59 | 8.49: 0.01 |
| Soyabe | 15.90 | 24.77 | 59.33 | 3.73 | 0.56: | 54.17 | 5.16 | 10.50 | 7.76: |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| an Oil | | | | | 0.87: 2.08 | | | | 0.74 |
| Sunflower Oil | 11.39 | 25.92 | 62.69 | 5.51 | 0.40: 0.91: 2.19 | 62.69 | ND | - | 8.50: 0.00 |
| Ghee | 71.02 | 26.44 | 2.54 | 0.04 | 2.49: 0.93: 0.09 | 2.00 | 0.55 | | 6.67: 1.83 |
| Vanaspati | 61.65 | 33.62 | 4.73 | 0.08 | 2.16: 1.18: 0.17 | 4.73 | ND | - | 8.50: 0.00 |

Table 4. The Most Consumed Blended Vegetable Oils and Their Fatty Acids Profile

| Blended Vegetable Oils | Fatty Acid Composition (%) | | | | | Essential Fatty Acid (%) | | | | References |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total Saturated Fatty Acids (TSFA)** | **Total Monounsaturated Fatty Acids (TMUFA)** | **Total Polyunsaturated Fatty Acids (TPUFA)** | **TPUFA /TSFA** | **Ratio TSFA: TMUFA: TPUFA comparing with Recommended by WHO (1:1.5: 1)** | **ω-6** | **ω-3** | **ω-6/ ω-3** | **Ratio ω-6: ω-3 comparing with Recommended by WHO (5-10:1)** | |
| Sesame Oil & Rice bran Blend (80:20) | 20.40 | 45.65 | 29.66 | 1.45 | 0.75: 1.67: 1.08 | 29.66 | ND | - | 8.50:0.00 | Gulla & Waghray, 2011 |
| Sesame Oil & Rice bran Blend (20:80) | 16.18 | 38.35 | 39.16 | 2.42 | 0.60: 1.43: 1.46 | 39.16 | 0.70 | 55.94 | 8.35:0.15 | Gulla & Waghray, 2011 |
| Sesame Oil & Mustard Oil | 11.05 | 20.25 | 25.45 | 2.30 | 0.68: 1.25: 1.57 | 24.88 | 0.57 | 43.64 | 8.31:0.19 | Gulla & Waghray, 2011 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Blend (80:20) | | | | | | | | | | |
| Sesame Oil & Mustard Oil Blend (20:80) | 11.14 | 20.43 | 25.37 | 2.27 | 0.68: 1.26: 1.56 | 24.78 | 0.59 | 42 | 8.30:0.20 | Gulla & Waghray, 2011 |
| Groundnut Oil &Linseed Oil Blend | 10.80 | 40.80 | 48.70 | 4.50 | 0.38: 1.42: 1.70 | 24.30 | 24.40 | 0.99 | 4.24:4.26 | Sharma &Lokesh, 2013 |
| Flax seed Oil & Safflower Oil Blend | 8.1 | 17.90 | 69.50 | 8.58 | 0.30: 0.66: 2.55 | 37.50 | 32.0 | 1.17 | 4.59:3.91 | Jones et al., 2014 |
| Corn Oil & Safflower Oil Blend | 7.90 | 17.70 | 69.60 | 8.81 | 0.29: 0.65: 2.56 | 69.30 | 0.30 | 231 | 8.46:0.04 | Jones et al., 2014 |
| Sunflower & Flax Seed Oil Blend | 8.80 | 24 | 67.30 | 7.64 | 0.31: 0.84: 2.35 | 47.20 | 20.1 | 2.34 | 5.96:2.54 | Umesha & Naidu, 2015 |
| Sunflower Oil & Garden Cress Seed Oil | 13.30 | 31.40 | 55.30 | 4.15 | 0.47: 1.10: 1.94 | 38.20 | 16.80 | 2.27 | 5.90:2.60 | Umesha & Naidu, 2015 |
| Rice bran Oil & Garden Cress Seed Oil | 20.50 | 39.80 | 39.80 | 1.94 | 0.72: 1.39: 1.39 | 27.30 | 12.50 | 2.18 | 5.83:2.67 | Umesha & Naidu, 2015 |

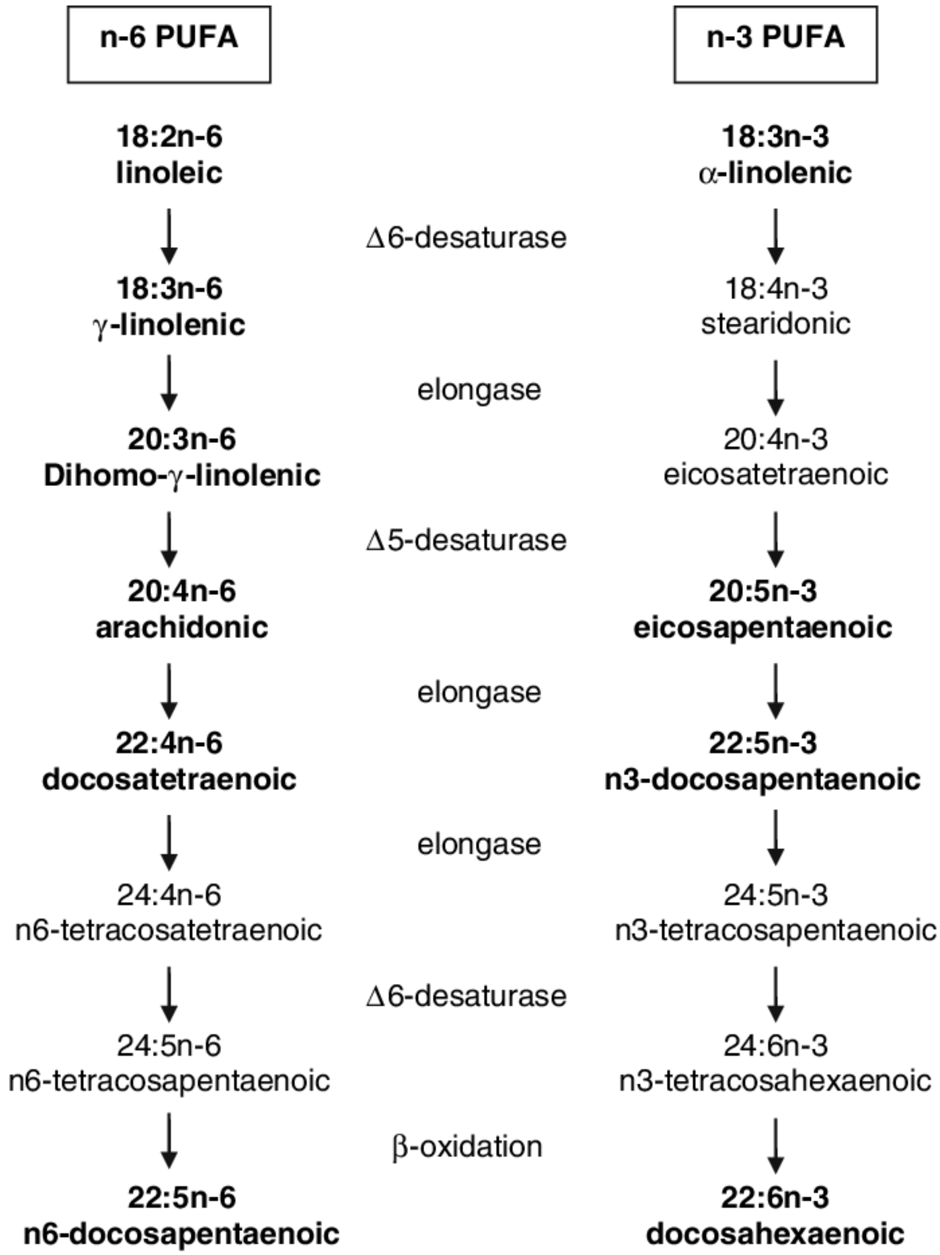
| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sesame Oil & Garden Cress Seed Oil | 15.10 | 41 | 44 | 2.91 | 0.53: 1.43: 1.54 | 31.30 | 12.70 | 2.46 | 6.05:2.45 | Umesha & Naidu, 2015 |
| Olive Oil & Soyabean Oil Blend | 15.10 | 67.90 | 16.40 | 1.08 | 0.53: 2.39: 0.58 | 15.18 | 1.24 | 12.24 | 7.86:0.64 | Jan et al., 2016 |
| Olive Oil & Sunflower Oil Blend | 15.30 | 65.0 | 19.50 | 1.27 | 0.54: 2.28: 0.68 | 18.14 | 1.35 | 13.43 | 7.91:0.59 | Jan et al., 2016 |
| Refined Olive pomace oil &Refined Palm oil Blend | 35.66 | 50.31 | 14.02 | 0.39 | 1.25: 1.76: 0.49 | 13.68 | 0.34 | 40.23 | 8.29:0.21 | Hammouda et al., 2017 |
| Safflower & Rice bran Blend | 19.31 | 36.90 | 43.79 | 2.27 | 0.68: 1.29: 1.53 | 49.92 | 0.87 | 49.33 | 8.35:0.15 | Dorni et al., 2018 |
| Sunflower Oil & Sesame Oil Blend | 13.08 | 34.67 | 50.03 | 3.82 | 0.47: 1.24: 1.79 | 49.34 | 0.45 | 109.64 | 8.42:0.08 | Ghosh et al., 2019 |
| Black Cumin Seed Oil & Sunflower Oil Blend | 9.14 | 44.55 | 43.48 | 4.75 | 0.33: 1.60: 1.57 | 44.46 | 0.12 | 370.5 | 8.48:0.02 | Mazaheri et al., 2019 |

Table 5. Health Benefits of Different Vegetable Oil Blends

| Blended Oil | Health Benefits | Experiments conducted on | References |
|---|---|---|---|
| Rice bran Oil + Sunflower Oil | Hypolipidemic effect | Humans | Kennedy et al., 2010 |
| Coconut Oil + Rice bran/Sesame Oil | Decrease in Platelet aggregation, Enhanced prostacyclin/thromboxane, decrease atherogenic potentials | Wistar Rats | Reena et al., 2010 |
| Sunflower Oil, Sesame Oil, Rice bran Oil + Garden Cress Seed Oil | Decreased Total Cholesterol (TC), Triacyl glyceride (TAG), Low-Density Lipoprotein Cholesterol (LDL-C) in serum and Liver | Wistar Rats | Umesha & Naidu, 2012 |
| Sesame Oil + Flaxseed Oil | Cardioprotective properties, Improving the radical scavenging activity, total cholesterol & triglyceride values decreased | Wistar Rats | Guimaraes et al., 2013 |
| Soybean + Sunflower Oil | Hypocholesterolemic | Wistar Rats | Kanjilal et al., 2013 |
| Rice bran Oil + Olive Oil | Prevention of cardiovascular diseases, hypocholesterolemic activity | Humans | Monika et al., 2013 |
| Groundnut oil + Linseed Oil | Neural functions improvement acts as a hypocholesterolaemia, hypotriglyceridaemic effect | Wistar Rats | Sharma & Lokesh, 2013 |
| Rice bran Oil + Partially Hydrogenated Vegetable Fat | Anti-inflammatory, | Wistar Rats | Rao et al., 2016 |
| Soy oil + Olive Oil+ Hydrogenated Crambe Oil | Obesity prevention | Mice | Moreira et al., 2017 |

**Figures and Schemes**

Figure 1. Metabolic Pathway of ALA & LA for the Biosynthesis of Long-Chain Fatty Acids from Plants

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**Conflict of Interest**

The author does not have conflicts of interest to declare.

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