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Impact of Consumption of Vegetable Oil and Fish Oil on Cardiovascular Disease: A Review

Umme Kulsum[1], Chandan Samanta[2]

[1, 2] M.Sc., Student, Department of Nutrition and Public Health,
The University of Burdwan, West Bengal, India
Email- [2] iam.chandan@yahoo.com

ABSTRACT:

Cardiovascular diseases are a group of disorders of the heart and main blood vessels in which the excess blood cholesterol is deposited as fatty streaks or plaque along the vessel wall thereby obstructing the flow of blood through those arteries. Atherosclerosis is the beginning of cardiovascular diseases. About 47% of the Indian population dies from cardiovascular diseases. Above 615,000 people in the United States are dying from cardiovascular diseases every year. There are various behavioral, environmental, and psychological factors that play a role in the formation of atherosclerosis. But the other most important factor is Indian dietary edible vegetable oils including mustard oil, coconut oil, sesame oil, soybean oil, sunflower oil, rice bran oil, palm oil, olive oil, and fish oils such as mackerel fish oil, salmon fish oil, tuna fish oil, cod liver oil shark liver oil which contains several fatty acids for example-butyric acid, caproic acid, lauric acid, myristic acid, palmitic acid, oleic acid, palmitoleic acid, alpha-linolenic acid, gamma-linoleic acid, arachidonic acid, docosahexaenoic acid, docosapentaenoic acid, eicosapentaenoic acid which plays very important roles on cardiovascular health. Some poly-unsaturated fatty acids and mono-unsaturated fatty acids help in reducing the chances of atherosclerosis by preventing the aggregation of platelets, inhibiting inflammation of blood vessels, increasing the level of high-density lipoprotein cholesterol in the blood, and decreasing the low-density lipoprotein and total cholesterol levels from the blood. Other fatty acids increase the risk of atherosclerosis by enhancing the low-density lipoprotein cholesterol level of blood and by synthesizing pro-inflammatory substances thereby helping in the inflammation process of the vessel wall. In this review, we discuss how the Indian dietary edible oils exert positive and negative effects on our cardiovascular health and which oils are best for long time consumption as well as best for keeping our heart and blood vessels healthy.

Keywords: Cardiovascular disease, atherosclerosis, platelets aggregation, fish oil, vegetable oil, fatty acids, polyunsaturated fatty acids, monounsaturated fatty acids, docosahexaenoic acid, eicosapentaenoic acid.

INTRODUCTION:

Cardiovascular diseases (CVDs) are non-communicable multifactorial chronic illnesses in which the heart and blood vessels are affected [1]. According to **World Health**

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Organization (WHO), "cardiovascular diseases are a group of disorders of heart and blood vessels and include coronary heart disease, cerebrovascular disease, rheumatic heart disease, and other conditions" [6]. Among non-communicable diseases, CVDs are the main cause of high mortality rates worldwide. In the year 2015, there were 17.9 million deaths from CVDs which is equivalent to 31% of death all over the world. In this worldwide death, 7.4 million people died from coronary heart disease, and 6.7 million died of stroke [186]. According to **WHO (World Health Organization)**, about 47% of people in India died from CVDs [2]. In the United States, moreover, 615,000 people died every year from CVDs [4]. In the year 2015, according to the **American Heart Association (AHA)** among adults above 18 years of old the incidence rate of CVDs in Caucasians is 12.1%, in African -Americans 10.2%, in Hispanics 8.1%, in Native Americans 12.1%, in Asians 5.2% and in Native Hawaiians or other Pacific Islanders is 19.7% [3].

The most common form of CVDs is coronary heart disease caused by atherosclerosis. The term atherosclerosis is derived from two Greek words (Athera means 'Gruel' and 'skleros' mean 'Hard') is a condition in which the inner walls of main arteries (that supply oxygen and nutrients to the heart muscles, brain and in the other parts of the body) are narrowed due to deposition of excessive blood cholesterol in the form of fatty streaks that develops into a fibrous complicated plaque which can eventually stop the flow of blood through those arteries [4, 8]. As a result of this condition's progression, other types of cardiovascular diseases occur which include - Myocardial infarction or Heart attack (blood vessels that provide oxygen and nutrients riches blood to the heart are affected), Cerebrovascular diseases or Stroke (blood vessels that supply the brain are damaged), Peripheral artery disease (blood vessels of legs and arms are affected), Rheumatic heart disease (due to rheumatic fever, caused by streptococcal bacteria, the heart valves and heart muscles are affected), Congenital heart disease (malformed heart from birth affect the normal activities of the heart), Pulmonary embolism (dislodged blood clots are moved from leg veins to heart and lungs) [6].

The most common events of CVDs are heart attack and stroke which have many symptoms such as angina pectoris (pain in the chest), abrupt weakness of the face, arms, and legs or on one side of the body, Pain in arms, and left shoulder, elbow, jaw or joint, difficulties in breathing, in walking and understanding speech, cold sweat, vomiting, fainting, severe headache without any reason [1]. Some behavioral, environmental, and psychological factors such as tobacco smoking, absence of physical activity, unhealthy food habits, hypertension, obesity, and diabetes mellitus all of these play an important role in the development of CVDs [2].

Numerous research studies suggested that there has an indistinguishable relationship between the quality of dietary oil and the pathogenesis of CVDs. Dietary oil is an important ingredient in making beautiful and delicious foods [7]. Dietary oil contains various components such as fatty acids which includes saturated fatty acids (butyric acid, caproic acid, caprylic acid, capric acid, lauric acid, myristic acid, palmitic acid, stearic acid, arachidic acid, and behenic

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acid) and unsaturated fatty acids such as monounsaturated fatty acids (palmitoleic acid, oleic acid, erucic acid) and polyunsaturated fatty acids (linoleic acid, linolenic acid, arachidonic acid, eicosapentaenoic acid, docosahexaenoic acid) and various other components such as tocopherols, sterols, triacylglycerols, monoacylglycerols, diacylglycerols and fat-soluble vitamins. All of these components have some good and bad effects on blood cholesterol levels as well as on cardiovascular health [5].

There are many different types of dietary oil used in our daily life and are associated with cardiovascular health. Some of these oils come from plant sources (extraction of seed endosperm and mesocarp) and some from animal sources (obtain from oily fish tissues). Examples of vegetable oils that are commonly used in daily food preparation are mustard oil, coconut oil, sunflower oil, rice bran oil, olive oil, sesame oil, palm oil, and soya bean oil. Examples of animal oils are fish body oil (from mackerel, herring, tuna, salmon, and sardines) and fish liver oil such as cod liver oil, halibut, or shark liver oil. Vegetable oils are rich sources of polyunsaturated fatty acids except for coconut oil and palm oil as they contain a high amount of saturated fatty acids which have bad effects on CVDs. Fish oil is an important source of eicosapentaenoic acid which improves cardiovascular health [5,9].

PATHOPHYSIOLOGY OF CARDIOVASCULAR DISEASES:

Most CVDs are caused by atherosclerosis. In atherosclerosis, the inner wall of coronary arteries is narrowed and hardened due to the deposition of excess blood cholesterol in the form of plaque. Atherosclerosis begins with the disturbance of the normal function of endothelial cells which make up the inner wall of the heart, blood vessels, and lymph vessels. These cells secrete a gaseous substance that regulates vascular relaxation and contraction. Besides that, by secretion of enzymes, they also regulate blood clotting, immune function, and platelet adhesion.

Various factors play an important role in the onset of endothelial dysfunctions which are Hypertension (high blood pressure injures the arterial walls when blood flows through them), Hypercholesterolemia (the presence of high levels of cholesterol in blood results in a fatty deposition in the arterial walls), Smoking (inflammation of endothelial cells is caused by the nicotine present in cigarettes), Hyperhomocysteinemia (high levels of homocysteine in the blood can affect the endothelial lining), Impaired glucose metabolism (elevated blood glucose levels can lead to endothelial dysfunction), Unhealthy eating habits such as consumption of junk foods and fast foods in a regular basis, saturated fat-enriched meal intake for a long period of time.

All of these conditions can lead to increased concentration of lipids (such as chylomicrons, very low-density lipoprotein, low-density lipoprotein, and high-density lipoprotein) in the blood which is associated with the pathogenesis of cardiovascular diseases. As a result, the concentrations of plasma Low-density Lipoprotein cholesterol (LDLC), as well as oxidative stress, are increased. Both of them play an important role in inhibiting the normal functions

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of endothelial cells by increasing the production of free radicals (such as hydroxyl radicals and superoxide anions) and hydrogen peroxide in plasma which decreases the concentration of Nitric Oxide (it is an important substance in maintaining vascular homeostasis and it protects the endothelial cells from harmful substances) in the vascular wall and activates the nuclear factor Kappa B (NF-kB) [3, 8].

As Nitric Oxide (NO) concentration decreases in the endothelial cells, vascular balance is disrupted which can lead to vasoconstriction, adherence of leukocytes, and activation of platelets and inflammation of blood vessels. NF-kB signaling pathway plays a significant role in regulating Proinflammatory genes which direct the adhesion molecule's expression such as vascular cell adhesion molecule-1(VCAM-1), selectins and Intercellular adhesion molecule-1 (ICAM-1). However, the protective agent of atherosclerosis is High-density lipoprotein cholesterol which inhibits the process of endothelium dysfunction and decreases the adhesion molecule’s expression. Due to the oxidation of lipoproteins, the monocytes and lymphocytes are attached to the wall of arteries. This can lead to the expression of biomarker molecules of blood vessel inflammation such as chemotactic proteins, adhesion molecules, and monocyte growth factors. Since successive penetration in the endothelial cell wall, monocytes are converted to macrophages and the accumulation of Oxidized lipids within the macrophages leads to the formation of foam cells. Cell-surface receptors mediate the process of foam cell formation by recognition of the Oxidized LDLC.

One characteristic feature of early atherosclerosis is foam cells. The gathering of foam cells with T-lymphocytes on the surface of blood vessels as fatty streaks (that are flat and yellow or gray in color) is visible without using a microscope.

When the endothelium is damaged the normal capacities of the endothelium (preventing the aggregation of platelets into microthrombi and regulating the entry of lipids into the wall of blood vessels) are decreased, resulting in platelets aggregation. So, platelet-derived growth factor (PDGF) is released which acts as a stimulant for migrating and proliferating the Smooth Muscle Cells (SMC). Besides that, endothelial cells, macrophages, and T-lymphocytes are involved in releasing growth factors and cytokines (such as TGF -beta and PDGF) and are also participating in the SMC migration from tunica media into the tunica intima of the blood vessel. This is followed by the rapid multiplication of SMC which decreases their normal capacity of being contracted. At the same time, an increase in the number of SMC results in increased uptake of lipids and so it is common that the foam cells are formed from SMC. A lipid lesion is converted into fibrous lipids containing atheromatous plaque when the collagens, elastin, and complex proteoglycans are begins to be synthesized and secreted by smooth muscle cells. The proliferation of fibroblast also activates plaque formation by means of synthesizing and secreting the collagens and other larger complex molecules.

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Advanced atherosclerosis has a characteristic wound known as fibro-lipid plaque which consists of a fibrous tissue cap and Smooth Muscle Cells. As a result, the plaque gets mechanical firmness from them and the thrombogenic core rich in lipid remains detached from the lumen of blood vessels and blood circulation. The enlargement of plaques is performed by continuous adherence to leukocytes. Fracture of fibrous cap results from the release of proteolytic and metalloprotease enzymes when macrophages are activated and leukocyte influx occurs within the plaque. A gradual rise of plaque size occurs when the plaque is repeatedly fractured by larger lipid cores and thin caps and at the same time, the fracture is resealed by platelet aggregation and thrombus incorporation inside complex lesions of the vascular lumen.

In coronary arteries, the formation of this unstable non-occlusive thrombus causes unstable angina pectoris and when the thrombus burst, it causes acute myocardial infarction due to complete blockage of blood flows through coronary arteries. On the other hand, the plaque becomes intact and stable and when ruptured it also causes acute coronary syndrome. The unstable plaque consists of a thin cap (which contains less collagen and vascular Smooth Muscle Cells), large amount of lipids, and many inflammatory cells. Whereas, the stable plaque consists of a small lipid core, a thick fibrous cap and fewer amounts of inflammatory cells. Atherosclerosis of coronary arteries may lead to various complications such as angina pectoris, myocardial infarction, cerebrovascular disease, peripheral artery disease, pulmonary embolism, etc. [8].

DIFFERENT TYPES OF DIETARY OILS AND THEIR NUTRITIONAL COMPOSITIONS:

There are different types of Vegetable oils and Animal oils that are used in our daily life and they contain several fatty acids and fat-soluble compounds. Here we discuss their sources and nutritional composition which are below –

Vegetable Oils

In the human diet as a component, vegetable oil plays an important role [10, 11]. Most of the vegetable oils which are used in daily life for consumption include sunflower oil, sesame oil, mustard oil, olive oil, rice bran oil, coconut oil, etc. Vegetable oils are excellent sources of some fatty acids that are stored in the plant seeds (mainly cotyledon or endosperm) as triglyceroles and also as wax esters. Fatty acids have many important functions in the human body such as helping in cell division, cellular metabolism, stored as a source of energy, and an important constituent of hormones, cell membranes, neurotransmitters, etc. Besides these, a fatty acid also has bad effects on human health such as overconsumption of fatty acids cause cardiovascular diseases. There are different types of fatty acids such as saturated fatty acids and unsaturated fatty acids which are present in vegetable oils. Examples of these fatty acids are stearic acid, palmitic acid, oleic acid, linoleic acid (omega-6 fatty acid), and alpha-linolenic acid (omega-3 fatty acid) [12, 13]. In the human body arachidonic acid is formed

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from linoleic acid and on the other hand eicosapentaenoic acid and docosahexaenoic acid are formed from alpha-linolenic acid [10, 14-16]. The nutritional compositions of some vegetable oil are discussed below –

Mustard Oil

Mustard oil is derived from different types of mustard seeds. Different species of mustard seeds are cultivated in different countries all over the world which includes Black mustard (*Brassica nigra L*.), Brown mustard (*Brassica juncea L*.), White mustard (*Sinapsis alba L*.), and Wild mustard (*Sinapsis arvensis L*.), Ethiopian mustard (*Brassica carinata A. Braun*). But all of these seeds are not used for extracting cooking mustard oil [17]. The oil extracted from black mustard seeds is used as cooking oil. Mustard oil contains levels of erucic acid (as it is considered harmful), so it is restricted for human consumption [18]. Mustard oil has a pungency flavor for which it is used as cooking oil. In India and China, its uses are very much popular [19]. The pungency flavor of black mustard seeds oil is because of the presence of glucosinolate (in the form of sinigrin) which produce a phytochemical known as Allyl-isothiocyanate [17] [20]. Mustard seeds contain about 24-40% of oil and 28-36% of protein [21] [22]. According to the USDA (United States Department of Agriculture) National Nutritional Database mustard oil contains about 12% saturated fatty acids. This oil also contains 62% monounsaturated fatty acids (erucic acid-42% and oleic acid-12%) and 21% polyunsaturated fatty acids (linoleic acid-6% and linolenic acid-15%) [21]. In mustard oil, the ratio of omega-3 and omega-6 fatty acids is 0.87 [23]. In 100 gm. of mustard oil 38.32 mg. tocopherols and 606.32 mg. sterols are present [24]. In black mustard seeds, several antioxidants are present such as 3, 4-dihydroxybenzoic acid, sinapic acid, ferulic acid, and rutin [25].

Coconut Oil

There are three types of coconut copra (dried kernel) which include ball copra, milling copra, and cup copra. Among them, only milling copra is used for extracting oil. All of this copra is derived from coconut tree fruits (*Cocos nucifera Linn*) [26]. In India, coconut palm plays an important role as a source of perennial oil. In the entire coastal belt, coconut is cultivated. In tropical countries, coconut oil is used as dietary oil for many years [27]. In infant milk powder coconut oil is used due to its high digestibility and flavor stability. In industries, coconut oil is widely used as fat in making Confectionaries such as ice cream. Coconut oil is also used as a substitute for cocoa butter which is used along with cocoa powder in emulating chocolates [28]. About 55-60% of the oil is taken from the dried kernel of a coconut palm. In coconut oil, high levels of lauric acid and myristic acid are present [5]. About 92% of saturated fatty acids are present in coconut oil as medium-chain triglycerides. This oil also contains 8% unsaturated fatty acids (mainly oleic and linoleic acid). Tocotrienols, phytosterols, and Tocopherols are also present in small quantities in coconut oil [29].

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Sunflower Oil

There are two types of sunflowers cultivated globally. One is an oilseed sunflower and another one a is confectionary sunflower. Among them, only oilseed sunflower is used for oil extraction [30]. Sunflower oil is nonvolatile oil used as cooking oil, especially in deep frying of foods [31]. It is also used in cosmetic products due to its water-holding capacity and non-flammability [32]. The principal constituents of sunflower oil are oleic acid (30%) and linoleic acid (59%). It also contains palmitic acid (5%) and stearic acid (6%) [33]. By plant reproduction and various industrial processing, other types of sunflower oils are produced such as high-oleic (oleic acid- 82%) sunflower oil, high-linoleic (linoleic acid- 59%) sunflower oil, mid-oleic (oleic acid- 65%) sunflower oil and high-stearic (stearic acid- 18%) with high-oleic (oleic acid- 72%) sunflower oil [34]. This oil also contains tocopherols, carotenoids, phytosterols, tocotrienols, and sterols [35].

Sesame Oil

Sesame oil is derived from the seeds of the sesame plant (*Sesamum indicum*), it belongs to the family Pedaliaceae [36]. Sesame seeds have high strength to resist oxidation and rancidity for which it is called the "Queen of Oilseeds" [37]. Sesame seeds are used as an ingredient in making candy, bread, cake and other snack foods. In Hindu culture it is used as an "immortality symbol" and the extracted oil is used in burial ceremonies [38]. Besides that, in Southern and Chinese cooking sesame oil is used as cooking oil [39]. In the Middle Eastern, sesame seeds are used as an ingredient in making the traditional food item i.e., known as tahini (Butter of the Middle East) [40]. In industries, sesame oil is widely used in making pharmaceuticals and margarine. In Chinese and India, this oil is also used in making traditional medicines [41]. About 55% of oil and 20% of protein can be taken from sesame seeds [39]. Sesame oil contains about 83-90% of unsaturated fatty acids mainly 37-40% linoleic acid (a polyunsaturated fatty acid) and 35-43% oleic acid (a monounsaturated fatty acid). It also contains 9-11% of palmitic acid, 5-10% of stearic acid and a small quantity of linolenic acid. Sesame oil alscontainsin phytosterols, phytate, tocopherols (mainly Gamma tocopherols) and some fat-soluble phenolic compounds known as Lignans which include sesamin, sesamolin, sesaminol, sesamolinol [42].

Rice Bran Oil

Rice bran oil is derived from the pericarp of rice (*Oryza sativa*) [43, 44]. Rice bran oil is popular as cooking oil due to its good cooking quality, prolonged shelf life and a well-balanced composition of fatty acids and availability of several antioxidants. It is a pale-yellow color, odorless, translucent oil with a mild nutty flavor and sweet neutral taste. In many Asian cultures, it is generally used and known as "premium edible oil" and in Japan, it is called "heart oil". Also in Western countries, it is known as healthy food [45]. Due to its low price and various health advantages, it is also gaining popularity in the USA and some parts of the world [46]. It is regarded as the best cooking oil for deep-frying. In sautéing,

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marinades, grilling and salad dressing its uses are very popular [44]. About 18-22% of oil can be taken from the pericarp of rice. Rice bran oil contains various unsaturated fatty acids such as oleic acid (38.4%), linoleic acid (34.4%), and alpha-linolenic acid (2.2%). In rice bran oil Trans fats are absent. This oil also contains saturated fatty acids such as stearic acid (2.9%) and palmitic acid (21.5%) [44]. In this oil, some bioactive components known as phytonutrients are present which include tocopherols, tocotrienols, gamma-oryzanol, phytosterols (beta-sitosterol, campesterol, and stigmasterol), and squalene and triterpene alcohols [47-51].

Palm Oil

The perennial monocotyledon tree is known as palm (*Elaeis guineensis*), it belongs to the Arecaceae family and is responsible for producing palm oil [52]. Two types of oil are extracted from this tree. One is crude palm oil that is derived from the mesocarp of fruit and another one is palm kernel oil that is derived from the endosperm of seed [53]. About 85% of total palm oil produced is widely used as cooking oil in various food preparations which include frying, shortenings, margarine and vegetable ghee etc. [54]. About 30-35% of oil is taken from the fruit of the plant. One palm tree consists of about 2000 fruits [55]. Palm oil contains high levels of antioxidants and phytochemicals which include carotenoids (500-700ppm), tocopherols and tocotrienols (600-1200ppm), phytosterols (300-620ppm), squalene (250-540ppm), polyphenols (40-70ppm), coenzyme Q10 (10-80ppm) [56, 57]. While there is a difference in fatty acid composition between palm oil and palm kernel oil. In palm oil saturated fatty acids are present such as palmitic acid (44%) and stearic acid (4.5%). Palm oil also contains several unsaturated fatty acids which include 39% oleic acid, a monounsaturated fatty acid, and 10% linoleic acid, a polyunsaturated fatty acid. In palm kernel oil about 82% saturated fatty acids are present which includes 47.8% lauric acid, 16% myristic acid, and 8.5% palmitic acid. Palm kernel oil also contains unsaturated fatty acids such as oleic acid (15%) and linoleic acid (3%) [58, 59].

Olive Oil

Olive oil is derived from the fruit of the olive tree (*Olea europea*). Various types of olive oil are used on regular basis in the Mediterranean diet such as virgin olive oil (25ml/day) and extra virgin olive oil (50ml/day) [60]. In addition to making olive oil from olive trees, it is also used in the production of table oil, an important food item in the Mediterranean diet [61]. Due to the presence of several phytochemicals and vitamins (those help in maintaining good health), the consumption of olive oil is increased at present [62]. Olive oil contains about 98% of saponifiable lipids or triglycerides, the main component of olive oil. Triglycerides contain various fatty acids such as 55%-83% oleic acid, a monounsaturated fatty acid and 2.5%-21% of linoleic acid, a polyunsaturated fatty acid [63]. Olive oil also contains several phenolic compounds which include oleuropein, tyrosol and Hydroxytyrosol [64]. Recently it is identified that in extra virgin olive oil some phenolic compounds are present in the density

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of 0.02-600mg/kg which includes phenolic acids, flavonoids, secoiridoids and lignans [63] [65]. Besides that, olive oil also contains phenolic alcohols (triterpenic alcohols, triterpenic dialcohols and fatty alcohols), sterols, and hydrocarbons (carotene, beta-carotene and squalene), tocopherols, xanthophyll, ketones and esters [66] [62] [67-70].

Soybean Oil

According to Food and Agricultural Organization (FAO), Soybean [*Glycine max (L.) Merrill* belongs to the *Leguminosae* family] is categorized as an oilseed instead of a pulse [71, 72]. It is the source of soybean oil. Soybean contains about 44% protein, whereas only 20% protein is present in other beans [73]. Dry soybean seeds can produce approximately 19% of oil, which will vary from 6.5%-28.7% due to their growth and genetic conditions [74]. Soybean is widely used for domestic purposes, industrial purposes, and currently as a bio-energy source [75]. The total oil (20%) from soybean seeds is composed of five fatty acids which include saturated fatty acids (15%) [Such as stearic acid (4%) and palmitic acid (12%)] and unsaturated fatty acids (85%) (Such as oleic acid -23%, linoleic acid- 53% and linolenic acid -12%) [76]. Another study reported that in soybean oil the concentration ranges of linoleic, oleic, and palmitic acids are 49-53.5%, 21.4-26.6%, and 9.2-11.2% respectively [77]. In another new study, it is found that in soybean oil the concentration of linoleic acid is 50.20%, linolenic acid is 7.75% and stearic acid is 3.69% [78].

Table No-1: Percentage of Fatty Acids of Indian Vegetable Oils

Vegetable oils	***Saturated fatty acids (SFA) (%)***	***Unsaturated fatty acids***	
		Monounsaturated fatty acid (MUFA) (%)	***Polyunsaturated fatty acid (PUFA) (%)***
Mustard oil	*10.7*	*56*	*32.6*
Coconut oil	*89.5*	*7.8*	*2*
Sunflower oil	*9.1*	*25.1*	*66.2*
Sesame oil	*21*	*43*	*40*
Rice bran oil	*22.1*	*41*	*35.7*
Palm oil	*46.3*	*43.7*	*10*
Olive oil	*14.8*	*74.5*	*10*
Soybean oil	*13.1*	*28.9*	*57.2*

Source: *Gopalan et al. reprinted 2011, Nutritive Value of Indian Foods, National Institute of Nutrition, Hyderabad.*

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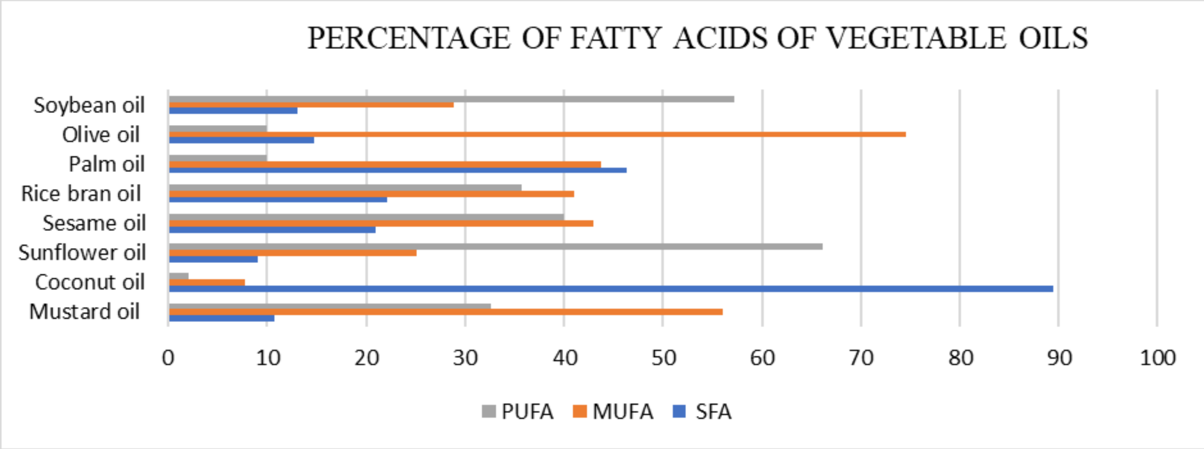

Fig-1: Percentage of Fatty Acids of Vegetable Oils

Fish Oil:

Fish oil is extracted from the tissues (such as liver, skin, viscera, head and frame) of various fatty marine fishes such as mackerel, tuna, salmon, cod and shark [79]. Fish oil contains essential fatty acids which are not synthesized by the human body but can convert other fatty acids into essential fatty acids [80]. So consumption of fish oil is very important for the human beings. Essential fatty acids contained in fish oil have various important functions in the human body such as helping in preventing atherosclerosis, heart attack, angina pectoris, congestive heart failure, stroke, peripheral heart disease and also important in the treatment of various diseases such as cancer, diabetes, rheumatoid arthritis etc. [81]. Essential fatty acids are mainly polyunsaturated fatty acid which includes omega-3 fatty acids and omega-6 fatty acids [80]. Examples of omega-3 fatty acids present in fish oil are eicosapentaenoic acid and docosahexaenoic acid [79]. Fish oil is taken either directly by consumption of fatty fish or indirectly as a supplement in the form of pills, capsules and soft gel [80]. The nutritional properties of some fish oil are discussed in the following:

Mackerel Fish Oil

For human beings, fish and its products are very much obtainable animal protein (about 80%) sources. In the coastal regions of the Indian Ocean Indian mackerel (*Rastrelliger kanagurta*, which belongs to the *Scombridae* family) is generally found. In the water of the Red Sea and Arabian Gulf, they are also found and in the summer season, they are abundant [82]. They are sold in markets of different countries as they are highly accessible and economical fish and also in many local dishes they are included [83, 84]. Mackerel oil contains 50% monounsaturated fatty acids, 32.61% polyunsaturated fatty acids and 17% saturated fatty acids. In this oil about 17 fatty acids are present. Among saturated fatty acids, myristic acid and Palmitic acid are abundant. Among monounsaturated fatty acids, the most abundant fatty acids are palmitoleic acid (28.93%) and oleic acid (21.46%). Among polyunsaturated fatty acids, eicosapentaenoic acid and docosahexaenoic acid are the most abundant fatty acids. In

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mackerel oil eicosapentaenoic acid and myristic acid are present in the concentration of 20.65% and 15.95% respectively [85].

Tuna Fish Oil

Malaysia is the main country for tuna (mainly neritic and oceanic tuna) fishery. Three types of neritic tuna species are seen in the water of Malaysia which includes Eastern little tuna (*Euthynnus affinis*), longtail tuna (*Thunnus tonggol*), and frigate tuna (*Auxis thazard*). In Malaysia, 90% of the total tuna are neritic species which comprises eastern little tuna 34%, longtail tuna 49% and frigate tuna 7% [86]. In the fish industry after the processing of fish, the by-products such as head, skin, viscera and frames are used from which fish oil, fish meal, and other products (such as fish gelatin and edible protein powder) are produced. The oil content that is extracted from fish by-products is highly varying between the ranges 1.4-4.0% [87]. In tuna fish, a high amount of omega-3-polyunsaturated fatty acid (mainly docosahexaenoic acid or DHA) is present in the head part [88]. The maximum amount of oil extracted from by-products of different species of tuna fish is 36.2% from the head of T. tonggol, 26.4% from the skin of E. affinis and 17.1% from the viscera of A. thazard [89]. There is no significant difference in the fatty acid composition of fish oil derived from three different species of tuna such as T. Tonggol, E. affinis and A. thazard. A high quantity of saturated fatty acids is present in the viscera other than the head or skin of the three species of tuna. In E. affinis the amount of saturated fatty acids the in viscera is 47.8-48.6 %, in the head is 41.3-41.4% and in skin is 41.4-41.9%. In T. tonggol the amount of saturated fatty acids in the viscera is 45.9-46.1%, in the head is 42.8 - 43.7% and in the skin is 39.7-40.8%. Saturated fatty acids are composed of 21.3- 31.0% Palmitic acid, 5.8-9.2% stearic acid, 4.3-6.1% Myristic acid and the amount of pentadecanoic acid and margaric acid varies from 0.7- 1.8%. In Tuna fish oil the percentage of total saturated fatty acids is higher than unsaturated fatty acids. The skin part of all three species of tuna contains high amounts of Monounsaturated fatty acids. Such as in E. affinis the quantity of Monounsaturated fatty acid in the skin is 26.6%, in A. thazard the quantity of Monounsaturated fatty acid (MUFA) in the skin is 25.9% and in T. tonggol the quantity of Monounsaturated fatty acid in the skin is 25% monounsaturated fatty acids are composed of 11.9-14.8% of oleic acid and 4.4-7.7 % of palmitoleic acid and 2.1-3.6 % of vaccenic acid. The head part of all species of tuna contents high quantity of polyunsaturated fatty acid than other parts such as skin and viscera. The total amount of polyunsaturated fatty acid in the head is 25.4 to 27the .2%, in skin is 24.1 to 26.0% and in the viscera is 24.1 to 25.8%. The total amount of polyunsaturated fatty acid is composed of about 80% docosahexaenoic acid. Among the three species of Tuna fish, the highest amount of docosahexaenoic acid is present in the head part of T. tonggol (19.9%), in E. affinis the percentage is 18% and in A. thazard the percentage is 17.1%. The amount of docosahexaenoic acid present in the skin of T. tonggol, E. affinis and A. thazard is 17.3%, 16.9%, and 16.2% respectively. Similarly, the amounts of docosahexaenoic acid present in the viscera of all three species of tuna are 16.1% in T. tonggol, 15.9% in A. thazard, and

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14.9% in E. affinis. The quantity of eicosapentaenoic acid present in by-products of Tuna fish is very low which is 1.3-3.7%. The high amounts of eicosapentaenoic acid present in the viscera of all three species of tuna [89]

Salmon Fish Oil

Out of total global salmon production, 8.2% was produced in Canada and it holds the fourth rank [90]. After processing of salmon fish, the by-products such as skin, gut, fins, tail and frame are used for the production of fish oil [91]. In Atlantic salmon fish 2.5% of fat is present and about 57% of total body fat is present in the inedible portions. Whereas 18% of total body fat is present in the skin of this fish [92]. The oil derived from the salmon head, frame and gut is composed of 19.21-21.93% saturated fatty acids, 36.82-39.58% of monounsaturated fatty acids and 38.89-39.83% of polyunsaturated fatty acids. Among all saturated fatty acids, Palmitic acid is present in the percentage of 10.99 -13.16%. In this oil, the amount of oleic acid (monounsaturated fatty acid) is 21.57-24.50%. The most abundant polyunsaturated fatty acids present in this oil are linoleic acid (8.48-10.20%), eicosapentaenoic acid (7.41-8.88%) and docosahexaenoic acid (7.53-8.90%). In salmon oil, the amount of omega-3-fatty acid is 23.41-25.73% and omega-6-fatty acid is 10.27-12.03% [93-96].

Cod Liver Oil

Cod liver oil is obtained from the byproduct of processed cod fish (such as liver) due to the low amount of fat present in the cod body. Two types of cod are available, one is the pacific cod (*Gadus macrocephalus tilesius*) and another one is the Atlantic cod (*Gadus morhua L.*) [97]. There are some products of fish oil are sold in the market as medicine or functional food. Besides, microencapsulation of cod oil is done through which some foodstuffs (such as infant formulas, baby food, pizza and bread) are enriched with several nutrients [98]. In cod liver oil high amounts of long-chain n-3 polyunsaturated fatty acids such as eicosapentaenoic acid and docosahexaenoic acid are present [99]. As a supplement (5mL) cod liver oil contains about 500 micrograms of vitamin A, 10 micrograms of vitamin D and 10 mg of vitamin E [100]. However, cod liver oil is an essential source of vitamin D [101, 102].

Shark Liver Oil

Different species of sharks are captured from the waters of the Cuban coastal which includes white trip shark (*Carcharhinus longimanus*), nurse shark (*Ginglimostoma cirratum*), and silky shark (*Carcharhinus falciformis*). The liver of these three shark species is used for the extraction of liver oil [103]. In shark liver oil high amounts of triglycerides are present which constitute 97.2% of the total lipid content [104, 105]. Besides triglycerides, omega-3 fatty acid constitutes 7% of the total lipid content of this oil [103]. Two saturated fatty acids as Palmitic acid and stearic acid are most common in this oil [106]. In shark liver oil about 32% monounsaturated and 26.5 % polyunsaturated fatty acids are present. Linoleic acid (4.3%) is

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an important fatty acid present in shark liver oil. In this oil Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are also present in the concentration of 1.7% and 5.3% respectively [103].

Table N0- 2: Percentages of Fatty Acids in Fish Oils

Fish oil	***Saturated fatty acid (SFA) (%)***	***Unsaturated fatty acid (%)***		***Reference***
		Monounsaturated fatty acid (MUFA) (%)	***Polyunsaturated fatty acid (PUFA) (%)***	
Mackerel fish oil	*17*	*50*	*32.61*	*85*
Tuna fish oil (T.tonggol), head	*42.82*	*23.95*	*27.85*	89
Tuna fish oil (T.tonggol), skin	*40.25*	*25.5*	*25.9*	
Tuna fish oil (T.tonggol), viscera	*46*	*23.55*	*25*	
Tuna fish oil (E.affinis), head	*41.35*	*25.75*	*25.8*	
Tuna fish oil (E.affinis), skin	*41.65*	*26.25*	*25.05*	
Tuna fish oil (E.affinis), viscera	*47.95*	*25.05*	*24.7*	
Tuna fish oil (A.thazard), head	*42.9*	*23.55*	*26.4*	
Tuna fish oil (A.thazard), skin	*39.95*	*25.15*	*23.15*	
Tuna fish oil (A.thazard), viscera	*46.85*	*23.15*	*25.6*	
Salmon fish oil, gut	*19.32*	*39.65*	*39.54*	93
Salmon fish oil, head	*21.89*	*37.27*	*39.21*	
Salmon fish oil, frame	*21.24*	*37.64*	*39.54*	
Cod liver oil	*15.3*	*45.9*	*27.2*	*94,95*
Shark liver oil	*25.42*	*15.64*	*46.73*	*103*

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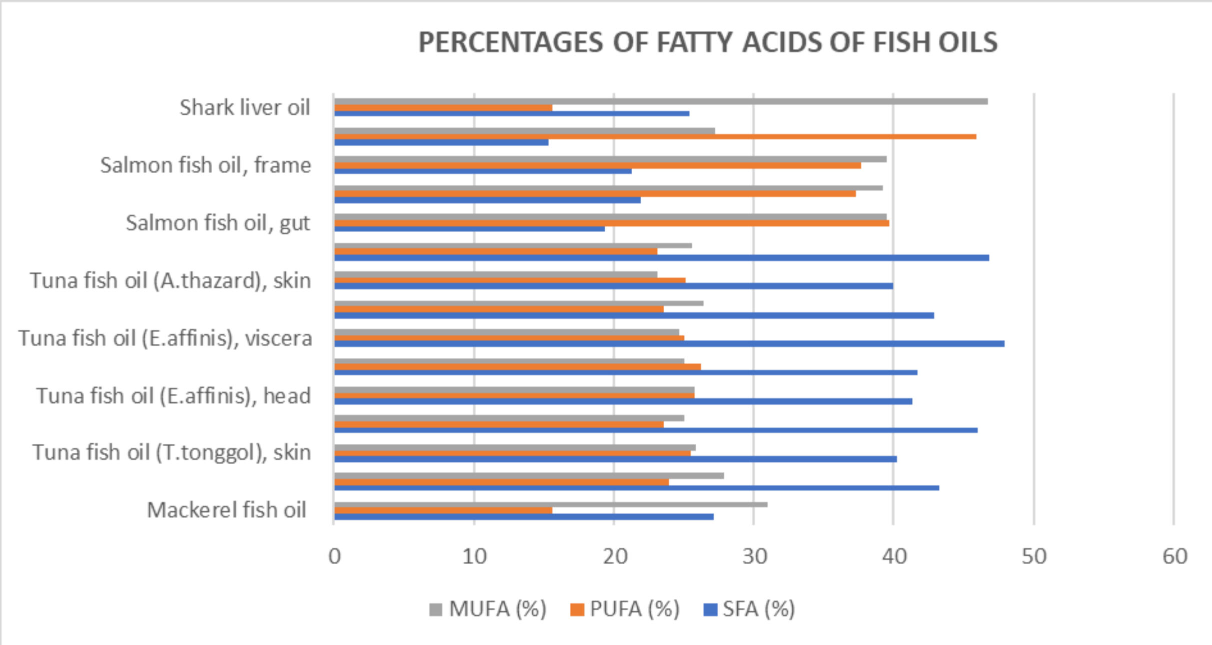

Fig -2: Percentages of Fatty Acids of Fish Oil

ROLE OF FATTY ACIDS ON CARDIOVASCULAR DISEASES:

Cardiovascular diseases are caused by the deposition of excessive plasma cholesterol in the lumen of arteries (known as atherosclerosis) [4]. Among the several risk factors (such as smoking, hypertension, physical inactivity, family history, age, and sex) of CVDs, abnormalities in the metabolism of fatty acids play an important role in the development of risk factors of CVDs [107-110]. Fatty acids are an important constituent of lipid which is present as solid or oil form in the diet. Based on the structure or presence/absence of double bonds, fatty acids are classified as saturated fatty acids (double bond is absent) and unsaturated fatty acids (one or more double bonds are present). Unsaturated fatty acids are of two types – monounsaturated fatty acids contain one double bond and polyunsaturated fatty acids contain two or more double bonds. Based on the position of the first double bond, polyunsaturated fatty acids are of two types – one is n-3 polyunsaturated fatty acid and another is n-6 polyunsaturated fatty acid. These two polyunsaturated fatty acids cannot be synthesized in the human body so they are known as essential fatty acids and are mostly available in fish oils and a lesser extent in vegetable oils [111-115, 116]. The effects of different types of fatty acids on cardiovascular diseases are as follows:

Saturated Fatty Acids and Their Effects on Cardiovascular Disease

Based on structure, saturated fatty acids are of three types which include short-chain saturated fatty acids containing 1-6 saturated carbons (such as butyric acid with four carbon atoms, caproic acid with 6 carbon atoms), medium-chain fatty acids containing 7-12 saturated carbons (such as caprylic acid with 8 carbon atoms, capric acid with 10 carbon atoms and

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lauric acid with 12 carbon atoms) and long chain saturated fatty acids containing 13 or more saturated carbons (such as myristic acid with 14 carbon atoms, palmitic acid with 16 carbon atoms, stearic acid with 18 carbon atoms, arachidic acid with 20 carbon atoms and behenic acid with 22 saturated carbon atoms).

Due to the variation in their structures, the absorption, transportation, and fate of these saturated fatty acids are different [5, 117, and 118]. For instance, medium-chain saturated fatty acids are more effectively absorbed from the gastrointestinal tract and are directly transported to the liver by the portal vein for oxidation. Whereas, long chain fatty acids (in the form of chylomicrons) are mainly absorbed through the lymphatic ducts and are taken by adipose tissues. Side by side, medium-chain fatty acids after getting into the cells are easily entered into mitochondria without the help of a membrane transporter (carnitine shuttle) for oxidation. However, long-chain fatty acids are transported to the mitochondria with the help of the carnitine shuttle transporter present in the mitochondrial membranes [119-121].

Increased consumption of saturated fatty acids raised the LDL Cholesterol level in the blood by suppressing the activity or formation of VLDL and LDL receptors which helps in the entry of LDL to cells for oxidation. On the other hand, saturated fatty acids also increase the level of C-reactive proteins which has an inflammatory effect on endothelial cells of blood vessels as a result endothelial dysfunction occurs [2]. Recently in Nurse's Health Study shows that there is no association between the intake of short to medium-chain saturated fatty acids and an increased risk of coronary heart disease. While intake of long-chain saturated fatty acids is associated with an increased risk of coronary heart disease [122]. Some clinical studies suggested that there is no appropriate evidence about the outcome of CVD risk due to the consumption of medium-chain saturated fatty acids [123]. A new analysis study including Health Professional Follow-Up Study and Nurse's Health Study revealed that the risk of CVDs is increased due to the consumption of long-chain saturated fatty acids [124].

Lauric acid (C12:0) is a medium-chain fatty that increases the plasma LDL Cholesterol level to a greater range and also raises plasma HDL Cholesterol level to a greater extent, thus the ratio of total cholesterol and HDL Cholesterol is decreased. So, the risk of CVDs is reduced [125, 126]. A high quantity of lauric acid is found in coconut oil (45%) and palm kernel oil (47.8%) [127]. Long-chain saturated fatty acids include myristic acid (C14:0), palmitic acid (C16:0), and stearic acid (C18:0). Palmitic acid increases both the plasma LDL Cholesterol and HDL Cholesterol but does not effectively reduce the ratio of total cholesterol and HDL Cholesterol. So, plasma LDL Cholesterol level is increased. Side by side palmitic acid causes inflammation of blood vessels by increasing the production of pro-inflammatory factors (such as interleukin-6, C- reactive protein, and TNF-α) from activated macrophages. As a result, LDL Cholesterol is oxidized and CVD risk developed [2, 126, 128-131]. Palmitic acid is found in palm kernel oil (44%), soybean oil (12%), rice bran oil (21.5%), and sunflower oil (5%) [126]. A prospective study on females and males revealed that an increased concentration of palmitic acid in plasma is linked with the onset of CVD risk [132]. In

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Ludwigshafen Risk and Cardiovascular Health study, it is shown that palmitic acid is associated with a high mortality rate of CVDs [133]. Myristic acid also increases both the plasma LDL Cholesterol and HDL Cholesterol. However, it has no significant effect on the ratio of total cholesterol and HDL Cholesterol [126]. On the other hand, stearic acid decreases the LDL Cholesterol level in plasma and causes no change in plasma HDL Cholesterol level [134,135]. So, stearic acid does not cause the development of risk factors for CVDs, possibly due to the desaturation of stearic acid into oleate (C18:1n-9) during metabolism [136].

Epidemiological research studies have suggested that long-chain saturated fatty acids (containing 12-16 saturated carbons) have a significant role in plasma LDL Cholesterol levels, hence they are associated with increased severity of atherosclerosis and increased risk of CVD [137-140]. The American Heart Association and American College of Cardiology guidelines have recommended the dietary intake of saturated fatty acids is only 5-6% of total daily energy that comes from saturated fatty acids to decrease the risk of CVD [141]. The National Lipid Association Expert Panel suggested that the replacement of saturated fatty acids with unsaturated fat, proteins, or carbohydrates decreases the cholesterol levels that cause atherosclerosis. However, replacing saturated fatty acids with unsaturated fats or proteins reduces the cholesterol level to a greater extent than replacing saturated fatty acids with carbohydrates [142].

Unsaturated Fatty Acids and Their Effects on Cardiovascular Health

Two types of unsaturated fatty acids, such as monounsaturated fatty acid and polyunsaturated fatty acid, are present in vegetable oils as well as in fish oils [115, 116]. The effects of these fatty acids on cardiovascular diseases are described below –

Monounsaturated Fatty Acids (MUFA)

Monounsaturated fatty acids contain only one double bond in their structures. Monounsaturated fatty acids have two types of configurations – one is *cis*-configuration in which the hydrogen atoms and double bond exist in the same direction and another one is *trans*-configuration in which the hydrogen atoms and double bond exist in opposite direction. Among these, the most abundant configuration is cis-configuration which includes oleic acid (C18:1n-9), palmitoleic acid (C16:1n-7) and vaccenic acid (C18:1n-7). In diet, the most predominant monounsaturated fatty acid is oleic acid (which comprises approximately 92% of monounsaturated fatty acids) [143]. The most common *trans*-configuration of monounsaturated fatty acid is elaidic acid (*Trans* C18:1n-9). There are some monounsaturated fatty acids (such as mystrioleic acid-C14:1n-5, gondoic acid-C20:1n-9, erucic acid-C22:1n-9 and nervonic acid-C24:1n-9) synthesized endogenously in very small quantity from another precursor monounsaturated fatty acids. The most common sources of monounsaturated fatty acids are canola oil, olive oil, and other sources are sunflower oil, mustard oil, sesame oil, soybean oil, and various fish oil such as mackerel fish oil, tuna fish

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oil, salmon fish oil, shark liver oil [144]. The oil derived from mustard seeds contains high levels of erucic acid which contain monounsaturated fatty acid and it is used in cooking oil in some populations [145]. Monounsaturated fatty acids reduce the plasma LDL Cholesterol level by increasing the activity of LDL receptors but do not reduce the plasma HDL Cholesterol level and also reduce the triglyceride level in plasma. A high quantity of monounsaturated fatty acids helps to dissolve the thrombus and maintain various functions of cells [2]. Few prospective studies suggested that in the human body, monounsaturated fatty acids participate in various physiological functions such as the metabolism of energy, membrane integrity maintenance, biosynthesis of lipids, antioxidant reactions, apoptosis, and aging [146, 147]. In the human body, palmitoleic acid and oleic acid play various important functional roles. In the omega-7 family, palmitoleic acid is the main monounsaturated fatty acid and in endogenous lipolysis, palmitoleic acid is the main product [148]. In the human body, the liver and adipose tissue is the main site for the continued biosynthesis of cis-palmitoleic acid. Afterward, they are united into triglycerides, phospholipids, cholesterol esters, and waxes [149]. Epidemiological studies indicate that palmitoleic acid is involved in the metabolism and homeostasis of cholesterol. In few randomized controlled trials showed that intake of diets or capsules rich in palmitoleic acid is related to reduced plasma LDL Cholesterol and triglyceride levels and increased concentration of plasma HDL Cholesterol [149, 150]. Other studies state that there is an association between the intake of palmitoleic acid and the risk factors of CVD such as hypertension, increased concentrations of plasma cholesterol, triglyceride, apolipoprotein A1 and apolipoprotein B, and dysfunction of the endothelium [151, 152]. But most investigators believed that palmitoleic acid helps in ameliorating the lipid profile of blood, thus it can be used as a nutritional supplement in the treatment of patients with dyslipidemia [153, 154].

In foods, oleic acid is the most predominant monounsaturated fatty acid. In adipose tissues, oleic acid comprises 50% of the triglycerides. There are some strong oxidants (such as superoxide-anion radical, nitrogen dioxide, and ozone) that oxidize the oleic acid and form short-chain saturated fatty acids or hydroxy derivatives [155, 156]. Research on oleic acid indicates that oleic acid influenced the cardiovascular system [157]. Oleic acid helps in improving the lipid profile of blood and in maintaining a healthy body weight. Side by side, oleic acid helps in preventing the dysfunction of mitochondria, insulin resistance, and inflammatory signaling in skeletal muscles and neuron cells [158-161]. The LDL particle in the artery wall remains for a short period of time after they are enriched with oleic acid and may decrease the atherosclerotic risks [162]. In heart disease patients, a positive association between plasma triglyceride and oleic acid has been seen [163]. In 2000, the American Heart Association recommended dietary intake of monounsaturated fatty acids that is less than 15% of total daily energy comes from monounsaturated fatty acids. In 2006, the recommendation on monounsaturated fatty acids given by American Heart Association is less than 20% of total daily energy comes from monounsaturated fatty acids [164, 165]. In 2007, the American and Canadian Dietetics Association recommended monounsaturated fatty acids intake that

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less than 25% of total daily energy comes from monounsaturated fatty acids [166]. United States Department of Agriculture gives no dietary recommendation for monounsaturated fatty acids [167]. The National Cholesterol Education Program III recommended less than 20% of total daily energy should come from monounsaturated fatty acids [168].

Polyunsaturated Fatty Acids (PUFA)

Polyunsaturated fatty acids contain two or more double bonds in their structure. Based on the position of the first double bond, polyunsaturated fatty acids are of two types – one is omega-3 fatty acid and another is omega-6 fatty acid [115, 116]. Polyunsaturated fatty acids lower the plasma cholesterol level by esterifying the cholesterols and increasing their utilization in the human body [2]. PUFAs help in decreasing the total cholesterol levels in the blood as it increases the activity of the Cholesterol 7 alpha-hydroxylase enzyme via elevating the transcription of the Liver x receptor gene as it helps in regulating the lipid levels in the blood through converting the excessive cholesterol into bile acid in the blood. Therefore, the total cholesterol level of the blood is decreased [169-171]. PUFAs also decreases the concentration of triglyceride levels in the blood by activating the Apo-C III and lipoprotein lipase enzymes via interacting with the receptors that help in the metabolism of lipid such as peroxisome proliferator-activated receptors. These enzymes help in breaking down VLDL Cholesterol into absorbable fatty acids thereby decreasing the concentration of Triglycerides levels in the blood [171-176]. On the other hand, these fatty acids reduce the enzyme level which helps in fatty acid synthesis such as acetyl coenzyme A carboxylase, diacylglycerols acyltransferase, and fatty acid Synthetase [177-181]. PUFAs also decrease LDLC levels in the blood by elevating the fluidity of the plasma membrane which in turn improves the activity of LDLC receptors and thereby accelerates the catabolism of LDL Cholesterols [171, 182-186]. PUFAs also reduced the concentration of VLDL Cholesterol levels in the blood by preventing the production of cholesterol and fatty acids in the liver via suppressing the transcription of a special gene factor (known as sterol regulatory element binding protein-1) that is involved in lipid and other fatty acids synthesis in human liver [187,188].

In the omega-3 fatty acids chain, the fast double is present at a distance of three carbons from the methyl terminal [189]. Omega-3 fatty acids play several important functions in the human body such as helping to diminish the difficulties of the nervous system, reducing the symptoms of inflammation, improving the metabolic activity of the whole body, and reducing the CVD risk [189-192]. The most important omega-3 fatty acids are α-linolenic acid (C18:3), eicosapentaenoic acid (C20:5), docosahexaenoic acid (C22:6) and docosapentaenoic acid (C22:5) [2]. A recent analysis of 79 randomized controlled trials showed that consumption of long-chain omega-3 polyunsaturated fatty acids does not have any positive or negative influences on cardiovascular risk [193]. In the 9, 12, and 15 carbon positions of α-linolenic acid double bonds are present. This essential fatty acid is predominantly present in fish oils and vegetable oils. Another meta-analysis suggested that an increased intake of α-linolenic acid i.e., 1g/day is related to a decreased mortality rate of ischemic heart disease by

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10% [194]. In a randomized controlled study fatty fish is supplied as a source of α-linolenic acid and showed that α-linolenic acid has a suppressive effect on plasma total cholesterol, triglyceride, and LDL Cholesterol level [195]. More prospective studies are required to be done to make a clear thought about the association between α-linolenic acid and cardiovascular diseases. But some authors accept that α-linolenic acid has protective influences on cardiovascular health [196]. Eicosapentaenoic acid is one of the essential polyunsaturated fatty acids. Eicosapentaenoic acid has some influences on atherosclerosis. It synthesized eicosanoids (which help in dilating blood vessels, decrease the formation of thrombus and reduce inflammation), inhibits dyslipoproteinemia and thus reduces the progress of atherosclerosis [197]. In a large prospective randomized controlled study, it is shown that administration of eicosapentaenoic acid 1.8g/day can reduce the events of CVD by 19% in statin-treated patients and after treatment, a reduction in plasma LDL Cholesterol concentration by 18% can be seen [198]. Eicosapentaenoic acid has beneficial effects on endothelial cell functions such as the balance between nitric oxide and peroxynitrite is improved by it and it also works synergistically with statin [199]. Eicosapentaenoic acid reduces the formation of Reactive Oxygen Species, inactivating apoptosis proteins, expression of cytokines and adhesion molecules and human umbilical endothelial cells apoptosis. Even in membrane vesicles, eicosapentaenoic acid suppressed the peroxidation of lipids [200-202]. The anti-inflammatory and antioxidant activity of eicosapentaenoic acid helps to reduce the adhesion of monocytes on the endothelial surface, inhibits macrophage accumulation and the formation of foam cells. Thus, preventing the formation of plaque that causes atherosclerosis [197, 203-205]. There is an inversed interrelationship between the amount of EPA and inflammation of the stable plaque. In a hypercholesterolemic patient, EPA helps in reducing the risk of atherosclerosis by decreasing the thickness of the innermost layer of carotid arteries [206-208]. EPA also prevents the process of inflammation of blood vessels by the production of special proteins and resolvins that diminishes neutrophils' adherence to the endothelium [209-211]. Besides the improvement of circulatory lipid profiles, EPA helps in preventing the development of other cardiovascular diseases by diminishing the levels of proinflammatory substances that have a role in the inflammation of blood vessels [212].

DHA is a highly unsaturated fatty acid and has a unique three-dimensional structure. It helps in preventing convulsions of blood vessels and heart muscles by ensuring the effectiveness of nerve cell signaling [213]. DHA also lowers the chances of atherosclerosis by decreasing the TG levels of blood, increasing the HDLC level of blood, and lowering the levels of proinflammatory biomarkers (such as IL 1-beta, TNF-alpha and IL -6] that cause inflammation of blood vessels and thereby improving the functioning of endothelial cells [214-217]. DPA is an intermediary fatty acid of DHA and EPA [218]. It is most effective in eliminating blood vessel inflammation because it is a precursor of isoprostanes, resolvins, maresins, and special proteins all have a role in delaying the inflammation process [219].

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DPA is very strong than other omega-3 fatty acids in inhibiting platelet aggregation [220,221].

In the omega -6- fatty acids chain the fast double bond is present at a distance of six carbons from methyl ends. There are different types of omega-6- fatty acids which include linoleic acid, gamma-linolenic acid and arachidonic acid. There has been a debate about the activity of omega-6 -fatty acids that are whether it is anti-inflammatory or pro-inflammatory. However, some researchers have indicated the antagonistic effects of these two PUFAs. But omega-3-fatty acids expressed their cardio-protective properties whereas omega -6-fatty acids are expressed as pro-inflammatory in their activity [222-224]. But in recent years, AHA expelled previous thoughts about the potential activity of omega -6- fatty acids in blood clot formation within the arteries, inflammation of blood vessels, and oxidation of LDLs. According to AHA, about 5-10% of daily energy requirements should be derived from omega - 6- fatty acids [225]. The human body is incapable of producing linoleic acid endogenously. Adipose tissues are composed of 10% linoleic acid in their structure. In the human body, linoleic acid helps in the production of arachidonic acid and they also help in the production of pro-inflammatory factors such as eicosanoids, thromboxane A4, leukotriene B4 [226-228]. High levels of eicosanoids in circulation may cause elevation of other pro-inflammatory factors such as IL-6, TNF-alpha, and C reactive protein. As a result, the CVD risks are increased. High amounts of linoleic acid consumption may lead to increased concentrations of alpha-linolenic acid, DHA, and EPA in blood circulation [229]. According to some clinical research studies, there is an inversed relation between the concentration of linoleic acid in the blood and the amount of pro-inflammatory factors (such as C reactive proteins, IL-6 and IL-1, TNF-alpha) in blood. The diameters of VLDL and LDL cholesterol are also inversely proportional to the amount of linoleic acid in circulation but the size of HDL cholesterol is directly proportional to the concentration of linoleic acid in blood [230-232]. Gamma–linolenic acid has anti-inflammatory and anti-proliferative properties. So, it can able to reduce the LDL and VLDL cholesterol levels in the blood and increases the HDL cholesterol levels in blood circulation [233-235]. GLA also keeps the blood vessels healthy by inhibiting hypertension and by involving in the blood-clotting mechanism they also reduce the complications of IHD [236].

Arachidonic acid consists of four double bonds at the 5, 8, 11, and 14 carbon positions in their 20-carbon long chain structure. It is synthesized by the human body with the help of the phospholipase A2 enzyme [237]. ARA helps in the production of pro-inflammatory substances such as eicosanoids and prostaglandins [238]. ARA also increases inflammatory responses and as a component phospholipid of lipid bilayers, they exert fluidity and flexibility to the plasma membrane of cells and help in nerve signaling by acting as a messenger [239]. On the other hand, ARA is also responsible for increasing the risk of atherosclerosis as it acts as an oxidative stress enhancer and also increases hypertension which affects blood vessels [240-242].

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CONCLUSION:

Atherosclerosis is the beginning of CVDs and there are several fatty acids that have great roles in the prevention and progression of atherosclerosis. These fatty acids are present in various dietary edible oils such as vegetable oils and fish oils which are used in our daily life for cooking foods. Fatty acids are of two types saturated fatty acids and unsaturated fatty acids. Various clinical and epidemiological studies show that long-chain saturated fatty acids such as myristic acid, palmitic acid, and stearic acid, increase the chance of atherosclerosis by elevating the bad cholesterol levels of blood (i.e., LDL and VLDL) and by increasing the production of pro-inflammatory substances (such as TNF-alpha, IL-6, and IL-1, C reactive protein) which causes inflammation of blood vessels. But medium-chain saturated fatty acid such as lauric acid doesn't increase the risk of atherosclerosis. The long-chain fatty acid mainly polyunsaturated fatty acids and monounsaturated fatty acids present in various vegetable and fish oil may reduce cardiovascular complications.

So, we came to the conclusion that if we can include the beneficial fish oil and vegetable oil in our daily diet which helps in maintaining cardiovascular health, then we can protect our heart from various diseases and that will give us a normal healthy life.

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