CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Tropical AgriSciences

Faculty of Tropical AgriSciences

Effects of nut consumption on the reduction of LDL "bad"cholesterol

BACHELOR'S THESIS

Prague 2021

Author: Bulanbek Zhekshenbekov

Supervisor: Ing. Klára Urbanová, Ph.D.

Declaration

I hereby declare that I have done this thesis entitled "Effects of nut consumption on the reduction of LDL "bad" cholesterol" independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague 16th of April 2021

....

Bulanbek Zhekshenbekov

Acknowledgements

I would like to take this opportunity to express my appreciation to my supervisor Ing. Klára Urbanová, Ph.D. for all the guidance, patience, and support provided throughout the whole process of writing of this Bachelor‘s Thesis already since the topic selection until its submission and additionally, I would like to thank for flexibility and willingness to help during the pandemic.

Abstract

Obesity is a complex disease involving excessive body fat that increases cardiovascular diseases, type 2 diabetes, and coronary heart diseases. In 2016 1.9 billion adults are overweight, 650 million obese. An unhealthy diet such as lack of vegetable and natural products increases the low-density lipoprotein cholesterol level in blood lipids. The low-density lipoprotein cholesterol is "bad cholesterol" because of collecting in the walls of blood vessels, raising heart disease risks. The high concentration of low-density lipoprotein cholesterol causes atherosclerosis, leading to the risk of blood clots in arteries. If the blood clots releases, blocks an artery in the heart or brain, it may be a risk of a heart attack. Nuts are a highly nutritious diet source and loaded with antioxidants; therefore, nuts are healthy for a human being. The main objective of this Thesis was to analyse and summarise current scientific findings, articles, trials regarding tree nuts and low-density lipoprotein (LDL-C). The specific objectives were to review obesity and its health risks, summarise the bioactive compounds and health benefits of tree nuts, and analyse the clinical trials on the effect of almonds, Brazil nuts, hazelnuts macadamias, cashews, pistachios, pecans, and walnuts consumption on LDL-C.

According to 36 clinical trials with approximately 1,340 participants from 1999 to 2018 comparing carbohydrate (CHO) low-calorie, olive-oil-based, high-fat-based, Step 1, Mediterranean, low-fat, full-dose muffins, and other control diets with almonds, pecans, hazelnuts, pistachios, macadamias, walnuts, cashews diets lowered total low-density cholesterol, the ratio of low-density lipoprotein cholesterol to high-density lipoprotein cholesterol. The interventions lasted between 3 and 26 weeks. Daily consumption of from 42.5 to 67 g of nuts resulted in a mean reduction of LDL-C 10.2 mg/dL or a 7.4 %. According to experts, nuts are rich in monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), plant sterols, L-arginine (improves artery walls making them flexible), Vitamin E (stops the development of plaques in the arteries), minerals such as magnesium, copper, phytonutrients. The favourable fat composition and fibre contribute to nut consumption's hypocholesterolemic benefit.

Keywords: nut consumption, tree nuts, obesity, LDL cholesterol, health effects of nuts

Contents

List of tables

List of figures

List of the abbreviations used in the thesis

BMI- Body mass index

Ca- Calcium

CHD- Coronary heart disease

CVD- Cardiovascular disease

DBP- Diastolic blood pressure

ESPEN- The European Society of Clinical Nutrition

EFSA- The European Food Safety Authority

FDA- The Food and Drug Administration

HDL-C- High-density lipoproteins cholesterol

Kcal- Kilocalories

LDL-C- Low-density lipoproteins cholesterol

Mg- Magnesium

Mg/dL- Milligrams per decilitre

Mmol/L- Millimoles per litre

MUFA- Monounsaturated fatty acids

NCEPS Step 1- National Cholesterol Education Program Step 1

NCEP Step 2- National Cholesterol Education Program Step "

P- Phosphorus

PUFA- Polyunsaturated fatty acids

RCT- Randomized controlled trial

SFA- A saturated fatty acid

T2DM- Type 2 diabetes

TC- Total cholesterol

USDA- The United States Department of Agriculture

WHO- The World Health Organisation

Zn- Zinc

µg/L- Micrograms per litre

1. Introduction

As people's lifestyle tends to be more sedentary, there is a decrease in physical activity. Automated transport, technologies and passive leisure make it hard for people to engage in physical activity (Kumanyika et al. 2002). The World Health Organization describes overweight and obesity as "an excessive fat build-up that may affect health" (WHO, n.d.). Obesity has been a significant health problem worldwide, and prevalence is doubling between 1980-2014 (WHO, n.d.). In 2015 alone, A. Afshin M. D. et al. stated an estimated 107.7 million children (uncertainty interval, 101.1 to 115.1) 603.7 million adults (uncertainty interval, 592.9 to 615.6) were obese worldwide. The mortality rate in 2015 accounts for 4.0 million caused by high BMI. One can identify obesity through body mass index (BMI), the most common metrics to quantify obesity. It provides a valuable measure of body fat percentage and obesity. The calculation is different for children and adults and men and women (Amianto et al. 2011). They are increasing the risk of other health problems like type-2 diabetes, heart disease, high blood pressure, sleep apnoea, cancer, and other diseases (NIDDK, n.d.). Eating disorders, specifically binge eating disorder (BED), anxiety disorders in line with mood disorders (MD.) are the comorbidities of obese people (Amiri & Behnezhad, 2019; McElroy et al. 2004; Segura-Garcia et al. 2017). Physical exercise, proper medical attention, and a healthy food diet are some of the means to fight/reduce obesity. Strategies to manage obesity are a blend of appropriate medical attention, adequate physical exercise, and food choices.

Nuts are rich sources of essential nutrients and fatty acids, consisting of health-promoting compounds like macro and micronutrients, fat-soluble bioactive, fibre, water-soluble vitamins such as folate, non-sodium minerals, and other phytochemicals like phytosterols and polyphenols (USDA, 2018). These unsaturated fatty acids can reduce the risk of CVD and diabetes. Many epidemiological, prospective, and cohort studies are trying to prove that the increase/continuous consumption of nuts can reduce the risk of CHD, diabetes, IHD, and especially obesity. Cholesterol is a waxy substance that circulates in the blood create cells, hormones and vitamin D. The liver produces all the cholesterol from fats in a diet. Cholesterol bonds to carriers called lipoproteins. It transports between cells. The LDL-C can build up in the arteries, causing heart disease. An unhealthy diet increases LDL-C level and can cause deposits on blood vessels' walls. It leads to a heart attack. People are suffering from obesity having a high concentration of LDL-C in blood lipids, which is one reason for coronary heart and cardiovascular diseases in obese people (Levine et al. 2019).

2. Aims of the Thesis

2.1. The main objective

The main goal was to analyse and summarise current scientific findings, articles, clinical trials regarding tree nuts consumption on Low-density lipoprotein (LDL-C).

2.2. The specific objectives

a) To review obesity and its health risks.

b) To review the bioactive compounds and health benefits of tree nuts.

c) To analyse the clinical trials on the effect of almonds, Brazil nuts, hazelnuts, macadamias, cashews, pistachios, pecans, walnuts consumption on the reduction of LDL-C concentrations in blood lipids.

3. Methodology

The data presented in this paper gathered from different scientific databases Web of Science, ScienceDirect, Google Scholar, PubMed. This work was focused on the effects of nut consumption and examined the feasible scientific articles and clinical trials on the impact of nut consumption on LDL-C concentrations in blood lipid and human health.

The keywords used in searching on the databases were: nut consumption, tree nuts, obesity, LDL cholesterol, health effects of nuts.

4. Literature Review

4.1. Obesity

A disease characterised by excessive fat accumulation in the body leads to increased body weight. In most cases (90 %), obesity develops due to excess food, reduced energy expenditure and metabolic disorders. Despite the effort to better understand obesity, its prevalence continues to rise (McCafferty and Hill, 2020). The majority of obesity worldwide has tripled since 1975. In 2019, 39 % of adults aged 18 years and over were overweight and, 13 % were obese. Also, there are over 340 million obese children and adolescents. In Africa, there is an increase of 24 % in the prevalence of obesity in children under five since 2000. In 2019, half of the children who were obese were residing in Asia (WHO 2011). It will lead to some metabolic changes that will increase chronic disease risk. According to the ESPEN society's consensus, nutrition disorders and nutrition-related conditions are malnutrition and overnutrition, which results in obesity. According to Finucane et al. (2011) there are about 297 million females and 205 million men (aged 20 years or older) obese in 2008 worldwide. Overall **Figure 1.** (WHO 2016) shows a pattern roughly in line with prosperity, richer countries across Europe, North America, Oceania and much lower across South Asia and Sub-Saharan Africa. 36 % of adults in the USA are obese.

In contrast, 3.9 % of Indians are suffering from obesity. The relationships between income and obesity generally hold, but Mexico 35 % and Algeria 27 % have very high rates of obesity. On the other hand, South Korea, Japan, and Singapore have deficient levels of obesity for their income level. (WHO 2016).

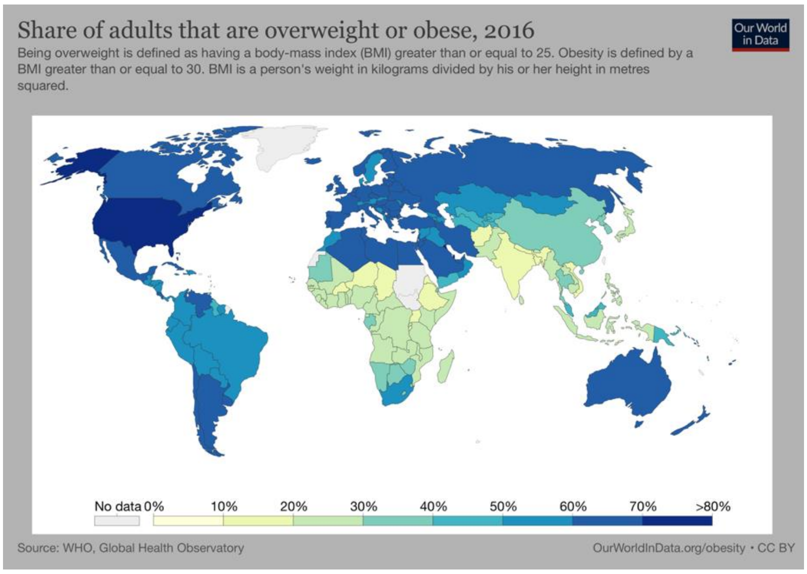

Figure 1. Share of obese adults

Source: WHO 2016

4.1.1. Measure of Obesity

Body mass index (BMI) is the most common metrics to quantify obesity. It calculates the ratio of an individual's weight in kilograms divided by the height in meters squared (BMI = kg/m^2). It also provides a valuable measure of body fat percentage and obesity. The calculation is different for children and adults or men and women. When a child's BMI is less than the 5th percentile of BMI for their age, they are underweight. Alternatively, they are overweight if their BMI is more than the 95th percentile of BMI for their age. Due to ethnic differences concerning BMI, the WHO recommended that Asians have lower BMI cut-offs. It is because Asians, in general, were observed to be at higher risk of adverse events at lower BMI cut-offs compared to international standards (Lam et al. 2016; WHO Expert Consultation). However, BMI cannot account for a body fat distribution (Neeland et al. 2018). There are other means to measure obesity, like waist size/circumference.

To better understand the risk, it is crucial to know the body mass index (BMI) and waist size. **Table 1.** (NIDDK n.d) shows BMI less than 18.5 considers underweight, more than 30 BMI displays the obese weight status. There are other measures of obesity according to **Table 2.** (WHO/FAO 2007); waist circumference is the simplest way to measure obesity in cm between the top of the hip bone and the lowest rib. The studies show this method predicts disease and death. If LDL-C concentrations in blood lipids are higher than 100 mg/dL, it can be a valuable sign to indicate obesity. Many studies show that obese and overweight persons have increased vascular resistance. The heart's extra activity puts extra strain on it and causes high blood pressure. Again, high cholesterol and insulin resistance occurs because of fat in obese people (WHO 2016).

Table 1. The categories of BMI Measurements.

BMI in Adults	Weight Status
<18.5	Underweight
18.5-24.9	Normal
25.0-29.9	Overweight
>30.0	Obese

Source: (NIDDK n.d.)

Table 2. Other Measures of Obesity

Measure	Target
Target BMI	18.5-24.9
Waist Size	Men: Less than 101.6 cm. Women: Less than 88.9 cm.
Blood pressure	120/80 Hg or less
LDL cholesterol	Less than 100 mg/dL
HDL cholesterol	Men: Less than 40 mg/dL Women: Less than 50 mg/dL
Triglycerides	Less than 150 mg/dL
Blood sugar (fasting)	Less than 100 mg/dL

Source: WHO/FAO (2007)

4.1.2. Health Risks of Obesity

One of the significant health problems and the risk factor of chronic disease is obesity (HHS, n.d; James, 2008). Not only does it attack the poor, but also rich people (Afolabi et al. 2020). Obesity links with mental disorders and develops the risk of T2D and CVD, high blood pressure, sleep apnoea (Amianto et al. 2011 & NIDDK, n.d.).

Type-2 diabetes is a common type of disease with an increase in blood sugar wherein the body does not produce enough or utilise insulin properly. It is familiar for overweight people and with a family history of diabetes. Blood pressure is equivalent to heart disease, stroke, and kidney failure. An increase in body size means the heart needs to pump harder to supply blood cells. People who are obese are prone to health problems like heart disease, high blood pressure, high cholesterol, and high blood sugar (NIDDK, n.d.). Besides, cardiovascular disease and cancer are the other aftermaths of obesity (Formica et al. 2020).

According to Afshin et al. (2015), there are an estimated 107.7 million children (uncertainty interval, 101.1 to 115.1) 603.7 million adults (uncertainty interval, 592.9 to 615.6) were obese worldwide. The mortality rate in 2015 accounts for 4.0 million caused by high BMI. This figure represents 7.1 % (95 % uncertainty interval, 4.9 to 9.6) of the total deaths. While in 2017, Afshin's group found that there were 11 million (95 % uncertainty interval (UI) 10–12) deaths and 255 million (234–274) DALYs caused by dietary risk factors. The main contributors to dietary risk mortalities were high sodium intake, low intake of whole grains, and low intake of fruits globally and in many countries. The data gathered are from mixed sources and not accessible for all countries making their estimates statistically inaccurate.

In another study in 2017, their results showed that 107.7 million children and 603.7 million adults were obese in 2015. The cases of obesity have increased two-folds since 1980. Moreover, it continues to rise in numbers. Two-thirds of deaths linked to high BMI due to cardiovascular disease.

4.1.3. Obesity in Developing Countries

Children and adolescent's obesity is a significant problem worldwide, accounts for the prevalence in developed and developing countries, specifically in Western nations (Aiello et al. 2015). It is a considerable health problem both in developed and developing countries.

A study conducted in China showed an estimated obesity percentage of 32.5 among boys and 17.6 among girls. Especially in the country's big cities (Ji and Cheng, 2008). The study conducted by Ji et al. (2007) confirmed an increase in obesity among Chinese youth ages 7-18 from 13.6 % to 23.6 %. In Argentina, childhood obesity prevalence is 9.7 % among boys and 11.9 % in Chile. 6.8 % among girls in Argentina and 18.1 % in Uruguay. While in Brazil is an estimate of obesity prevalence of 6.8 % among boys and 7.6 % among girls (IBGE, 2008).

Besides, there are over 135 million obese in India (Ahirwar et al. 2019). There are varying obesity cases in India from rural and urban areas caused by different factors such as geographical condition, lifestyle, and dietary pattern (Ahirwar et al. 2019). In the Philippines, the number of obese adults jumps from 16.6 % to 31.1 % in the last ten years (Food and Nutrition Research Institute 8th National Nutrition Survey 2013).

Meanwhile, there is an increasing case of obesity in Brazil every decade consequently, increasing cardiovascular and metabolic diseases, which are the primary cause of hospitalization and death in the country. A meta-analysis consisting of 21 studies conducted by Marshall et al. (2013) showed that children and adolescent obesity prevalence in Brazil were 14.12 %, with 18,463 children and adolescents aged two-19 years.

Malawi, one of the world's poorest countries, has an overweight and obesity prevalence of 10 % in 1992 to 21 % in 2015–16 (National Statistical Office (NSO) of Malawi n.d.). Like other developing countries, Thailand's rates of obesity had increased in the past two decades. It stated that the possible reason for this increase was economic growth, globalisation, changes in lifestyle, diet, and physical activity (Aekplakorn et al. 2009).

4.2. Cholesterol

As a lipid metabolism marker, the patient's cholesterol level provides essential information about the nutritional status. The plasma cholesterol level serves as a parameter for pathogenetic risk factors. The interplay between exogenous cholesterol intake and endogenous cholesterol synthesis is essential. Cholesterol is a fat (lipid) and a necessary part of membranes, the outer covering of cells. It is crucial for many metabolic processes (formation of hormones). Cholesterol plays a significant role in the human body. The liver is a vital organ for cholesterol metabolism, and the human body produces 80% of it. Only more minor is ingested with food. Why does the body need cholesterol?

- Cholesterol is a part of the human cell
- Cholesterol is the starting material for the formation of various hormones
- Without cholesterol, the body cannot produce vitamin D, which is essential for building bones
- Cholesterol is the primary building material for bile acids, which is necessary for fat digestion

The body's cholesterol builds from two parts: a) cholesterol produced in the body, the liver produces around 1200 mg of cholesterol per day. About 80 % of serum cholesterol is made in the liver directly from the fats (SFA) in food. 20 % comes from the intake of high-cholesterol foods, b) Cholesterol ingested with animal food sources. Too much cholesterol in the blood and the vessel wall leads to severe damage to health and premature mortality from vascular calcification (arteriosclerosis) and its consequences. Triglycerides are also among the most critical blood lipids. They are the main ingredients of fats that we ingest from food through the intestines and essential energy sources (Levine et al. 2019)

There is good cholesterol, known as HDL cholesterol, while LDL cholesterol is known as the "bad" cholesterol. On the other hand, triglycerides are another blood fat connected with atherosclerosis and elevated blood sugar levels. There is an ideal or "normal" amount of cholesterol the human body should possess. Total cholesterol should be less than 200 mg/dL for total cholesterol. 40 mg/dL for HDL cholesterol in men, while 50 mg/dL for women. LDL cholesterol should be less than 100 mg/dL, and triglycerides ideally should be less than 150 mg/dL. Coronary artery disease is a heart disease wherein the arteries that supply blood to the heart muscle are blocked. The blockage causes the accumulation of plaque within the arteries walls, also known as atherosclerosis. Cholesterol is one of the main reasons for plaques' formation (Levine et al. 2019). Nuts contain proteins, fibre, healthy monounsaturated fats, vitamins, nutrients, and antioxidants. A significant number of studies suggested that nuts have a cholesterol-lowering effect. LDL cholesterol is known as the bad cholesterol, which is a significant risk factor for coronary heart disease (CHD), so is total cholesterol (TC) (Demonty et al. 2009).

4.2.1. LDL Cholesterol

Low- density lipoprotein cholesterol is lipoproteins consists of fats, lipids protein. LDL cholesterol transports fat molecules around the human body. LDL transports the most significant part of the cholesterol (50 %) in the blood. It has the five most prominent types from its speed. It is not suitable for the human blood system because of the collection in the blood vessels' walls, which brings health issues leading to cardiovascular diseases (Levine & Rao & Michos, 2019). LDL-C one of the significant factors for CAD risk. If LDL-C is oxidized, it makes it atherogenic and is very important for atherosclerosis's pathogenesis. The lowering of LDL-C level depends on the fatty acid composition and vitamins in the LDL particle (Reaven et al. 1998). According to Laufs et al. (2019) a misconception is confusing overweight with high cholesterol levels. The LDL-C in the blood mainly depends on the regulation in the life, which is genetically determined. Weight normalisation is generally positive for the CV system. A healthy diet has a beneficial effect on LDL-lowering therapy. A heart-healthy lifestyle is essential to quitting smoking and exercising regularly to move. Endurance sports such as hiking, running, swimming or dancing are well suited. Daily physical activity of at least 30 minutes is ideal. For everyone, LDL-C target value below 115 mg/dL is healthy. Suppose overall CVD risk is high (high blood pressure, high genetic cholesterol, or smoker individuals). LDL-C target value should be below 100 mg/dL. In diabetes, the LDL-C target value should be below 70 mg/dL (Laufs et al. 2019).

4.2.2. HDL Cholesterol

High-density lipoprotein observes and transports cholesterol back to the human body's liver and reduces cardiovascular, heart diseases, and stroke risks. The most crucial HDL function is it carries the LDL cholesterol away from the blood system and brings it back to the liver. Unfortunately, it cannot eliminate LDL (Levine & Michos, 2019). Triglycerides are a type of fat, play a significant role in the human body, and save the diet's energy. A high level of triglycerides combined with a high LDL cholesterol level can cause heart attack and stroke. The doctors suggest checking the cholesterol level once a year and change the diet if the LDL cholesterol level is high. Also, it should be controlled regularly with a doctor if needed (Levine & Michos, 2019).

4.3. Tree Nuts

Tree nut is a fruit with one seed, becomes hard by maturity. However, they include various types of fruits. In the Thesis, I have included nuts, which are botanically single-seeded non-cracking fruits with hard woody fruit. The most consumed and famous tree nuts are walnuts (*Juglans regia*), pistachios (*Pistacia vera*), hazelnuts (*Corylus avellana L*), pecans (*Carya illinoinencis*), almonds (*Prunus dulcis*), Brazil nuts (*Bertholletia excelsa*), macadamias (*Macadamia integrifolia*), cashews (*Anacardium occidentale*). Nuts have been part of the diet of our ancestors. They even appeared in archaeological finds and excavations several hundred thousand years old. With industry development, people began to use them as sources of oils for cosmetics, shells as fuel. The nuts present many macronutrients such as protein, fat, carbohydrate, micronutrients, vitamins and minerals, fat-soluble bioactive, MUFA, PUFA, monoacylglycerols, diacylglycerols, triacylglycerols, sphingolipids, sterol esters (USDA 2007). Almond is the most edible and popular nuts worldwide, 3.9 million tonnes (FAO 2018). Because of their high-fat content, nuts are often mistakenly labelled as evil. However, many studies show nuts have sound effects on human health due to their unique composition of fatty acids. (Carrión et al. 2007). They are rich sources of essential nutrients and fatty acids, consisting of health-promoting compounds like macro and micronutrients, fat-soluble bioactive, fibre, water-soluble vitamins such as folate, non-sodium minerals, and phenolics (USDA 2018).

4.3.1. Chemical Composition of Edible Nuts

Nuts are nutritionally valuable food that has lack water and high energy content. The energy value of nuts consists of high content of fats from them MUFA and PUFA are essential. The content of SFA is low. Nuts are a good source of precious protein. Besides, they are a valuable source of vitamins, minerals and trace elements. They contain essential non-nutritive substances with a bioactive effect. Water in nuts is usually below 10 %. The water in nuts depends on harvest, storage and climatic conditions during growth. Moisture content is essential for the longer shelf life and sensory quality of the product. Low humidity prevents undesirable biochemical changes. (Maskan et al. 1999).

The total carbohydrate content is average around 12 %, compare to other plants, nuts do not contain a high amount of starch as a storage polysaccharide below 1.5 %. Sucrose is the main disaccharide, and its proportion is more than 0.5 %. The carbohydrates content also depends on growing conditions. The fibre content in nuts is 5-10 % of the portion's daily requirement. Fibre has good affection on health, especially a significant effect on the gastrointestinal system. It is involved in preventing colon cancer and positively impacting the cardiovascular system, blood cholesterol levels, and postprandial glucose levels (Nanos et al. 2002).

Almost all nuts are a good source of proteins. Pistachios, almonds, and cashews have the highest amount of proteins, 18-26 %, and proteins from animal products. Nuts do not contain essential amino acids. For example, nuts lack lysine, tryptophan, cysteine, methionine amino acids. In contrast to animal products, nuts are rich in arginine. The fat content of nuts is high (from 46 %) in cashews, in macadamias (76 %). Hazelnuts, pecans, walnuts content of fat is more than 60 %. Usually, fat content in nuts depends on geographical location and climate. Walnuts have five times more PUFA than MUFA.

In contrast, cashews, macadamias, almonds, pecans, and pistachios are rich in PUFA and oleic acid. MUFA and PUFA play a big part in tree nuts chemical composition. It ranges from 0.4 g/100 g in chestnut to 58.9 g/100 g in macadamia nuts or 47.2 g/100 g in coconuts. Cashew, pecan, brazil nuts predominate in MUFA over PUFA, according to Ryan et al. (2006). However, because of the high-fat content in nuts, their intake must correspond with other fat sources' input to not exceed the recommended daily energy intake's total income. The WHO (2002) and FAO (2003) studies compared in all type of tree nuts except macadamia the tryptophan amino acids are limiting. The total amino acids in tree nuts are between 31.2 % to 53.1 %. It means all tree nuts have the highest ratio of essential amino acids recommended by the World Health Organization (Alasalvar et al. 2010).

Nuts are also a good source of vitamins such as vitamin E, B2, B6, K, A, C. This macronutrient has antioxidant effects on its own PUFA. Most antioxidants are in the skin on the nut' surface. Peeled nuts are without most of the antioxidants. Nuts contain a high amount of Ca, Mg, P, Mn, K. Some nuts also contain Zn, Fe. Almonds contain high amounts of Ca, cashew Fe. A low Na content can be the advantage of nuts because low Na intake with high K intake positively affects CVD. However, salted or roasted nut consumption discards this advantage. **Figure 2.** (Alasalvar et al. 2010) shows that macadamias and hazelnuts are rich in MUFA. In contrast, walnuts and pine nuts contain a high amount of PUFA. Pine nuts contain just 58 mg of total polyphenols.

Nuts	Energy (kJ)	Protein (g)	Fibre (g)	Fat (g)	SFA (g)	MUFA (g)	PUFA (g)	LA (g)	ALA (g)	PS (mg)	Na (mg)	K (mg)	Ca (mg)	Total polyphenols (mg)
Almonds	2418	21·3	8·8	50·6	3·9	32·2	12·2	12·2	0·00	120	1	728	248	287
Brazil nuts	2743	14·3	8·5	66·4	15·1	24·5	20·6	20·5	0·05	NR	3	659	160	244
Cashews	2314	18·2	5·9	46·4	9·2	27·3	7·8	7·7	0·15	158	12	660	37	233
Hazelnuts	2629	15·0	10·4	60·8	4·5	45·7	7·9	7·8	0·09	96	0	680	114	687
Macadamia nuts	3004	7·9	6·0	75·8	12·1	58·9	1·5	1·3	0·21	116	5	368	85	126
Peanuts	2220	25·8	8·5	49·2	6·8	24·4	15·6	15·6	0·00	220	18	705	92	396
Pecans	2889	9·2	8·4	72·0	6·2	40·8	21·6	20·6	1·00	102	0	410	70	1816
Pine nuts	2816	13·7	3·7	68·4	4·9	18·8	34·1	33·2	0·16	141	2	597	16	58
Pistachios	2332	20·6	9·0	44·4	5·4	23·3	13·5	13·2	0·25	214	1	1025	107	1420
Walnuts	2738	15·2	6·4	65·2	6·1	8·9	47·2	38·1	9·08	72	2	441	98	1558

Figure 2. Chemical Composition of Edible Nuts

Source: Tree Nuts Composition Alasalvar et al. 2010

4.3.2. Bioactive Compounds

Almonds, Brazil nuts, cashews, hazelnuts, macadamias, pecans, pistachios, and walnuts are frequently consumed nuts. Although peanuts are considered legumes, the beneficial health effects and nutrient composition are identical, which is why they are part of the nut's food group by nutritionists. Different nuts contain different nutrient compositions, although some have the same nutrient composition (International Nut and Dried Fruit Council, 2019; USDA, 2018). Antioxidant and anti-inflammatory compounds present in nuts can reduce the risk of various cancer such as pancreatic cancer, colorectal cancer, endometrial cancer, and prostate cancer (Grosso et al. 2015). There has been an increasing interest in nut oils since they are a source of bioactive constituents. Fatty acids have beneficial effects on the cardiovascular system (Soumia et al. 2013). Besides, they have an anti-inflammatory effect, which means that they can modify prostaglandin and lipid synthesis. It can also help in the brain development and neuronal functioning of growing children and people with Zellweger syndrome, multiple sclerosis, and other disease conditions. It is possible because of monoenoic fatty acids such as erucic acid and nervonic acid (Anyasor et al. 2009). Natural, unprocessed fats such as linoleic acid and oleic acid within nuts are anti-obesogenic. Phenolic compounds like flavonoids, phenolic acids, stilbenes, coumarins, lignans, and tannins are also present in nuts (Atanasov et al. 2018).

Nevertheless, the dominant phenolics compounds present in nuts are flavonoids, phenolic acids, and tannins (Bolling et al. 2011; Alasalvar et al. 2020). The most decadent number of polyphenols in nuts are proanthocyanins (condensed tannins) and hydrolysable tannins. In comparison, hazelnuts contain the highest total content of proanthocyanins (491 mg/100 g) among nuts (Lainas et al. 2016; USDA, 2018). Unsaturated fatty acids (MUFAs and PUFAs), phytosterols, and fibre in nuts are responsible for their lipid-lowering effect. In the following **Figure. 3** (Cardoso et al. 2017), the impact of nuts assessed blood pressure.

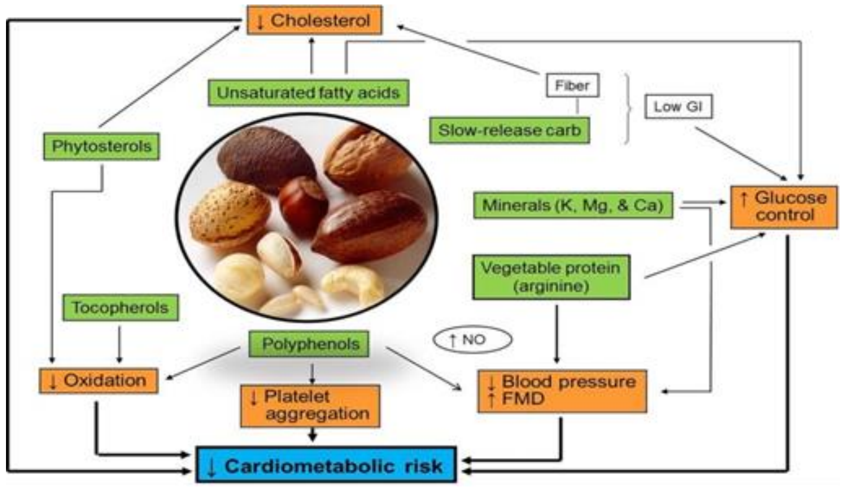

Figure 3. Mechanisms of cardiometabolic protection by nut constituents

Source: Cardoso et al. (2017)

The same meta-analysis inferred that there was no significant effect. Nut consumption did not boost blood pressure but correlated with a lower incidence of hypertension. Their unique composition in bioactive nutrients and phytochemicals prevent CVD risk (Cardoso et al. 2017). Based a recent 2- year randomised clinical trials administered showed that a diet with walnuts at 15 % of energy culminated in lower office systolic blood pressure (- 4.61 mm Hg) and reduced 24-hour ambulatory systolic blood pressure (-8.5 mm Hg) in hypertensive participants (Doménech et al. 2019). PUFA´s in nuts, slow-release carbohydrates, and non-sodium minerals are responsible for glycaemic control. Consumption of nuts has a significant effect on reducing BMI, based on 39 trials and o waist circumference in 23 attempts (Li et al. 2018).

Figure 4. (Alasalvar et al. 2015) shows the phenolic compounds (e.g., anthocyanins, flavan-3-ols, flavanols, flavanonols, flavanones, flavones, phenolic acids, hydrolysable tannins, stilbenes, tyrosyls, dihydrochalcones, and isoflavones) in nuts. It shows that almonds, chestnuts, hazelnuts, peanuts, pecans, pine nuts, pistachios, and walnuts contain diverse phenolic. Pecans have the highest numbers of phenolic acids. Flavan-3-ols are present in all nuts except heartnut and macadamias. Pistachios are the only nuts that contain isoflavones, while dihydrochalcones are present only in hazelnuts.

Tyrosyls, derivatives of phenethyl alcohol, are also included in almonds, chestnuts, hazelnuts, pistachios, and walnuts (Alasalvar et al. 2015).

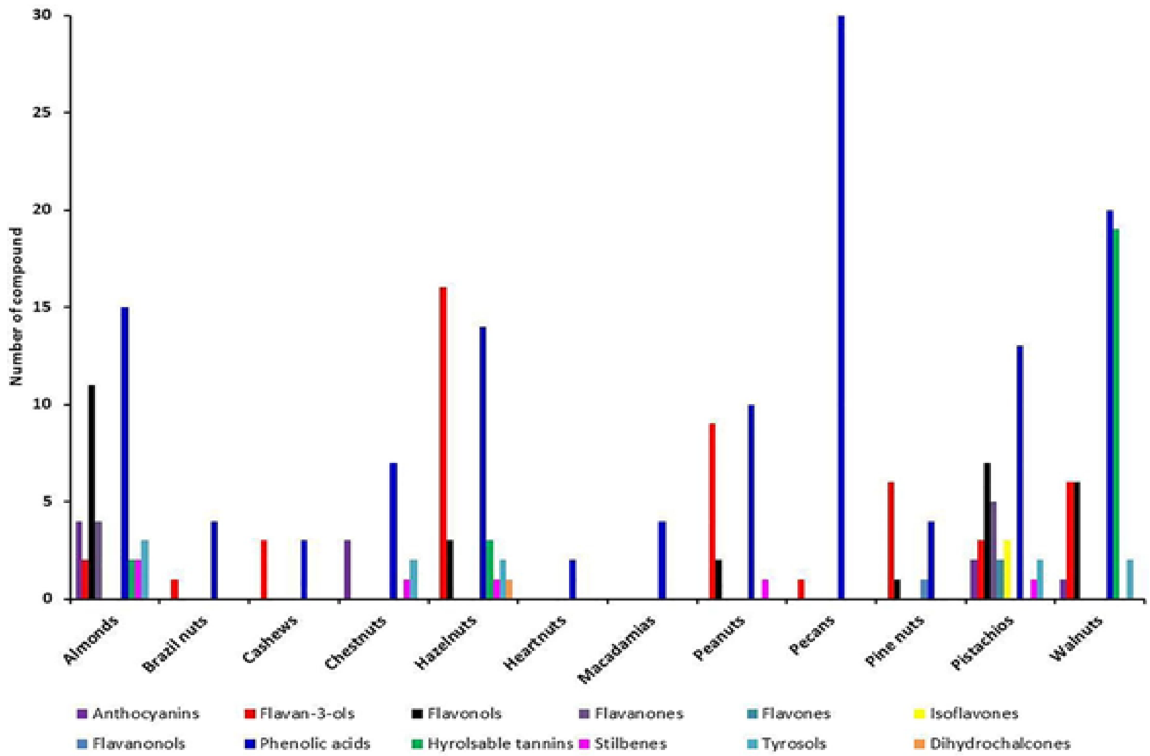

Figure 4. The Phenolic Compound in Edible Nuts.

Source: Alasalvar et. al (2015)

4.3.3. Health Benefits of Nuts

There is an inverse relationship between nut consumption and type-2 diabetes, and it is because of high bioactive compounds present like fibre, polyunsaturated fatty acids, monounsaturated fatty acids, and magnesium (Sabate et al. 2009). On the other hand, CVD is the main focus of epidemiological research. A recent meta-analysis, reviewed by Becerra-Tomás et al. (2019) based on cohort studies, has examined the consumption of nuts and nut components like peanut butter with CVD outcomes. The meta-analysis idea suggests that consuming nuts is beneficial for fatal and non-fatal CVD, CHD, and atrial fibrillation. However, there are no effects on stroke incidence of heart failure. Another study confirmed that when men and women with type 2 diabetes increased their consumption of nuts in their diet., they have decreased the risk of CVD, CHD, and all-cause and cancer mortality (Li et al. 2011). Based on the evidence presented, nut consumption can also reduce hypertension risk. Recent meta-analyses report a 15% reduction in hypertension by increased nut consumption (Schwingshackl et al. 2017).

Although there is no supporting evidence between dementia and nut consumption (Arab and Ang, 2015; O'Brien et al. 2014), there are developing epidemiological and clinical trials (Valls-Pedret et al. 2015). Long-term consumption can improve cognitive function. A review made in 2014 proposed that nuts do not affect adiposity (Jackson & Hu, 2014). Another meta-analysis confirmed a 3-5 % reduction of weight gain for each serving per day (Li et al. 2011). Scientific evidence also suggests the health benefits of nuts on adiposity. A meta-analysis of 61 randomised controlled trials lasting from 3 to 26 weeks concluded that consumption of nuts per serving each day could decrease total cholesterol (−4.7 mg/dL), low-density lipoprotein LDL cholesterol (−4.8 mg/dL), apolipoprotein B (−3.7 mg/dL) and triacylglycerol (TAG) (−2.2 mg/dL) but no significant effect on high-density lipoprotein HDL cholesterol (Del Gobbo et al. 2015). Although there is no solid evidence, some epidemiologic studies proposed that consuming nuts reduces the risk of T2D (Luo et al. 2014; Schwingshackl et al. 2017).

Furthermore, a meta-analysis was conducted with 40 randomised control trials (3 months duration) to conclude that tree nuts consumption has a significant effect on insulin resistance (IR), but no effect on fasting glucose (Tindall et al. 2019). According to some intervention and epidemiological studies, nuts’ high consumption leads to a decreased risk of heart disease and other health problems like diabetes, gallstones, and colorectal cancer (Fraser et al. 1992; Sabate and Ang, 2009; Sabaté et al. 2010). Randomized controlled trials findings share the same idea (Del Gobbo et al. 2015; Tindall et al. 2019).

According to some studies, another nuts´ benefit is enhancing lipid profiles and reducing inflammatory factors (Miller et al. 2005; Mukuddem-Petersen et al. 2005). A few studies suggest that it can significantly reduce the average risk of coronary artery disease by 37 % by consuming nuts. The same goes for fatal coronary heart disease, sudden cardiac death, and non-fatal myocardial infarction (Kelly and Sabaté 2006). Yang et al. (2009) and Vos et al. (2015) stated a significant inverse relationship between nuts and body weight consumption. The satiating effect of nuts is why there is no weight gain even if consumed in high amounts. It results in incomplete digestion, partial fat malabsorption, and metabolizable energy reduction (Jackson & Hu et al. 2014).

The PREvención con DIeta MEDiterránea (PREDIMED) trial tested the Mediterranean diets supplemented with extra-virgin olive oil or mixed nuts vs low-fat control diets. The results showed that two Mediterranean diets decrease CVD by 30 % (Estruch et al. 2018). In comparison, incident stroke decreased by 45 % by nut versus the control diet. Concerning cardiometabolic outcomes, a Mediterranean diet with nuts has a 46 % reduction in peripheral artery disease incidence (Ruiz-Canela et al. 2014). The trial also proposed the nut´s effects on classic and emergent cardiovascular risk factors and genetic predisposition to disease (Ros et al. 2014). Overall, PREDIMED trial results showed the effects of nuts and other healthy foods in improving health (Alasalvar et al. 2020).

L-arginine is a substrate for the enzyme nitric oxide synthase responsible for endothelium-dependent vascular movements producing important nitrogen oxides. With these ingredients, nuts have a great capacity to Regulating inflammatory conditions in the body and for this reason, is frequent consumption of nuts with a reduced risk of diabetes and CHD associated (Salas-Salvadó et al. 2008).

A study conducted by Bes-Rastrollo et al. (2009) examined the correlation of nut consumption and weight change over eight years of free-living women population from the Nurses' Health Study (NHS) II, a prospective cohort study in the US female nurses. The results exhibited that women who ate nuts ≥two times/week experienced a slightly lower weight gain (5.04 ± 0.12 kg) than those who seldom ate nut.

4.3.3.1. Effects of nut consumption on Cardiovascular, Type-2 Diabetes, Hypertension and other diseases

Since nuts contain high-fat, energy-dense foods presumably, regular ingestion of nuts can result in weight gain and, consequently, increase the risk of many chronic degenerative diseases (Sabate et al. 2009). The Seguimiento Universidad de Navarra (SUN) prospective study disputed the notion that regular or nut intake can result in weight gain. This study directly assessed the effect of nut consumption on body weight. Their results showed that subjects who ate nuts two or more times per week had a significantly lower risk of weight gain than those who never ate nuts. They also stated that nut consumption was not significantly associated with incident overweight/obesity in the cohort (Bes-Rastrollo et al. 2007).

As the body fat increases, the probability of developing type-2 diabetes also rises. An estimated 85 % of people with diabetes are type-2, and 90 % are obese or overweight (Kumanyika et al. 2002). Type-2 diabetes mellitus (T2DM) is tantamount to other health complications such as CVD, certain cancers, retinopathy, neuropathy, nephropathy, and gallstone disease (Grundy et al. 1999). Another population-based prospective cohort study among middle-aged Chinese women in Shanghai showed the association between legumes consumption and type-2 diabetes. According to their results, there is an inverse association between quintiles of total legume intake and three mutually exclusive legume groups (peanuts, soybeans, and other legumes) and T2DM incidence (Villegas et al. 2008). Studies have suggested that high consumption of MUFA's and PUFA's while low consumption saturated and trans-fat can reduce the risk of T2D (Risérus et al. 2009).

Nuts are rich in proteins, dietary fibre related to increased satiety, which may increase oxidation that potentially decreases body fat accumulation. The protein, fibre, and unsaturated fat content in nuts may also increase thermogenesis and resting energy expenditure (Alper & Mattes, 2002). The presence of dietary fibre (especially viscous fibre) reduces gastric emptying and subsequent absorption, potentially suppressing hunger (Jenkins et al. 2000). Oleic acid is a fatty acid present in olive oil, which accounts for 49 %–83 % of its total fatty acids and has beneficial cardiovascular effects. (Piroddi et al. 2017).

A significant number of scientific studies suggest that regular consumption of the recommended number of nuts (30 or 42.5 g/d, depending on recommendation by the European Food Safety Authority (EFSA) or the Food and Drug Administration (FDA) respectively) results in lower rates of some NCDs. Furthermore, FDA approved three types of nuts for health claims. Thus, walnuts and macadamias proposed to reduce the risk of CHD (Food and Drug Administration, 2003, Food and Drug Administration, 2004, Food and Drug Administration, 2017), and EFSA has approved one authorized health claim for walnuts related to their vascular protective properties (European Food Safety Authority, 2011). Although, FDA and EFSA recommend different amounts of consumable nuts, 42.5 g/day, whereas EFSA recommends 30 g/day respectively.

According to suggestive evidence, nut consumption can also reduce hypertension risk. A recent meta-analysis reported a hypertension reduction risk by 15 % by increased nuts' consumption (Schwingshackl et al. 2017). Although there is no supporting evidence between dementia and nut consumption (Arab and Ang, 2015; O'Brien et al. 2014), there are developing epidemiological and clinical trials (Valls-Pedret et al. 2015). Long-term consumption can improve cognitive function.

There is an inverse relationship between Mg intake and incidence of hypertension after a long-term follow-up, according to the results of Dominguez et al. (2020). The results confirmed that participants who were overweight and obese but magnesium intake was below 200 mg/dL had a further significantly excess than lean and overweight or obese participants with higher Mg intake. Besides, they have various health benefits due to their high content of nutrients, minerals, antioxidants and other phytochemicals. This study confirmed that nuts' consumption could help reduce blood cholesterol and has other beneficial effects on the cardiovascular risk profile (Ros and Mataix, 2006).

In 2003, the US Food and Drug Administration claimed the inverse relationship of nut consumption and reduced risk of CHD and intermediate biomarkers, such as blood cholesterol. Same findings from Sabate & Kelly (2006) and Griel et al. (2006) that frequent nut intake has been associated with lesser rates of CVD events and sudden death in observational studies of large cohorts and with a consistent hypocholesterolemia effect in short-term feeding trials. Another cohort study also suggests that increased intake of nuts is related to decreased CVD risk according to the observational and extensive cohort studies with a consistent hypocholesterolaemia effect in short-term feeding trials (Ros & Mataix, 2006). In another study conducted by Jiang et al. (2002), their study showed the inverse relation of frequent consumption of nuts or peanut butter prevents the risk of developing type-2 diabetes (Grundy et al. 1999).

Consumption of tree nuts correlates with improvements in blood lipid parameters and reduced waist circumference. Dietary intake of unsaturated fatty acids has a lower hazard ratio for all-cause mortality (Wang et al. 2016). Luo et al. (2014) showed that nut intake is inversely associated with IHD, overall CVD, stroke in women, and all-cause mortality. Nuts also contain a variety of vitamins, minerals, phytosterols, and antioxidants (e.g., folic acid, vitamins E and B-6, calcium, magnesium, copper, zinc, selenium, phosphorus, arginine, potassium, and niacin) that may all have additional benefits for chronic disease prevention (Segura et al. 2006).

Based on the evidence presented from prospective studies, it is safe to confirm that long-term nut consumption correlates with low weight gain and overweight/obesity. Furthermore, higher consumption of walnuts has a significant effect in lowering the risk of T2D in women, and much of the inverse association with T2D mediates through bodyweight (Jackson and Hu, 2014).

Adventist Health Study, Iowa Women's Health Study, Nurses' Health Study, and the Physicians' Health Study are the four cohort studies that showed the significance of nut consumption to CHD risk. There is a 37 % reduction in CHD mortality and an 8.3 % reduced risk of CHD death for each weekly serving of nuts (Fraser et al. 1992; Hu et al. 1998; Kushi et al. 1996). Nuts contain phytosterols, tocopherols, and squalene responsible for cardioprotection. They are nutrient-rich food containing antioxidant, anti-inflammatory, or anticarcinogenic properties like tocopherols, folic acids, selenium, magnesium, and several phytochemicals (Maguire et al. 2004).

Nuts contain many beneficial minerals such as Ca, Mg, and K. These minerals protect against hypertension, insulin resistance, and overall cardiovascular risk aside from bone demineralization (Karppanen et al. 2005). A prospective cohort study in Taiwan investigated the effect of peanut consumption concerning colorectal cancer. Their results showed that the consumption of peanuts safeguards against colorectal cancer. Their results showed a significant impact on women and not on men (Yeh et al. 2006).

Yazdekhasti et al. (2013) conducted a study on the relationship between nut consumption and blood pressure in the Iranian population. Their results showed that nut consumption was associated with lower SBP and DBP means. Their study also showed a lower risk of hypertension by frequent nut consumption on overweight and obese people.

4.3.4. Almonds

Scientific name: *Prunus dulcis*

Family: Rosaceae

Almonds come from the Middle East (Iran, Syria) and the South Asian climate (Pakistan). People discovered them in the Bronze Age. The fruits of almond are not edible because they are stone fruit in botanical points of view. The leading producer of almonds is the USA. It supplies one-third of world production, the other European states like Germany and Spain produce in large amounts. Almonds are sources of wood, pharmaceutical and cosmetic industries. They are also famous for cooking and baking purposes than other tree nuts. Almonds have a high energy value of 579 kcal/100 g, contain precious proteins, 28.4 g of almonds provide 7.27 mg of Vitamin E and rich in minerals such as Ca, Mg, P, Zn and K. (Alasalvar et al. 2008) (**Table 3**).

Table 3. The values of nutrients on almonds.

	USDA Database Content per 100 g
Energy (kcal)	579
Proteins	21.2 g
Carbohydrates	21.5 g
Fibre	12.5 g
Fats	49.9 g
SFA	3.8 g
MUFA	31.5 g
PUFA	12.3 g

Source: USDA 2010

4.3.4.1. Effects of almond consumption on the reduction of LDL Cholesterol

According to studies regarding the effect of tree nuts consumption, almonds have a consistent LDL-C- lowering effect in healthy individuals and among high cholesterol or type-2 diabetes individuals. Berryman et al. (2015) stated that almonds have a low SFA content, high content of protein, fibre and unsaturated fatty acids. This type of nuts has a particular number of cardioprotective nutrients such as arginine, Mg, Ca and Cu. Almonds' nutrients play a significant role in solid mechanisms to reduce LDL-C level. For example, reducing absorption between cholesterol and bile acids or excretion between cholesterol and bile acids increases LDL-C receptor activity. Many epidemiologic studies proved that almonds reduce CVD risk. That is why it is vital to research edible nuts´ health effects to reduce leading death diseases globally. The epidemiological studies from 1996 to 2015 on the impact of almond consumption on LDL-C have used different diet to see the effect of almond consumption on blood lipids.

Lovejoy et al. (2002) examined the effects of almonds in 2 human studies on insulin and serum lipids. In 1st study, they got 20 healthy people for four weeks 100 g of almonds a day to see the effect on insulin sensitivity. The 2nd study was a randomised, double-blind crossover study with 30 type-2 diabetics and four different diets for four weeks period.

- A fat-rich diet with almonds 37 % of the fat of which 10 % in the form of almonds
- A low-fat diet with almonds 25 % fat, of which 10 % form of almonds
- A fat-rich control diet in which olive oil replaced the almonds
- A low-fat control diet in which olive oil replaced the almonds

In the 2nd study, the researchers tested various MUFA sources' effects. In 1st study, the participants' body weight increased slowly. However, the total cholesterol and LDL-C significantly reduced their concentrations after four weeks. The fat intake increased, and the carbohydrate intake decreased considerably in the healthy participants. This study showed that after all four diets, the LDL-C and HDL-C concentrations were lower than before the intervention. In particular, the LDL-C levels lowered in an almond fat-rich diet. Compare to other diets, almond-rich diets resulted in the lowest total cholesterol levels, most likely due to the reduction of LDL-C levels. The researchers summed up that an almond-rich diet can lower plasma cholesterol levels in healthy and diabetics.

Berryman et al. (2015) examined the effects of a cholesterol-lowering diet with almonds (43 g/d) vs a cholesterol-lowering diet with a banana muffin and butter on 48 generally healthy individuals for six weeks. Table 4 shows almond diet decreased LDL-C to -5.3±1.9 mg/dL. The control diet decreased only for -1.7±0.6 mg/dL. The researcher concludes that almonds' daily consumption (43 g) may be a simple dietary strategy to prevent the onset of cardiometabolic diseases in healthy individuals (Berryman et al. 2015).

Abazarfard et al. (2016) investigated the effects of an almond-rich (50 g/d) diet in comparison to a balanced hypocaloric nut-free diet on 108 women with BMI >25 for 12 weeks. As a result, the almond diet group successfully reduced LDL-C (-11.72±1.69

mg/dL). TC and triglycerides improved more in almond-rich diet, also led to more significant weight loss and reduced the CVD risk factors (Abazarfard et al. 2014)

Damasceno et al. (2011) examined 18 people randomised into three diets

- Virgin olive diet
- Walnuts-rich diet
- Almonds rich diet for four weeks

To assess the effects on serum lipids replacing 40 % of the fat. LDL-C was reduced the most from baseline by 13.4 % in the almonds-rich diet compared to virgin olive oil diet (7.3 %) and walnuts-rich diet (10.8 %). According to Damasceno et al. (2011), walnut and almonds should be in health claims because of high content of unsaturated fatty acids.

Hollis & Mattes (2007) made a randomised intervention study. The aim was to determine the daily consumption of 344 kcal in almonds to see the body composition change. The study lasted for 20 weeks. Participants (20 women) consumed almonds for ten weeks. They were required to follow a standard diet for the rest of ten weeks. The trial on the almond-rich diet lowered LDL concentrations and oxidised- LDL-C while preventing HDL-C. Since the study focused on body composition change, there were no LDL-C details on the results tables.

A randomised, controlled, crossover trial by Jenkins et al. (2002) compared a self-selected low-fat diet with an almond muffin (73 g/d) low-saturated-fat diet with a muffin. 27 individuals consumed three isoenergetic supplements

- Full-dose almonds 73 g/d
- Half-dose almonds and half-dose muffin
- Full-dose muffin

The results showed that full-dose almonds performed the most significant reduction of LDL-C levels, but half-dose almonds also reduced blood lipid levels. Full-dose muffins had no reductions in LDL-C.

Kurlandsky et al. (2006) examined additive effects of consumption of dark chocolate with almonds and nuts free dark chocolate. Forty-nine healthy women followed randomised to 4 treatments for six weeks.

- Chocolate (41 g/d)
- Almonds (60 g/d)
- Chocolate and almonds
- Control diet

After the six week trial, the almond group achieved the most significant LDL-C reduction by an almonds-rich diet.

The Taiwanese researchers made a randomised crossover clinical trial to see if almond consumption would improve glycaemic control in 20 Chinese patients with type-2 diabetes. Patients followed an almond (60 g/d) or National Cholesterol Education Program diet for four weeks. Then they had a 2-week washout diet. The almond diet decreased LDL-C levels and LDL-C ratio to HDL-C by 11.6 %. In contrast control diet increased it only by 1 % (Li et al. 2011).

In a randomised crossover design, 25 subjects trial's aim was comparing the effects of 2 amounts of almond intake with the National Cholesterol Education Program Step 1 diet on serum lipids. The diets of the trial were Step 1 diet (without nuts), a low-almond diet (10 % almonds), a high-almond diet (68 g/d, 20 % almonds) for four weeks. After four weeks, a high-almond diet reduced total cholesterol (0.24 mmol/L or 4.4 %) and LDL-C by 7.0 %, the ratio of LDL-C to HDL-C was also reduced (Sabate et al. 2003).

Sweazea et al. (2004) aimed to determine if almond consumption (42 g/d) without other diets would improve diabetic and CVD risk markers in participants with type-2 diabetes. An almond-rich diet reduced the LDL-C levels. The researcher suggests almonds as a good snack option for individuals with type-2 diabetes (Sweazea et al. 2004).

Tamizifar et al. (2005) examined the effect of almonds (25 g/d) on hypercholesterolemic patients' serum lipoproteins. The study's design was NCEP 1 diet compared with NCEP 1 diet with almonds (25 g/d) for eight weeks. After an 8-week almond diet, the trial resulted that a reduction in total cholesterol and LDL-C for 9±29 mg/dL. The author states that almond (25 g/d) consumption has a favourable lipid-altering effect because of their numerous bioactive constituents (Tamizifar et al. 2005).

Spiller et al. (1998) compared the effects of the almond diet with olive oil diet against the control diet (cheese and butter-based). Forty-five men followed one of 3 diets for four weeks. Reductions of LDL-C between 3 different diet groups was entirely further. Almond-based diet group significantly induced reduction of LDL-C.

The review **Table. 4** (Google Scholar) of Randomized Controlled Trials on effects of almond consumption on LDL-C indicate that LDL-C levels lowered significantly. The main reason for almond consumption's potential mechanisms is that almonds contain beta-sitosterol, a phytosterol that is very similar to the body's cholesterol. It lowers concentrations of circulating LDL-C. The slow circulation of LDL-C reduces foam formation in the arteries. It helps to reduce the CVD risk factors and body weight.

Table 4. The effects of almond consumption on the reduction of LDL-C

References	Treatment and Almond quantity	Baseline LDL-C mg/dL In almond-rich diets	Observed LDL-C mg/dL In almond-rich diets
Abbey et al. (1994)	Almond-enriched diet vs Australian diet (pecan and coconut), 84 g/d	129.8	112.5
Wien et al. (2010)	Low-calorie almond diet vs Complex CHO low-calorie diet 84 g/d	120.5	98.5
Jenkins et al. (2002)	Full-dose almond diet vs full-dose muffin diet 73 g/d	172.08	155.07
Hyson et al. (2002)	Mean of almond supplemented diet vs baseline 65 g/d almond 35 g/d almond oil	159.2	139.3
Sebate et al. (2003)	High-almond diet vs Step 1 diet, 68 g/2.000 kcal	149.27	134.57
Lovejoy et al. (2002)	High-fat, high-almond diet vs high-fat control, 85 g/2.500 kcal	116.4	85.85
Tamizifar et al. (2005)	NCEP step 1 diet with almonds with (25 g/d) vs NCEP step 1 diet without almonds	110.8	89.96

Source: Google Scholar

Table 4. The effects of almond consumption on the reduction of LDL-C (cont.)

References	Treatment and Almond quantity	Baseline LDL-C mg/dL In almond-rich diets	Observed LDL-C mg/dL In almond-rich diets
Berryman et al. (2015)	Almond-rich (43 g/d) diet vs isocaloric muffin substitution diet	149±20	129±3
Abazarfard et al. (2016)	Almond-rich (50 g/d) diet vs a balanced hypocaloric nut-free diet	134±9.22	123±8.61
Damasceno et al. (2011)	Virgin olive oil diet vs walnut-rich (40 g/d) and almond-rich diets (50 g/d)	123.74	112.14
Li et al. (2011)	National Cholesterol Education Program Step 2 diet vs Almonds diet (56 g/d)	135.35	116.01
Kurlandsky et al. (2006)	A low-fat diet with dark chocolate and almonds (60 g/d) vs a low-fat diet with dark chocolate	123.74	116.01
Sweazea et al. (2004)	A customary diet with almonds (43 g/d) vs customary diet without almonds	120.55	102.09
Spiller et al. (1998)	Almond-based diet (100 g/d) vs olive-oil based diet	128.9	118.8

Source: Google Scholar

4.3.5. Macadamia Nuts

Scientific name: *Macadamia integrifolia*

Family: Proteaceae

Macadamia nuts are fruits of the four-leaved *Macadamia tetraphyllae*. The origin is the east coast of Australia. Afterwards, they were spread to Latin America and Africa. The trees can be up to 15 m high. The shell of macadamia is hard to crack, so they are taken to factories to take off the surface and fruits. The nuts are sold peeled, rousted or salted and usually expensive enough. Unroused macadamia is sources of oil and fuel. According to **Table 5.** (USDA 2010), nuts' energy is 718 kcal/100g, and the contents of fats are 75.5 g. Rich in minerals such as K, Mg, P. The most significant difference between macadamias from other edible nuts containing a high level of MUFA, 75.7 g fat/100 g, rich in 1.28 mg/g lipid of sterols. The diets containing high levels of MUFA reduce LDL while not lowering the level of HDL- C (Rajaram et al. 2001).

Table 5. The values of nutrients on macadamias.

	USDA Database Content per 100 g
Energy (kcal)	718
Proteins	7.9 g
Carbohydrates	13.8 g
Fibre	8.6 g
Fats	75.7 g
SFA	12.1 g
MUFA	58.9 g
PUFA	1.5 g

Source: USDA 2010

4.3.5.1. The effect of Macadamia nut consumption on the reduction of LDL-C

Griel et al. (2008) investigated the effects of macadamia nuts on 25 people with moderate to severe hypercholesterolemia who consumed a macadamia-rich diet and a control diet without nuts for five weeks in a crossover. 42.5 g/d macadamias with 33 % total fat, 7 % SFA, 18 % MUFA and 5 % PUFA. The control diet also contained 33 % total fat, 13 % SFA, 11 % MUFA and 5 % PUFA. After five weeks, macadamias' consumption decreased SFA and increased MUFA, PUFA proportion remained the same. **Table 6.** (Garg et al. 2008) shows diminishing total cholesterol and the ratio LDL-C to HDL-C. This type of nuts can lower the risk of CVD. However, only a few studies investigated macadamia nuts' effect on LDL-C.

Table 6. Plasma lipid and homocysteine concentration

	Baseline	Postintervention
Total cholesterol, mmol/L	6.51±0.15	6.30±0.15
LDL cholesterol, mmol/L	4.49.1±0.11	4.22±0.11
HDL cholesterol	1.20±0.11	1.28±0.12
Total cholesterol/HDL-cholesterol	5.91±0.37	5.37±0.34
VLDL cholesterol, mmol/L	0.81±0.09	0.80±0.08
Triglycerides, mmol/L	1.79±0.21	1.74±0.17
Homocysteine, mmol/L	7.90±0.99	9.13±0.52

Source: (Griel et al. 2008)

4.3.6. Brazil Nuts

Scientific Name: *Bertholletia excelsa*

Family: Lecythidaceae

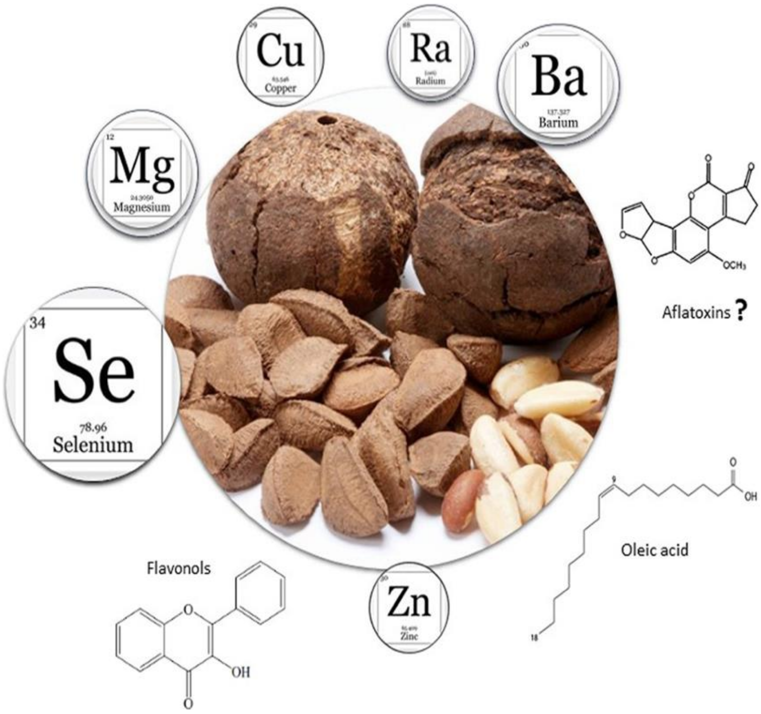

Figure 5. Brazil nuts

Source: Cardoso et al. (2017).

Brazil nuts are the fruit of *Bertholletia excelsa*. They are one of the giant trees in South America reaching 50 meters tall belonging to the family Lecythidaceae (pot family). The origin is Amazon rainforests and spread over Brazil, Bolivia and Peru. Brazil nuts play a massive role in Amazonian agriculture, and the following countries considered the leading producers. The fruit consists of a capsule with 30 centimetres in diameter, 25 triangular seeds inside. **Figure 5.** (Cardoso et al.2017) shows the seed of Brazil nut covers with a brown hard-shell within white core inside. The kernels contain 60 % fat, the nuts taste sweet, eaten mostly roasted and used in the food industry, cosmetics (soap), and the hard shell is a source for furniture. Brazil nuts are very rich in fat up to 70 %, 17 % protein with a predominance of sulphur-containing amino acids, saturated fatty acids 15 %. The MUFA and PUFA acids are equally contained (**Table 7.** USDA 2010). Vitamin E, from minerals, Ca, Mg, P, Cu, Ra, Se, Zn, Ba, predominate. Table 9 shows the values of selected nutrients of Brazil nuts. (Alasalvar & USDA 2010)

Table 7. The values of nutrients for Brazil nuts

	USDA Database Content per 100 g
Energy (kcal)	659
Proteins	14.3 g
Carbohydrates	11.7 g
Fibre	7.5 g
Fats	67.1 g
SFA	16.1 g
MUFA	23.9 g
PUFA	24.4 g

Source: USDA 2010

4.3.6.1. Effects of Brazil nuts on the reduction of LDL cholesterol

Maranhao et al. (2008) researched whether brazil nuts' consumption could change or affect the plasma lipids, HDL-C and LDL-C. Fifteen persons in 27.3±3.9 with BMI of 23.8±2.8 kg/m^2 consumed 45 g of Brazil nuts per day for 15 days. Analysis of blood was on day 0 and 15. According to studies, LDL-C level moved from 84±32 mg/dL to 88±40 mg/dL, HDL-C was higher 62±17 mg/dL to 63±17 mg/dL. Maranhao et al. (2008) state that brazil nuts, compared to other nuts such almonds, pistachios, walnuts, pecans, have no more considerable improvement of the plasma lipid profile, decreasing the level of LDL-C. Because brazil nuts content a high SFA level, there is no reduction of LDL-c consuming brazil nuts. However, the nuts' good side can affect the established atherosclerosis lipid and apolipoprotein markers. (Carvalho et al. 2008).

Table 8. shows (Maranhao et al. 2008) no substantial change in HDL-C and LDL-C levels before and after brazil nut consumption (Strunz et al. 2008).

Table 8. Effect of Brazil nuts on LDL-C and HDL-C

Parameters	Baseline	Postintervention
Total cholesterol, mg/dL	166±39	170±36
LDL cholesterol, mg/dL	84±32	88±30
HDL cholesterol	62±17	63±17
Selenium (μg/L)	56±9	208±55
Triglycerides, mg/dL	102±62	96±66

Source: Maranhao et.al 2008

4.3.7. Walnut

Scientific name: *Juglans regia*

Family: Juglandaceae

Walnuts are fruits of walnuts tree (*Juglans*), the origin comes from Iraq or Mesopotamia. The English colonists brought to North and South America, and then California became one of the world's biggest producers. The walnut trees can grow up to 35-45 meters. From a botanical point of view, walnuts are stone fruits. They can be eaten raw or cooked, often used in a bakery. Leaves are the source for colouring hair (Alasalvar et al. 2010). Walnuts are a highly nutritious food, rich in fats high proportion of PUFA oleic acid, linoleic acids, and such minerals Mg, P, and K. **Table 9.** USDA database (2010) shows the high content of PUFA in walnuts.

Table 9. The values of nutrients on walnuts

	USDA Database Content per 100 g
Energy (kcal)	654
Proteins	15.2 g
Carbohydrates	13.7 g
Fibre	6.7 g
Fats	65.2 g
SFA	6.1 g
MUFA	8.9 g
PUFA	47.2 g

Source: USDA 2010

4.3.7.1. Effect of walnut consumption on the reduction of LDL-C

Three hundred sixty-five participants have taken the 12 studies regarding the effect of nut consumption on blood lipids. The diet's meta-analysis lasted for 4 to 24 weeks, providing 24 % of calories. Walnuts decreased total cholesterol, including LDL-C concentrations (-10.3 mg/dL), the HDL-C and triglycerides were not significantly affected. The meta-analyses support that walnuts can lower serum cholesterol concentrations since walnuts contain a high level of antioxidants, which is beneficial for insulin resistance and blood pressure. According to studies, despite walnuts are rich in fats, they do not affect body weight. All 13 studies outcomes have a 6.7 % significant decrease in LDL-C concentrations. The studies are from the year 1993 to 2008. **Table. 10** (The American Journal of Nutrition 2009) compares the levels of LDL-c by consumption walnuts. The trials used different control diet types- average American, meat provided, Mediterranean, modified low fat, traditional Japanese, low fat/cholesterol (<30 % E from fat, <200 mg cholesterol) and cholesterol-lowering.

A trial by Spaccarotella et al. 2008 took eight weeks long 21 participants consumed 75 g/d of walnuts 24 % of energy intake based on 200 kcal/d. The consumption of walnuts lowers LDL-C. Compare to a various control diet. The high levels of antioxidants in walnuts increase enzyme activity and stable oxidation of LDL-C. Overall, walnuts are beneficial for oxidative stress and inflammatory markers.

The study by Tapsell et al. (2004) tested walnuts' effect on type-2 diabetics. The 58 subjects were on three different diets:

- A low-fat diet
- Modified diet (consumed different fats from other sources)
- Walnut 30 g/day diet (most of the PUFA consumed)

Only walnuts diet lowered the total cholesterol and the LDL-C levels. The researcher concluded that the walnut diet improved the lipid profile. (Tapsell et al. 2004).

Almario et al. (2001) compared the effect of 4 different diets in people with combined hyperlipidaemia. Participants followed either a conventional low-fat diet or a walnut-rich diet for four weeks. Afterwards, 48 g walnuts were consumed per day for six weeks in both diets. Despite the increased energy intake through the walnuts, there was no weight gain in the test subjects. The triglyceride levels did not change. The low-fat and walnut-rich diets reduced total cholesterol level compared to the walnut-free interventions. PUFA admissions to conventional MUFA and SFA-rich diets lowered HDL-C levels. To achieve an excellent fat distribution and an optimal lipid profile in the organism, the diet's amount and composition are crucial (Almario et al. 2001).

Table 10. The results of trials effect of walnuts on LDL-C by 12 Studies 1993-2008

Study	Baseline lipid values Total Cholesterol mg/dL	LDL cholesterol mg/dL	HDL cholesterol mg/dL	Triglycerides mg/dL	Walnut Diet	Results LDL cholesterol mg/dL
Spaccarotella et al. 2008	193.7	120.3	52.6	1 16.0	24 % (75 g/d)	-5.03
Canales et al. 2007	218.1				13 %	
Mukuddem-Petersen et al. 2007	185.6	120.3	36.3	168.3	20 % (63-108 g/d)	
Perez-Martinez et al. 2007	Normal	Normal	Normal	Normal	5 %, low fat	-0.39
Ros et al. 2004	268.0	187.7	62.3	123.1	18 %	-11.99
Tapsell et al. 2004	Walnut:158.9 Control:177.1	Walnut: 83.9 Control: 99.8	Walnut:42.5	Walnut:168.3	10 %	-6.58
Zhao et al. 2004	226.2	153.9	44.9	136.4	18 % (62 g/d) oil, high PUFA	-17.79

Source: The American Journal of Clinical Nutrition 2009

Table 10. The results of trials effect of walnuts on LDL-C by 12 Studies 1993-2008 (cont.)

Study	Baseline lipid values Total Cholesterol mg/dL	LDL cholesterol mg/dL	HDL cholesterol mg/dL	Triglycerides mg/dL	Walnut Diet	Results LDL cholesterol mg/dL
Morgan et al. 2002	232.0	154.7	58.0	159.4	20 % (64 g/d) low-fat/cholesterol	-3.87
Almario et al. 2001	230.9	138.1	49.1	218.8	16.5 % (48 g/d) Low-fat	-17.40
Zambon et al. 2000	276.9	195.3	55.7	136.4	18 % (41-56 g/d)	-11.21
Chrisholm et al. 1998	254.4	179.0	40.6		20 % (78 g/d)	-6.19
Sebate et al. 1993	197.2				20 % (84 g/d)	-18.20 Overall: -9.23
Iwamoto et al. 2002	Women: 175.2 Men: 183.7			Women: 133.7 (166.5) Men: 226.7 (123.1)	12.5 % (52 g/d) Japanese meals	Women: -8.12 Men: -6.57

Source: The American Journal of Clinical Nutrition 2009

Table 11. (Ros et al. 2004) shows the positive results of walnut consumption by participants. Compared to a Mediterranean diet, the walnut-rich diet increased total cholesterol and LDL-C levels. The entire unique composition of walnuts is very suitable for protective effects in people with hypercholesterolemia (Ros et al. 2004).

Table 11. The comparison of LDL-C levels at baseline and end of trial consuming walnuts

Variables	Baseline	Walnut Diet
Bodyweight, kg	70.6±10.3	70.5±10.2
Total cholesterol, mmol/L	6.93±0.70	6.43±0.69
LDL cholesterol, mmol/L	4.75±0.62	4.33±0.47
HDL cholesterol, mmol/L	1.61±1.59	1.57±0.44
Blood pressure (Systolic), mm Hg	131±17	127±17
Blood pressure (Diastolic), mm Hg	80±9	77±9

Source: Ros et al. (2004)

4.3.8. Pecan nuts

Scientific Name: *Carya illinoinensis*

Family: Juglandaceae

Pecan nuts are fruits of the pecan tree (*Carya illinoinensis*). They belong to the walnut (Juglandaceae) family and originally from the Mississippi River, considered traditional nuts in the USA. The USA, Australia, and Mexico are leading producers. From a botanical perspective, just like walnuts, pecans are stone fruits and grow up to 5 centimetres. They are eaten fresh, suitable for bakery and used for high-quality oil. Pecans have incredibly high energy value. The content of fats can reach 75 % depending on growing conditions. According to **Table 12.** (USDA 2010) pecans are rich in MUFA and fats, amino acids arginine and glutamic acid, from minerals P, Mg, Zn and Vitamin E. (Alasalvar et al. 2010).

Table 12. The values of nutrients on pecans

	USDA Database Content per 100 g
Energy (kcal)	691
Proteins	9.2 g
Carbohydrates	13.9 g
Fibre	9.6 g
Fats	72 g
SFA	6.2 g
MUFA	40.8 g
PUFA	21.6 g

Source: USDA 2010

4.3.8.1. Effects of pecan consumption on LDL cholesterol

The trial by Morgan et al. (2000) took eight weeks, pecan-diet against control-diet on nineteen participants with normal lipid levels. The pecan group consumed 68 g/d, control group 450 kcal (44 g) fat. The LDL-C level and total cholesterol were analysed before and after the trial. **Table 13.** (Morgan et al. 2000) shows the reduction of LDL-C during eight weeks long of pecan group. LDL-C was lower in the pecan group by 10 % (week four) and 6 % (week eight). According to Morgan et al. (2000), pecan consumption affects LDL-C-based reductions despite higher fat intake. Their findings support the hypothesis that MUFA and PUFA diet compare to SFA diet is more important than total fat intake. An infusion of antioxidant nutrients accompanies the MUFA and PUFA in tree nuts.

Table 13. The comparison of LDL-C levels at baseline and end of trial consuming pecans

Variables Serum lipid values	Baseline	Week 4	Week 8
Total cholesterol, mmol/L **Pecan Group**	4.37±0.59	4.16±0.67	4.22±0.83
Control Group	4.68±0.26	4.64±0.44	5.02±0.54
LDL cholesterol, mmol/L **Pecan Group**	2.61±0.49	2.35±0.4	2.46±59
Control Group	2.74±0.26	2.72±0.43	3.03±0.57
HDL cholesterol, mmol/L **Pecan Group**	1.29±0.10	1.32±0.23	1.37±0.23
Control Group	1.40±0.28	1.45±0.26	1.47±0.34
Total triglycerides **Pecan Group**	1.04±0.45	1.14±0.62	0.90±0.52
Control Group	1.19±0.60	1.12±0.53	1.14±0.50

Source: Morgan et al. (2000)

Based on Del Gobbo et al. (2015), a systematic review and meta-analysis of controlled trials found that pecan consumption lowered total cholesterol, LDL cholesterol, and its primary apolipoprotein. Their results showed a more significant effect on total and LDL cholesterol in non-randomised trials than randomised trials, yet evident in both trials. Their findings proposed that pecan intake significantly improves the lipid profile, Apolipoprotein B, triglycerides and provides critical mechanistic evidence to support a causal link between nut intake and lower CVD risk.

A randomised crossover, controlled trial with twenty-three participants for weeks 72 g/d pecan-diet decreased the level of total cholesterol and LDL cholesterol by 0.32 mmol/L, triglycerides by 0.14 mmol/L and HDL cholesterol by 0.06 mmol/L (Rajaram et al. 2001).

4.3.9. Hazelnuts

Scientific name: *Corylus avellana L*

Family: Betulaceae

Hazelnuts are the fruits of *Corylus avellana*. Hazelnut tree is part of deciduous forest, and they still grow in the wild. Back in the Mesolithic period, these nuts were produced in China's current territory and widely used in the Roman Empire. The tree can grow up to 7 meters, seed up to 2.5 centimetres and ripen in mid-August in Europe. The shell is wooden with an oval pointed core having rotten skin. The kernel has a sweet taste. Turkey is one of the leading producers of hazelnuts (up to three-quarters of global production). These nuts are dried and peeled before storage, famous for mixed nuts and three-quarters. Hazelnuts are suitable for medical purposes in the past times. **Table 14. (**USDA 2010) shows a high content of MUFA (80 %) of the total amount, oleic acid predominates, 17 % contain PUFA, a large number of proteins with high content of glutamic acid and a high amount of folic acid in hazelnuts. Minerals- Mg, P, Ca, and Vitamins E, are presented in high amounts (Alasalvar et al. 2008).

Table 14. The values of nutrients on hazelnuts

	USDA Database Content per 100 g
Energy (kcal)	628
Proteins	14.9 g
Carbohydrates	16.9 g
Fibre	9.7 g
Fats	60.8 g
SFA	4.4 g
MUFA	45.6 g
PUFA	8 g

Source: USDA 2010

4.3.9.1. Effects of hazelnuts on the reduction LDL-C

Hazelnuts were not studied extensively compare to almonds, walnuts or macadamia nuts. Only a few studies investigated the effects of hazelnut on reducing LDL-C. However, the Department of Medical Biochemistry of the Karadeniz Technical University in Trabzon, Turkey, made an investigation in 2002 regarding the LDL's susceptibility to oxidation on hazelnuts' consumption. According to Yücesan et al. (2010), hazelnuts are beneficial for the human body because of their biochemical composition, cardioprotective compounds such as vitamin E, phytosterols, and the highest content of MUFA among other tree nuts. MUFA has hypolipidemic effects. The trial examined 21 healthy participants. As a result, despite high-calorie intake, there was no significant change in participants' body weight.

Table 15. (Yücesan et al. 2010) shows the most profound changes were visible at the end of the fourth week, the LDL-C changes on the 15^{th} and 30^{th} days. HDL-C on the 15^{th} to 30^{th} days (Yücesan et al. 2000). Numerous studies found out that oxidised LDL-C

plays a massive role in atherosclerosis's pathogenesis. MUFA and vitamin E's high content can significantly influence LDL cholesterol's susceptibility, and high MUFA is associated with reducing CAD risk. Another reason can also be the high content of tocopherol in hazelnuts (15.03 mg/g) (Yücesan et al. 2010).

Table 15. Lipid values at baseline, 15th day and 30th day on hazelnuts consumption

Variables Serum lipid values	Baseline	15th day	30th day
Total cholesterol, mmol/L	4.21±0.59	3.94±0.72	3.75±0.63
LDL cholesterol, mmol/L	2.81±0.66	2.58±0.81	2.60±0.68
HDL cholesterol, mmol/L	1.38±0.49	1.42±0.29	1.44±0.31
Total triglycerides, mmol/L	1.01±0.67	0.97±0.59	0.88±0.48

Source: Yücesan et al. (2000)

4.3.10. Pistachios

Scienticfic names: *Pistacia vera*

Family: Anacardiaceae

Pistachios are often confused with other genus Pistacia species and are not ripe fruits of the natural as *Pistacia.* They belong to as cashew nuts in the kidney family. The origin of pistachios is Central Asia and Afghanistan. Pistachios were a source of fuel. In the 1st decade of our era, they reached Italy and spread throughout Mediterranean countries. In the 10th century, almost all over China, Australia. They grow up to 10 meters. Fruits grow up to 2.5 centimetres. From the botanical point of view, pistachios pits grow in clusters. Inside the green pericarp is a pistachio nut with red-brown skin.

Before maturity, the flesh begins separating from the shell. The nuts are usually dried or roasted with a skin. They are widely famous in the food industry, ice creams, pastries as flavourings. Also, they have low-fat content compare to other tree nuts. Oleic and linoleic fat contents reach 60 %. Proteins contents 20 % of total weight, carbohydrates are low compare to other nuts. They are rich in vitamins such as A, C, B6 thiamine, B6 pyridoxine and minerals such as Ca, P. High amount of phytosterols predominate (Alasalvar et al. 2010).

Table 16. The values of nutrients on pistachios

	USDA Database Content per 100 g
Energy (kcal)	560
Proteins	20.2 g
Carbohydrates	27.2 g
Fibre	10.6 g
Fats	45.3 g
SFA	5.9 g
MUFA	23.3 g

Source: USDA 2010

4.3.10.1. Effects of pistachios consumption on the reduction of LDL-C

In an animal study with healthy rats by Aksoy et al. (2007), after an intervention with 20 % intake in pistachios, LDL oxidation was slow. The paraoxonase activities- a Ca dependent protein increased by 35 %, and arylesterase increased by 60 %, which inhabits LDL-C oxidation. Probably, because of the large fat intake. Overall, pistachios positively affect the lipoprotein profile (Aksoy et al. 2007).

Pistachios are high in lutein compare to other nuts. Studies of the effect of pistachios on the reduction of LDL-C is lacking. However, there has been a trial researched by Kay et al. (2010). The crossover-controlled-feeding study evaluated two doses of pistachios on serum antioxidants and biomarkers of oxidate status in 28 hypercholesterolemic adults. The patients consumed three isoenergetic diets for four weeks.

1). The 1st diet- a lower-fat control diet without pistachios 25 % of total fat with one serving per day 32-63 g/d of pistachios (1 PD 10 % energy from pistachios 30 % total)

2). The 2nd diet- two serving per day 63-126 g/d of pistachios (2 PD 20 % energy from pistachios 34 total fat)

As a result, the pistachio diet significantly affected LDL-C, uric acid, lutein and lycorine. **Table 17.** (Kay et al. 2010) shows the rapid decrease of LDL-C levels from baseline to 1 PD and 2 PD. The control diet did not succeed in the improvement of lipoprotein profiles. The study demonstrates the beneficial effects of pistachios on LDL-C levels since the oxidised- LDL is a risk factor for CVD. The decrease in oxidised-LDL has occurred with a significant increase in antioxidants´ serum concentration. In conclusion, pistachios´ consumption in the context of a heart-healthy diet confirms CVD prevention beyond established affection of LDL-C levels by consuming pistachios (Kay et al. 2010).

Table 17. The results of pistachios diet on reduction of LDL-C

Biomarker	Baseline	Control Diet	1 PD diet	2 PD diet
LDL-C mmol/L	3.43±0.11	3.42±0.11	3.08±0.11	2.98±0.11

Source: Kay et al. 2010

4.3.11. Cashew Nuts

Scientific name: *Anacardium occidentale*

Family: Anacardiaceae

Cashew nuts are the fruit of *Anacardium occidentale* belong to the kidney family as pistachios. The origin of cashews is Brazil. Lately, the nuts spread over Asia and Africa. The most prominent producers are Brazil, Vietnam, Nigeria and India. The evergreen tree can grow up to 15 meters with many flowers ripen 1 to 2 fruits, and each fruit has only one eye, and it develops to cashew apple ripen. Cashew nuts are essential nuts because they are source in the food industry, bakery, confectionery, and chocolate. They contain less fat than other tree nuts (**Table 18.** USDA 2010). Only 46 % is unsaturated fatty acids of the total weight. About 16 % have protein with a very high amount of glutamic acid. They are rich in K, thiamine and pyridoxine. From minerals Mg, P and Fe predominate. (Alasalvar et al. 2010).

Table 18. The values of nutrients on cashew nuts

	USDA Database Content per 100 g
Energy (kcal)	553
Proteins	18.2 g
Carbohydrates	30.2 g
Fibre	3.3 g
Fats	43.8 g
SFA	7.8 g
MUFA	23.8 g

Source: USDA 2010

4.3.11.1. Effects of cashew nuts consumption on the reduction of LDL-C

The study by Mukuddem-Petersen et al. (2007) directly compared the effects of cashew nuts and walnuts employed in people with metabolic syndrome. The 64 participants followed a 3-week run-in control diet. They were divided into three groups and followed either a walnut-rich diet, a cashew-rich diet and a diet without nuts. 20 % of the total energy were from nuts, with the walnuts containing more linoleic acid and cashews increased oleic acid. Despite the different composition of these two types of nuts, no diet was significant on blood pressure or C-reactive protein concentrations. As a result of this study, the plasma glucose concentrations increased significantly in the cashew group compared to the control group (Mukuddem-Petersen et al. 2007).

Cashew nuts are one of the most consumed tree nuts in the world. Rich in MUFA and PUFA are strongly associated with reduced CVD risks. One recent study by Mah et al. (2017) investigated the effect of moderate intakes of cashews on serum lipids in adults with or at risk of high LDL-C. The design was a crossover-isocaloric-controlled-feeding study. 51 men and women age from 21 to 73 with a median LDL-C concentration of 159 mg/dL at screening consumed American diet with cashew nuts 64 g/d and 50 % of kilocalories from carbohydrate, protein- 18 %, and fat- 32

The 2nd diet was potato chips carbohydrates 54 %, protein- 18 % of kcal and fat- 32 % of kcal. The diets lasted for 28 days. **Table 19.** (Mah et al. 2017) shows LDL-C level during baseline and at the end of the trial. The cashew nuts diet significantly lowered LDL-C and total cholesterol concentrations, but the attention of HDL-C and triglycerides brought no changes. Reduction of LDL-C by 4.8 %, total cholesterol by 3.9 %, by 5.3 % HDL-C and triglyceride (Mah et al. 2017).

Table 19. The effects of cashew nuts and control diets on the reduction of LDL-C

Variable mg/dL	Baseline lipid values Control diet mg/dL	End of control diet mg/dL	Baseline Lipid values of cashew nuts diet mg/dL	End of cashew nuts diet mg/dL
LDL-C	146	150.5	155.5	142.8
Total cholesterol	224.5	227.8	224.5	220.0
HDL-C	51.0	49.3	52.5	50.5
Total cholesterol: HDL-C	4.5	4.6	4.3	4.3
Triglycerides	88.5	101.3	95.0	95.0

Source: Mah et al. (2017)

Nevertheless, in contrast, FDA and EFSA did not include cashews in the health claim for nuts and heart diseases because of the amount of SFA (4 g/50 g), representing 20 % of the total fat. SFAs´ are known as hypercholesterolemic than the MUFAs and PUFAs. SFAs´ increase LDL-C concentrations. The top 3 abundant SFAs in cashews are palmitic (48 %), stearic (32 %), lauric (9 %) acids. Palmitic acids are most hypercholesterolemic, but stearic acid significantly lowers LDL-C concentrations. Despite this fact, cashews decreased the level of LDL-C. It explains the possibility of de novo synthesis of most SFAs from carbohydrates. This study did not investigate the specific cashew components that lower the LDL-C concentrations. Future studies are needed to explore further cashew's health benefits (Mah et al. 2017).

5. Conclusions

Obesity is an epidemic worldwide, increasing CVD risk, T2DM. Unhealthy food (fats) can cause dyslipidemia and atherosclerosis. High LDL-C develops fatty deposits in blood vessels, causing stroke or heart attack.

Nuts are nutrient-dense food rich in plant protein 25 % and fat 75 %. According to 36 clinical trials, approximately 1,340 participants from 1999 to 2018 compare carbohydrate (CHO) low-calorie, olive-oil-based, high-fat-based, Step 1, Mediterranean, low-fat, full-dose muffins, and other control diets with eating almonds, pecans, hazelnuts, pistachios, macadamias, walnuts, and cashews diets lowered TC, LDL-C, the ratio of LDL-C to HDL-C. The interventions lasted between 3 and 26 weeks. Daily consumption of 67 g of nuts resulted in a mean reduction of LDL-C 10.2 mg/dL or a 7.4 % change. The nuts improve endothelial function-lowering oxidative stress. According to experts, nuts are rich in monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), plant sterols, L-arginine (improves artery walls making them flexible), Vitamin E (stops the development of plaques in the arteries), minerals such as magnesium, copper, phytonutrients.

The favourable fat composition and fibre contribute to nut consumption's hypocholesterolemic benefit. The more significant LDL-C effect comes when nuts replace saturated fat and carbohydrates. The trials confirm that nut consumption lowers CHD risk and supports the inclusion of nuts in therapeutic dietary interventions to improve lipid profiles. However, this confirmation remains elucidated since data on the long-term effect of nuts on LDL-C is lacking. Therefore, there is a need for further investigations to test the effects of long-term consumptions of nuts on LDL-C.

6. References

Abazarfard Z, Eslamian G, Salehi M, Keshavarzi S. 2016. Randomised Controlled Trial of the Effects of an Almond-enriched, Hypocaloric Diet on Liver Function Tests in Overweight/Obese Women. Iranian Red Crescent Medical Journal **19**:457-64.

Abbey M, Noakes M, Belling GB, Nestel PJ. 1994. Partial replacement of saturated fatty acids with almonds or walnuts lowers total plasma cholesterol and low-density lipoprotein cholesterol **59**:995-999.

Aekplakorn W and Mo-suwan L 2009. Obesity Reviews **10:**587-588.

Afolabi HA, Zakariya ZB, Shokri ABA, Hasim MNBM, Vinayak R, Afolabi-Owolabi OT, et al. 2020. The relationship between obesity and other medical comorbidities. Obesity Medicine **17:** 100-164.

Afshin A, Forouzanfar M, et al. 2017. Health Effects of Overweight and Obesity in 195 Countries over 25 Years. The New England Journal of Medicine **377:**13-27.

Afshin A, Sur PJ, Fay K, et al. 2019. Health effects of dietary risks in 195 countries, 1990–2017: A systematic analysis for the Global Burden of Disease Study 2017. The Lancet **393:**1958-1972.

Ahirwar R. and Mondal PR. 2019. Prevalence of obesity in India: A systematic review. Diabetes & Metabolic Syndrome: Clinical Research & Reviews **13:**318-321.2

Aiello AM, de Mello LM, et al. 2015. Prevalence of Obesity in Children and Adolescents in Brazil: A Meta-analysis of Cross-sectional Studies. Current Pediatric Reviews **11:**36-40.

Alasalvar C, Bolling BW. 2015. Review of nut phytochemicals, fat-soluble bioactive, antioxidant components and health effects 113:68-78.

Alasalvar C, Salvador JS, and Ros E. 2020. Bioactives and health benefits of nuts and dried fruits. Food Chemistry.

Alasalvar C, Shahidi F. 2007. Tree nuts composition, phytochemicals and health effects. Taylor & Francis/CRC Press.

Almario RU, Vonghavaravat V, Wong R, Kasim-Karakas SE. 2001. Effects of walnut consumption on plasma fatty acids and lipoproteins in combined hyperlipidemia **74:**72-9.

Amianto F, Lavagnino L, Abbate-Daga G, Fassino S. 2011. The forgotten psychosocial dimension of the obesity epidemic.

Amiri S and Behnezhad S. 2019. Obesity and anxiety symptoms: a systematic review and meta-analysis **33:**72-89.

Anyasor GN, Ogunwenmo KO. et al. 2009. Chemical analyses of Groundnut (Arachis hypogaea) oil Pakistan. Journal of Nutrition **8**:269-272.

Arab L and Ang A. 2015. A cross-sectional study of the association between walnut consumption and cognitive function among adult US populations represented in NHANES. Journal of Nutrition Health and Aging **19:**284-290.

Atanasov A, Sabharanjak S, Zengin G. et al. 2017. Pecan nuts: A review of reported bioactivities and health effects. Trends in Food Science & Technology **71:**246-257.

Berryman CE, Preston AG, Karmally W, Deckelbaum RJ, Kris-Etherton PM. 2011. Effects of almond consumption on reducing LDL-cholesterol: a discussion of potential | mechanisms and future research directions **69**:171-185.

Berryman CE, West SG, Fleming JA, Bordi PL, Kri-Etherton PM. 2015. Effects of daily almond consumption on cardiometabolic risk and abdominal adiposity in healthy adults with elevated LDL-cholesterol: a randomised controlled trial **4**:e000993.

Bes-Rastrollo M, Sabaté J, Gomez-Gracia E. et al. 2007. Nut consumption and weight gain in a Mediterranean cohort: the SUN study. Obesity (Silver Spring) **15:**107–16.

Calle EE, Rodriguez C, Walker-thurmond K. et al. 2003. Overweight, obesity, and mortality from cancer in a prospectively studied cohort of U.S. adults. New England Journal of Medicine **348:**1625-1638.

Cardoso BR, Silva Duarte GB, Reis BZ. et al. 2017. Brazil Nuts: Nutritional composition health benefits and safety aspects. Food Research International **100**:9-18.

Cederholm T, Barazzoni R, Austin P. et al 2016. ESPEN guidelines on definitions and terminology of clinical nutrition **36:**49-64.

Chrisholm A, Mann J, Skeaff M, et al. 1998. A diet rich in walnuts favourably influences plasma fatty acids profile in moderately hyperlipidaemic subjects **52:**12-6.

Damasceno N, Perez-Hras A, SerraM, Cofan M, Sala-Vila A, Salas-Salvado J, et al. 2011. A crossover study of a diet enriched with virgin oil, walnut or almond. Effects on lipids and other cardiovascular risk markers. Nutrition, Metabolism and Cardiovascular Diseases **21**:14-20.

Damasceno NR, Sala-Vila A, Cofán M. et al. 2013. The Mediterranean diet supplemented with nuts reduces waist circumference and shifts lipoprotein subfractions to a less atherogenic pattern in high cardiovascular risk subjects—atherosclerosis **230:**347-353.

Del Gobbo LC, Falk MC, Feldman R, Lewis K. et al. 2015. Effects of tree nuts on blood lipids, apolipoproteins, and blood pressure: Systematic review, meta-analysis, and dose-response of 61 controlled intervention trials. The American Journal of Clinical Nutrition **102:**1347-1356.

Demonty I, Ras R, Van der Knaap H. et al. 2009. Continuous dose-response relationship of the LDL-cholesterol-lowering effect of phytosterol intake. Journal of nutrition **139:**271-284.

Finucane MM, Stevens GA, Cowan MJ, Danaei G. et al. 2011. National, regional, and global trends in body-mass index since 1980: systematic analysis of health examination surveys and epidemiological studies with 960 countries-years and 9.1 million participants. Lancet **377:**557–567.

Food and Nutrition Research Institute8th National Nutrition Survey 2013. Food and Nutrition Research Institute, Department of Science and Technology, Taguig City (the Philippines). Available from http://www.fnri.dost.gov.ph/index.php/nutrition-statistic/19-nutrition-statistic/118-8th-national-nutrition-survey (accessed February 2021).

Fraser GE, Sabate J, Beeson WL. et al. 1992. A possible protective effect of nut consumption on risk of coronary heart disease: The Adventist health study. Archives of Internal Medicine **152:**1416-1424.

Garg ML, Blake RJ, Wills RBH. 2003. Macadamia Nut Consumption Lowers Plasma Total and LDL Cholesterol Levels in Hypercholesterolemic Men. The Journal of Nutrition **133:**1060-1063.

Gebauer SK, West SG, Kay CD, Alaupovic P, Bagshaw D, Kris- Etherton PM. 2008. Effects of pistachios on cardiovascular disease risk factors and potential action mechanisms: a dose-response study. The American Journal of Clinical Nutrition **88:**651-659.

Griel A. and Kris-Etherton P. 2006. Tree nuts and the lipid profile: a review of clinical studies. British Journal of Nutrition **96:**68-78.

Grundy SM, Benjamin IJ, Burke GL. et al. 1999. Diabetes and Cardiovascular Disease A Statement for Healthcare Professionals from the American Heart Association. Circulation **100:**1134-1146.

Hall JE, Do carmo J, Da silva AA. et al. 2015. Obesity-induced hypertension: Interaction of neurohumoral and renal mechanisms. Circulation Research **116:**991-1006.

HHS.gov. 2021. Reports and Publications. Available from https://www.hhs.gov/surgeongeneral/reports-and-publications/index.html (accessed 3 March 2021).

Hu FB, Stampfer MJ, Manson JE. et al. 1998. Frequent nut consumption and risk of coronary heart disease in women: prospective cohort study **317:**1341–1345.

Hubert HB, Feinleib M, Mcnamara PM. et al. 1983. Obesity as an independent risk factor for cardiovascular disease: A 26-year follow-up of participants in the Framingham Heart Study. Circulation **67:**968-977.

Hyson DA, Schneeman BO, Davis PA. 2002. Almonds and almond oil have similar effects on plasma lipids and LDL oxidation in healthy men and women **132:**703-707.

Instituto Brasileiro de Geografia e Estatística (IBGE). POF 2008-2009 - Antropometria e Estado Nutricional de Crianças, Adolescentes e Adultos no Brasil. 2010. Available from http://www.ibge.gov.br/home/ presidencia/noticias/imprensa/ppts/0000000108.pdf (accessed January 2020).

James WPT. 2008. The epidemiology of obesity: the size of the problem. Journal of Internal Medicine **263:**336-352.

Jenkins DJ, Kendall CW, Marchie A, Parker TL, Conelly PW, Qian W, Haight JS, Faulkner D, Vidgen E, Lapsey KG et al. 2002. Dose-response of almonds on coronary heart disease risk factors: blood lipids, oxidised low-density lipoproteins, homocysteine, and pulmonary nitric oxide: a randomised, controlled, crossover trial. Circulation **106**:1327-32.

Ji, C.Y. 2007. Working Group on Obesity in China (WGOC)Report on childhood obesity in China (4) prevalence and trends of overweight and obesity in Chinese urban school-age children and adolescents, 1985–2000. Biomedical and Environmental Sciences **20:**1-10.

Karppanen H, Karppanen P, and Mervaala E. 2005. Why and how to implement sodium, potassium, calcium, and magnesium changes in food items and diets?. Journal of Human Hypertension **19**:10–19.

Kay C, Gebauer S, West S, Kris-Etherton. 2007. Pistachios reduce serum oxidized LDL and increase serum antioxidant levels **21**:847

Kelly JH, Sabate' J. 2006. Nuts and coronary heart disease: an epidemiological perspective. British Journal of Nutrition **96:**61–67.

Kornsteiner M, Wagner, K. H, Elmadfa I. 2006. Tocopherols and total phenolics in 10 different nut types. Food Chemistry **98:**381-387.

Kumanyika S, Jeffrey RW, Morabia A. et al. 2002. Obesity prevention: the action case. International Journal of Obesity **26**:425–436.

Kurlandsky DR, Stote KS. 2006. Cardioprotective effects of chocolate and almond consumption in healthy women. Nutr Res **26**:509-16.

Kushi LH, Folsom AR, Prineas RJ, Mink PJ, Wu Y, Bostick, RM. 1996. Dietary antioxidant vitamins and death from coronary heart disease in postmenopausal women. New England Journal of Medicine **334:**1156–62.

Lam CS, Teng T-HK, Tay W. T, Anand I, Zhang S, Shimizu W. et al. 2016. Regional and ethnic differences among patients with heart failure in Asia: the Asian sudden cardiac death in heart failure registry. **37:**3141-3153.

Levine D, Rao V, and Michos E. 2019. The Cholesterol Problem: a Guide to the Best Foods to Improve Those Numbers. U.S. News & World Report.

Li SC, Liu YH, Liu JF, Chang WH, Chen CM, Chen CY. 2011. Almond consumption improved glycemic control and lipid profiles in patients with type 2 diabetes mellitus—metabolism **60**:474-9.

Lovejoy JC, Most MM, Lefevre M, Greenway FL, Rood JC. 2002. Effect of diets enriched in almonds on insulin action and serum lipids in adults with standard glucose tolerance or type 2 diabetes **76**:1000-1006.

Maguire LS, O'Sullivan SM, Galvin K, O'Connor TP, O'Brien NM. 2004. Fatty acid profile, tocopherol, squalene and phytosterol content of walnuts, almonds, peanuts, hazelnuts and the macadamia nut. International Journal of Food Sciences and Nutrition **55:**171–178.

Mah E, Schulz JA, Kaden VN, Lawless AL, Rotor J, Mantilla LB et al. 2017. Cashew consumption reduces total and LDL cholesterol: a randomized, crossover, controlled-feeding trial—the American Journal of Clinical Nutrition **105:**1070-1078.

Maranhao RC, Carvalho PO, Strunz CC, Pileggi Fundefined. 2014. Lipoprotein: Structure, Pathophysiology and Clinical Implications. Arquicos Brasileiros de Cardiologia .

Marshall SJ, Simoes EJ, Eisenberg CM. et al. 2013. Weight-related child behavioural interventions in Brazil: a systematic review. American Journal of Preventive Medicine **44**:543-549

Mattes R, Hollis. 2007. Effect of chronic consumption of almonds on body weight in healthy humans **98**:651-6.

McCafferty BJ, Hill Gunn AJ. 2020. Obesity: Scope, Lifestyle Interventions, and Medical Management. Techniques in Vascular and Interventional Radiology **23:**1-3.

McElroy SL, Kotwal R, Malhotra S, Nelson EB, Keck PE, Nemeroff CB. 2004. Are mood disorders and obesity-related? A review for the mental health professional. The Journal of Clinical Psychiatry **65:**634–651.

Morgan WA and Clayshulte BJ. 2000. Pecans low-density lipoprotein cholesterol in people with normal lipid levels. Journal of the American Dietetic Association **100:**312-318

Mozaffarian D. 2016. Dietary and policy priorities for cardiovascular disease, diabetes, and obesity: A comprehensive review. Circulation **133**:187-225.

Mukuddem-Petersen J, Stonehouse Oosthuizen W, Jerling JC, Hanekom SM, White Z. 2007.Effects of a high walnut and high cashew nut diet on selected metabolic syndrome markers: a controlled feeding trial **97**:1144-53.

Neeland IJ, Poirier P, Despres JP. 2018. Cardiovascular and metabolic heterogeneity of obesity: clinical challenges and implications for management. **137:**1391-406.

Niddk.nih.gov, 2021. Health Risks of Being Overweight | NIDDK. [online] National Institute of Diabetes and Digestive and Kidney Diseases. Available from https://www.niddk.nih.gov/health-information/weight-management/health-risks-overweight (accessed March 2021).

Niddk.nih.gov, 2021. Health Risks of Being Overweight | NIDDK. [online] National Institute of Diabetes and Digestive and Kidney Diseases. Available from https://www.niddk.nih.gov/health-information/weight-management/health-risks-overweight#type2 t (accessed March 2021).

O'Neil CE, Fulgoni VL, Nicklas TA. 2015. Tree nut consumption is associated with better adiposity measures and cardiovascular and metabolic syndrome health risk factors in US adults: Nutrition Journal **7:**14-64.

O'Neil CE. and Nicklas TA. 2015. Tree nut consumption is associated with better nutrient adequacy and diet quality in adults: National Health and Nutrition Examination Survey 2005–2010. Nutrients **7:**595-607.

O'Brien J, Okereke O, Devore E. et al. 2014. Long-term intake of nuts concerning cognitive function in older women. Journal of Nutrition Health and Aging **18:**496-502.

Perez- Martinez P, Lopez-Miranda J, Blanco-Colio L, et al. 2007. The chronic intake of a Mediterranean diet enriched in virgin olive oil, decreases nuclear transcription factor kappaB activation in peripheral blood mononuclear cells from healthy men **194**:141-6.

Phenol-explorer.eu. 2021. Database on Polyphenol Content in Foods - Phenol-Explorer. Available from http://phenol-explorer.eu/ (accessed March 2021).

Piroddi M, Albini A, Fabiani R, Giovannelli L, Luceri C, Natella F, et al. 2017. Nutrigenomics of extra-virgin olive oil: A review. Bio factors **43**:17-41.

Rajaram S, Burke K, Connell B, Myint T, Sabaté J. 2001. A monounsaturated fatty acid-rich pecan-enriched diet favourably alters healthy men and women's serum lipid profile—the Journal of Nutrition **131**:2275-2279.

Rajaram S, Connell KM, Sebate J. 2010. Effect of almond-enriched high-monosaturated fat diet on selected inflammation markers: a randomised, controlled, crossover study **103**:907-912.

Risérus U, Willett WC, Hu FB. 2009. Dietary fats and prevention of type 2 diabetes. Progress in Lipid Research **48:**44–51.

Ros E, Nunez I, Perez-Heras A, et al. 2004.A walnut diet improves endothelial function in hypercholesterolemic subjects: a randomized crossover trial **109:**1609-14.

Ros E. 2015. Nuts and CVD. British Journal of Nutrition **113:**111-120.

Ros E. and Mataix J. 2006. Fatty acid composition of nuts – implications for cardiovascular health. British Journal of Nutrition **96:**29–35.

Ros, E. 2010. Health benefits of nut consumption. Nut Nutrients **2**:652-682.

Sabate J. and Ang Y. 2009. Nuts and health outcomes: new epidemiologic evidence. The American Journal of Clinical Nutrition **89:**1643–1648.

Schwingshackl L, Schwedhelm C, Hoffmann G.et al. 2017. Food groups and risk of hypertension: A systematic review and dose-response meta-analysis of prospective studies. Advances in Nutrition **8:**793-803.

Sebate J, Cordero-Macintyre Z, Siapco G, Tobian S, Haddad E. 2005. Does regular walnut consumption lead to weight gain? **94:**859-64.

Sebate J, Frazer GE, Burke K, Knutsen SF, Bennet H, Lindsted KD. 1993. Effects of walnuts on serum lipid levels and blood pressure in normal men **328**:603-7.

Sebate J, Haddad E, Tanzman JS, Jambazian P, Rajaram S. 2003. Serum lipid response to the graduated enrichment of a Step | diet with almonds: a randomized feeding trial **77**:1379-1384.

Sebate J, Oda K, Ros E. 2010. Nut consumption and blood lipid levels: a pooled analysis of 25 trials **170**:821-827.

Segura-Garcia S, Caroleo M, et al. 2017. Binge eating disorder and bipolar spectrum disorders in obesity: psychopathological and eating behaviours differences according to comorbidities. Journal of Affective Disorders **208:**424-430.

Skinner A and Skelton J. 2014. Prevalence and Trends in Obesity and Severe Obesity Among Children in the United States, 1999-2012. **168:**561-566.

Smyth S. and Heron A. 2006. Diabetes and obesity: the twin epidemics. Nature Medicine **12:**75-80.

Soumia P, Sandeep C, Jubbin JJ. 2013. A fish a day keeps the cardiologist away – a review of the effect of omega-three fatty acids in the cardiovascular system—Indian Journal of Endocrinology and Metabolism **17:**422-429.

Spaccarotella KJ, Kris-Etherton PM, Stone WL, et al. 2008. The effect of walnut intake on vascular health in older men and factors related to prostate **7**:13.

Spiller GA, Jenkins DA, Bosello O, Gates JE, Cragen LN, Bruce B. 1998. Nuts and plasma lipids: an almond-based diet lowers LDL-C while preserving HDL-C **17**:285-290.

Spiller GA, Miller A, Olivera K, Reynolds J, Miller B, Morse SJ, Dewell A, Farquhar JW. 2003. Effects of plant-based diets high in raw on roasted almonds, or roasted butter on serum lipoproteins in humans **22:**195-200.

Sweazea K, Johnston C, Ricklefs K, Petersen K. 2014. Almond supplementation in the absence of dietary advice significantly reduced C-reactive protein in subjects with type 2 diabetes. **10:**252-9.

Tamizifar B, Vosough A, Aminzadeh A, Riskankarzadeh M, Rafieian M. 2005. A low-dose almond-based diet decreases LDL-C while preserving HDL-C. Archives of Iranian Medicine **8**:45-51.

Tapsell LC, Gillen LJ, Patch CS, et al. 2004. Including walnuts in a low-fat/modified-fat diet improves HDL cholesterol-to-total cholesterol ratios in patients with type 2 diabetes. Diabetes Care **27**:2777-83.

U.S. Department of Agriculture. Available from https://fdc.nal.usda.gov/ (accessed March 2021).

Valls-Pedret C, Sala-Vila A, Serra-Mir M, et al. 2015. Mediterranean diet and age-related cognitive decline: A randomized clinical trial. JAMA Internal Medicine **175:**1094-1103.

Venkatachalam M and Sathe SK. 2006. Chemical composition of selected edible nut seeds. Journal of Agricultural and Food Chemistry **54:**4705-4714.

Viguiliouk E, Kendall CW, Mejia SB, Cozma AI, Ha V, Mirrahimi A. et al. 2014. Effect of tree nuts on glycemic control in diabetes: A systematic review and meta-analysis of randomized controlled dietary trials.

Villegas R, Gao Y-T, Yang G, et al. 2008. Legume and soy food intake and the incidence of type 2 diabetes in the Shanghai Women Health Study. American Journal of Clinical Nutrition **87:**162–167.

Wang DD, Li Y, Chiuve SE, Stampfer MJ. Et al. 2016. Association of specific dietary fats with total and cause-specific mortality. JAMA Internal Medicine **176:**1134-1145.

WHO Expert Consultation 2004. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet **363:**157–63.

WHO Expert Consultation. 2004.Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet. **363:**157–63.

Who. Int. 2021. Obesity and overweight. Available from: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight (accessed March 2021).

Who. Int. 2021. WHO Global InfoBase. Available from https://www.who.int/ncd_surveillance/infobase/en/ (accessed February 2021).

Wien M, Bleich D, Raghuwanshi M, Gould-Forgerite S, Gomes J, Monahan-Couch L, Oda K. 2010. Almond consumption and cardiovascular risk factors in adults with prediabetes **29:**189-97.

Wien MA, Sebate JM, Ikle DN, Cole SE, Kandeel FR. 2003. Almond versus complex carbohydrates in a weight reduction program **27:**1365-72.

Wolin KY, Carson K, Colditz GA. 2010. Obesity and cancer. Oncologist. 15(6):556-565

World Health Organization. Obesity and overweight. Geneva: World Health Organization; 2011. https://www.who.int/en/news-room/fact-sheets/detail/obesity-and-overweight (accessed November 2020).

Yazdekhasti N. and Mohammadifard N. et al. 2013. The relationship between nut consumption and blood pressure in an Iranian adult population: Isfahan Healthy Heart Program. Nutrition, Metabolism and Cardiovascular Diseases **23**:929-936.

Yeh C-C, You S-L, Chen C-J, Sung F-C. 2006. Peanut consumption and reduced risk of colorectal cancer in women: a prospective study in Taiwan. World Journal of Gastroenterology **12:**222–227.

Young T, Skatrud J, Peppard PE. 2004. Risk Factors for Obstructive Sleep Apnea in Adults. JAMA **291:**2013-2016.

Yücesan FB, Orem A, Kural BV, Orem C, Turan I. 2010. Hazelnut consumption decreases LDL's susceptibility to oxidation. Plasma oxidated LDL level and large/small LDL ratio in normolipidemic healthy subjects. Anadolu Kardiyoloji Dergisi/The Anatolian Journal of Cardiology 28-35.

Zambon D, Sebate J, Munoz S, et al. 2000. Substituting walnuts for monosaturated fat improves hypercholesterolemic men and women's serum lipid profile—a randomized crossover trial **132**:538-46.