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ANTIOXIDANT ACTIVITY OF DIFFERENT TREATMENTS OF SESAME SEEDS ON LIPID PROFILE IN RATS WITH ATHEROSCLEROSIS

Asmaa A. Mohammed, Lamiaa A. Ahmed and Hoda S. Ibrahim,
Nutrition and Food Science Dep., Faculty of Home Economics,
Helwan University, Cairo – Egypt.

ABSTRACT

This study was carried out to investigate the antioxidant activity of different treatments of sesame seeds on lipid profile in rats with atherosclerosis. Adult male Sprague-Dawley rats (n= 72) were divided into two main groups the first main group (n=9) was fed on basal diet as a negative control group. Atherosclerosis was induced in the second main group (n = 63) which was assigned to groups 2-8. Group 2 was positive control group; the others were treated with raw, roasted and fermented sesame seeds at two levels of intake (100 and 150 gm/kg diet). At the end of the experimental period (8 weeks), feed intake was recorded and feed efficiency ratio was calculated Heart and aorta from all rats were collected for histological studies. Blood samples were collected for estimating lipid profile and its fractions. Results revealed that treatment of atherosclerotic rats with raw, roasted and fermented sesame seeds at the two levels of intake improved daily food intake, body weight gain and feed efficiency ratio. Supplementation with all forms of sesame seeds improved blood lipids parameters and atherogenic index. Results showed that the addition of sesame seeds led to a significant improvement in the results of histological studies which were coincided with the biochemical analysis .The present study recommends increasing the consumption of sesame seeds in different formsdue to its beneficial effects on lipid profile. Nutrition education programs are needed to clarify the importance of sesame seeds in reducing the risk of developing arteriosclerosis. Further studies are required to evaluate the health benefits of consuming fermented sesame seeds.
***Keywords*:** raw sesame seeds, roasted sesame seeds, fermented sesame seeds, atherosclerosis, rats, histology

Introduction

Sesame (*Pedaliaceae* family, *Sesamum indicum L.*) is one of the most important oil seed crops and is widely cultivated in tropical and subtropical areas such as Myanmar, India, China, and Africa (Yushiro *et al.*, 2018). Recently it has attracted research attention for its medicinal properties and physiological effects such as its oil quality, sterols, and antioxidative agents i.e., methylenedioxyphenyl compounds, sesamin, sesamolin, and tocopherols that act as nutraceuticals and impartresistance to oil against oxidative deterioration (NitiPathak *et al.*, 2019).

Cholesterol is an essential lipid that maintains membrane integrity and serves as a precursor of several classes of signaling molecules. However, cholesterol accumulation in the endocytic pathway is associated with neurological diseases (Vance, 2012). Dysregulation of cholesterol metabolism has been implicated in numerous diseases, including atherosclerosis and cardiovascular diseases (Vallejo *et al.*, 2017). Elevated plasma cholesterol and especially LDL cholesterol levels remain a major risk factor in cardiovascular diseases (CVD) (Ference *et al.*, 2017)The lipid profileor panel is an important blood test that serves as an initial screening for abnormalities in cholesterol and triglyceride concentrations (Reddy *et al.*, 2016). Lipoproteins qualitatively contain triglycerides, cholesterol, phospholipids and protein and are soluble means of cholesterol transport and homeostasis (Guyton and Hall 2011). Several types of lipoproteins are present in the blood in the order of increasing density, chylomicrons, very low-density lipoproteins (vLDL), intermediate-density lipoprotein (IDL), low-density lipoprotein (LDL) and high-density lipoprotein (HDL) (Kandutsch *et al.*, 1978). High-density lipoprotein cholesterol (HDL-C) is the smallest and densest of the lipoprotein. It contains the highest proportion of protein to lipids. In health, about 30% of blood cholesterol is carried by HDL (AHA, 2009), thus the cholesterol carried within HDL is called the 'good' cholesterol. Individuals with high levels of HDL-C tend to have fewer problems with cardiovascular disease while those with low HDL-C have increased propensity for heart disease (Toth *et al.*, 2016). High HDL level has been correlated with good cardiovascular health (Sirtori and Fumagalli, 2006). The low-density lipoprotein cholesterol (LDL-C) is a major lipoprotein that assists in lipid transfer in the extra cellular fluid and causes atherosclerosis by attracting macrophages into the arterial wall and hence called 'bad' cholesterol. Imbalance in cholesterol homeostasis results in early atherosclerosis (Alexander and Veronika, 2019).

Atherosclerosis is the most predominant and critical cardiovascular ailment which includes the heart and brain. This malady advances gradually and is the real reason for mortality that starts from childhood and prompts clinical appearances in adulthood. Epidemiological investigations have shown a marked relationship between specific elements and the advancement of atherosclerosis. These components are alluded as coronary artery illness (CAD) hazard factors and incorporate hypercholesterolemia, oxidative stress-related with expanded free radicals in the blood, smoking, hypertension, diabetes, age, male gender, hyper homocysteinemia, inflammatory elements, family history, past heart ischemia, atherogenic diet, and expanded lipoprotein A (Singh, 2019).

The aim of the present study was to evaluate the antioxidant activity of different treatments of sesame seeds on lipid profile in experimental atherosclerotic rats.

Materials and Methods

Materials

- Chemicals: Cholesterol (white crystalline powder), casine, vitamins, minerals, cellulose, choline chloride and formalin were obtained from Elgomhoria Company for chemical industries, Cairo, Egypt. Kits for biochemical analysis were obtained from the Chemical Trading Company, Cairo, Egypt.
- White sesame seeds *(Pedaliaceae family, Sesamum indicum L.)*, were purchased from the Agricultural Research Center, Giza, Egypt. Cornstarch and corn oil were obtained from the local market, Cairo, Egypt.
- Animals: Adult male albino rats of Sprague-Dawely strain weighing 120 – 130g were obtained from laboratory animal colony, Ministry of Health and Population, Helwan, Cairo, Egypt.

Methods:

Preparation of raw, roasted and fermented sesame seeds:

White sesame seeds *(Pedaliaceae family, Sesamum indicum L.)* were cleaned manually to remove dust, stones and any foreign material. Sesame seeds were roasted and fermented in the labs of National Research Center, Department of Nutrition and Food Science, Giza, Egypt.

Raw: Sesame seeds were milled (Wiley mill, 30 meshes) and were stored in a sealed clean glass container at room temperature (25°C) to preserve the quality of sesame seeds till use.

Roasting: Raw sesame seeds were roasted by putting a thin layer of raw seeds on a tray in preheated oven at 160 °C for about 15 min. till the seeds start getting some light golden color as described by (Hama, 2017).

Fermentation: Fermented sesame seeds were prepared by cooking raw sesame seeds in boiling water at 100ºc (1:1) for 6 h. The cooked seeds were placed in a plastic container with a tight lid and sealed. The samples were allowed to ferment in drying oven (GENTI) cell model at 35 ±2°C for 7 days and oven dried at 105°C for 12 h**.** to bring an end to fermentation. Fermented sesame seeds were stored in a sealed clean glass container according to (Makinde and Akinoso, 2014).

Experimental Animals and Design:

Seventy two adult male albino rats were adapted for one week on AIN-93M basal diet (Reeves *et al.,* 1993) before being the seated dietary groups, and received water and diet ad libitum. The room was lighted on a daily photo period of about 12 h light dark cycles. The experiment was conducted at the animal colony, Agricultural Research Center, Giza, Egypt.

After this week, rats were divided into two main groups as follows: The first main group (n=9) was kept as a control negative group, the second main group (n=63) was fed atherogenic diet to induce atherosclerosis according to Teklad Custom Diet, (2015). Random blood samples were taken weekly from the eyes using capillary tubes to insure the atherogenic index (AI) induction according to Hanglund *et al.,* (1991). Atherosclerotic rats were assigned to groups 2-8 a follow:

Group1: negative control, fed on basal diet

Group2: atherosclerotic rats, fed on basal diet (positive control)

Group3: atheroscleroticrats, fed on basal diet +100 gm/kg diet raw sesame seeds.

Group4: atherosclerotic rats, fed on basal diet+ 150 gm/kg diet raw sesame seeds.

Group5: atherosclerotic rats, fed on basal diet +100 gm/kg diet roasted sesame seeds.

Group6: atherosclerotic rats, fed on basal diet+ 150 gm/kg diet roasted sesame seeds.

Group7: atherosclerotic rats, fed on basal diet +100 gm/kg diet fermented sesame seeds.

Group8: atherosclerotic rats, fed on basal diet+ 150 gm/kg diet fermented sesame seeds.

Blood samples and tissue collection:

Body weight and feed intake were recorded daily. Feed efficiency ratio was calculated at the end of the study. At the end of the experimental period (8weeks), rats were fasted for12 h., anesthetized by diethyl ether before scarifying. Blood samples were centrifuged and serum were obtained then stored at - 20ºC in a clean well stopped vial until analysis. Total lipid, triacylglycerols, cholesterol, high density lipoprotein cholesterol, low density lipoprotein cholesterol and very low density lipoprotein cholesterol were determined in serum.

Organs such as aorta and heart were removed immediately after sacrificing, excised, rinsed, blotted dry with tissue paper, weighted and kept in formalin solution (10%) for histological examination.

Biochemical Analysis:

The biochemical analysis was carried out at Animal Health Research Institute (AHRI), Agriculture Research Center

- Serum total lipid was calorimetrically determined according to the method described by Zollner and Kirsch, (1962). Triacylglycerols was determined enzymaticlly according to the method described by Fassati and Perncipe, (1982). Serum total Cholesterol was enzymaticlly determined according to the method described by Ellefson and Caraway, (1976). Serum HDL-C was determined calorimetrically according to the method described by Lopez-Virella *et al.,* (1977). Serum VLDL-C was calculated according to Friedewald's formula (Friedewald *et al.,* 1972) as well as LDL-C.
- All sesame samples were subjected to chemical analysis to determine proximal composition. Moisture

content was determined according to Fennema *et al.,* (1996).Total nitrogen of samples for protein content was determined by Microkjeldahl apparatus as described in the (A.O.A.C., 1995). Crude fat was determined in samples according to (A.O.A.C., 1995). Total fiber was determined according to (A.O.A.C., 1990).Ash was determined in samples using Muffle Furnace at 555 ºC according to the method reported by Fennema *et al.,* (1996).

Histological examination

Specimen from aorta and heart from all groups were washed, dehydrated in 85% alcohol for 24 hours, cleared in xylene and embedded in paraffin wax. Histological sections of 5-6 µm in thickness were cut out, deparaffinized and stained with heamatoxylin and eosin for examination under the light microscope.

Statistical analysis:

Data was statistically analyzed using SPSS, PC statistical software (version 16, SPSS INC, Chicago, USA). Results were expressed as mean ± SD. Differences among groups were analyzed by analysis of variance (ANOVA) using Duncan's test as a post hoc test. The P-value of ≤ 0.05 was considered to be statistically significant according to Armitage and Berry, (1987).

Results and Discussion

Chemical Composition of Raw, Roasted and Fermented Sesame Seeds (per 100 gm)

The chemical composition of raw, roasted and fermented sesame seeds was shown in Table (1). The proximate analysis of sesame seed samples showed that the highest moisture and carbohydrates content was that of raw sesame seeds (3.91% and 19.71 %, respectively)**.** Roasted sesame seeds had the highest content of protein roasted and fermented seeds (28.49% and 26.19%, respectively). Fermented sesame seeds had the highest content of crude fibers (5.92%, 7.76% and 8.89%) for raw, roasted and fermented seeds, respectively. Results in Table (1) pointed out that raw sesame seeds had the lowest content of protein, ash, fat and fibers compared with the other studied sesame forms.

Sesame seed is rich in oil and protein. The seeds contain 4.50-11.00% moisture, 48.20-56.30% fat, 19.10-26.94% protein, 2.00-5.59% ash, 2.50-3.90% fiber and 10.10-17.90% carbohydrate. The composition of the sesame seed is dependent on genetic, environmental factors, variety, cultivation, climate, ripening stage, the harvesting time of the seeds and the analytical method used (Kinman and Stark, 1954; Salunkhe *et al.,* 1992). The present results were in agreement with Makinde and Akinoso (2014) who reported that the ranges of proximate contents from sesame were: protein 15.4-26.5 g/100 g, fat 52.4-62.8 g/100 g, crude fiber 3.34-3.89 g/100 g, ash 3.93-6.78 g/100 g, carbohydrate 11.7-13.4 g/100 g and energy value 550.7-593.7 kcal/g. In the light of the effect of various treatments on the the proximate composition of sesame seed, Kajihausa *et al.* (2014) investigated the effect of soaking, sprouting and boiling, on the proximate composition of sesame seed. Results revealed that moisture and protein content were increased by soaking and sprouting but were reduced after boiling from a value of 4.99% and 47.64% to 4.92% and 42.06%, respectively. Fat, crude fiber, ash and carbohydrate contents were reduced by soaking and sprouting while boiling of the sprouted seeds increased the fat and carbohydrate content.

In the light of the present results, Onain *et al.,* (2018) studied the proximate analysis of sesame seed samples (raw, de-hulled, pre-pressed and cooked).The dry matter content was highest in raw seed representing 96.16% but there were no significant differences between the treatment means. There were also no significant differences in the means of crude fiber, and ash. Pre-pressed sesame seeds had the highest crude protein level (38.60%), which differed significantly from the other treatments among which there was no significant difference.

In addition, Ebere *et al.* (2019) reported that the proximate analysis of proximate and mineral characterization of seeds of sesame indicia showed that moisture representing 6.21±2.41%, ash 8.46±0.24%, crude fiber 6.12±4.10%, crude protein 14.73±6.39% and carbohydrate was 64.00±86.14%.

Effect of Raw, Roasted and Fermented Sesame Seeds Intake on Feed Intake (FI), Body Weight Gain (BWG) and Feed Efficiency Ratio (FER) of Atherosclerotic Rats

The effect of raw, roasted and fermented sesame seeds on feed intake (FI), body weight gain (BWG) and feed efficiency ratio (FER) of atherosclerotic rats were recorded in Table (2). Results indicated that the mean value of feed intake of the normal rats (negative control group) was 22.56±0.82g/day.When rats were become atherosclerotic (+ve control) their feed intake decreased significantly with a mean value of 20.66±0.84g / day. Mean feed intake of atherosclerotic rats fed on diet supplemented with roasted sesame seeds at level 2 were significantly higher than that of level 1. The opposite trend was observed regarding mean feed intake of atherosclerotic rats fed on diet supplemented with fermented sesame seeds representing (18.52±0.71g / day and 17.46±0.52g/day) for level 1 and 2, respectively. No significant differences were observed regarding feed intake of roasted at level 2 (150 g/kg diet), and raw sesame seeds supplemented groups at level 1(100 g/kg diet), when compared with that of the positive control group.

Regarding body weight gain, results indicated that the mean value of the negative control group was 73.53±11.62g. When rats were become atherosclerotic (+positive control) their BWG decreased (45.17±9.76g) .Rats were fed on level 2 roasted sesame seeds (150 gm. /kg diet) in the diet showed the highest BWG with a mean value of 74.4± 11.39 g. However, BWG for rats had the highest level of fermented sesame seeds in the diet (150 g /kg diet) had the lowest BWG with a mean value of 21.13± 5.23 g.

Data of feed efficiency ratio (FER) were shown in Table (2). Results revealed that the atherosclerotic positive control group decreased significantly (P< 0.05) when compared with the negative control one with a mean value of 0.03 ± 0.004 and 0.05±0.007, respectively. FERof rats fed on diet supplemented with roasted sesame seeds (level 1 and level2) were increased significantly FER with a mean value of (0.05 ±0.005, and 0.06 ± 0.008, respectively) when compared with the positive control group (0.03 ± 0.004). However, FER of rats fed on diet supplemented with fermented sesame seeds (level 2) was decreased significantly with a mean value of 0.02± 0.005, and when compared with the positive control group (0.03 ± 0.004).

The present result is supported by Diao *et al.* (2016) who reported that the atherosclerotic group had less bodyweight gain as compared to the normal group of rats at the end of the study (9th week). Mohamed and Wakwak, (2014) reported that the average body weight increased significantly in both females and males in group of birds fed on the basal diet supplemented with 2% and 4% sesame seeds, or 2% and 4% sesame oil. These results may be attributed to the presence of minerals (copper, iron, zinc, manganese, magnesium, calcium, phosphorus and potassium) in the feed supplemented with sesame seeds or oil that are required for regulation of body's metabolic functions.

Kamal-Eldinand Appelqvist, (1994) concluded that the significant increase in weight gain inethanolic extract sesame group (EESG) can be linked to the high fat composition and its high caloric content. Ashamu *et al.,* (2010) stated that the weight gain in ethanolic extract sesame group (EESG) was significantly higher than that of the control. In addition, Mahabadi *et al.,* (2013) reported that Wister rats fed on normal or experimental diet (70% normal diet and30% sesame seed) after infancy for 12 weeks showed non-significant differences in animal's body weight.

Mallick *et al.* (2016) reported that body weight was increased at the time of experiment in hyperlipidemic group compared to control group. Treatment with sesame seed extracts at a dose of 50mg/kg body weight/day showed drastically less body weight than the other two groups (25mg/kg and 75 mg/kg body weight/day).

Furthermore, Onain *et al.* (2018) stated that the pre-pressed sesame seeds had significantly higher crude protein but the ether extract was significantly lower than those of other treatments. The mean values for mean weekly feed intake of groups fed de-hulled and pre-pressed and de-hulled were significantly higher than that of the control, which was significantly lower than cooked sesame fed group. The results for body weight gain and feed conversion ratio follow the same trend. A cooked sesame seed give better feed conversion ratio than other processing methods but does not necessarily correspond to the best performance.

Li *et al.* (2020) reported that the final body weights of hyperlipidemic rats supplemented with white sesame seed and kernel (dry peeling) groups were higher than those of the black sesame seed and kernel groups. The weights of the black and white sesame seed groups were lower than those of the black and white sesame kernel groups. At the same dose, the final body weights of the rats fed on white sesame seed and kernel groups were higher than those of the black sesame seed and kernel fed groups. The weights of the black and white fed sesame seed groups were lower than those of the black and white fed sesame kernel groups.

In contrary with the present study, Friedman (1996) reported lower feed intake (FI) in rats fed with raw sesame than control and processed sesame. These differences were probably due to the difference between the diets component in protein quality and effects of anti-nutritional compounds. The reduction in the levels of various anti-nutritional substances by roasting and fermentation might be related to larger FI values compared to raw sesame. The raw sesame exhibits low FER value when compared to control and processed sesame since the food and protein intake were low. Results inconsistency between the present study and the previous study may be attributed to the differences in the used sesame variety, the percentage level of sesame supplementation and treatment techniques were used during roasting and fermentation processes.

The Effect of Raw, Roasted and Fermented Sesame Seeds Intake on Organs Relative Weight of Atherosclerotic Rats:

Results in Table (3) showed the effect of raw, roasted and fermented sesame seeds intake on liver, heart and kidney relative weight of normal and atherosclerotic rats. Results revealed that the induction of atherosclerosis caused significant increase in liver relative weight of the positive control group compared to that of the negative control one (6.16 ± 0.68 % and 3.36 ± 0.37%, respectively). Atherosclerotic rats fed on diet supplemented with raw, roasted and fermented sesame seeds had significant improvement in liver relative weight compared to positive control group. Regarding the level of supplementation, raw and fermented sesame seeds at level 2 showed significant improvement in liver relative weight compared to that of level 1.

Regarding heart relative weight, the induction of atherosclerosis caused significant increase in heart relative weight of the positive control group compared to that of negative control one (0.53 ± 0.05 %and 0.44 ± 0.03 %, respectively. Results revealed that there were non-significant differences in heart relative weight of raw and roasted sesame seeds fed groups at level 1 compared to positive control group. On the other hand, fermented sesame seeds fed groups at level 1 and 2 showed non-significant differences in heart relative weight compared with that of the negative control group, representing 0.45 ± 0.03 %and 0.46 ± 0.05 % vs. 0.44 ± 0.03 %, respectively.

Concerning kidneys relative weight results, the mean value of kidney relative weight was increased significantly when rats were fed on high fat diet (positive control group) with a mean value of (1.02 ± 0.07%)compared with the negative control group (0.71 ± 0.08%). The addition of raw, roasted and fermented sesame seeds to the high fat diet at level 1 and 2 showed non-significant differences in the kidney relative weight compared with that of negative control group except raw and roasted sesame seeds at level1 representing 0.92 ± 0.07% and 0.91 ± 0.05 % vs. 0.71 ± 0.08%, respectively.

In agreement with the present study, Murray *et al.* (1996) and Kahlon *et al.* (1997) reported thatthe increase in relative liver weight of high fat diet fed rats may be attributed to the higher fat content that in turn increased the fat accumulation in liver. Similarly, Lutz *et al.* (1998) reported that cholesterol ester may accumulate in the liver of cholesterol fed rats.

On the other hand, Hanzawa *et al.* (2013) reported that relative liver weights were slightly greater (P< 0.05) in the rats fed a diet containing 2 g sesam in/kg than in rats fed a control diet (basal diet). In addition, Li *et al.* (2020) concluded that the liver indexes of the experimental groups fed on high fat diet with different levels of sesame (90% high fat diet + 10% sesame seeds) or (90% high fat diet + 30% sesame seeds) in the form of seeds or kernels of white and black sesame, increased significantly compared with control group fed on high fat diet. Moreover, the liver indexes of white/ or black sesame seed high dose groups increased significantly compared with normal control group, the reason may be that the high fat content of sesame causes a slight swelling of the liver in high-dose groups. The opposite trend was observed regarding the liver indexes of white/ or black sesame seed low dose groups indicating that black and white sesame seed and kernel could reduce the lipid accumulation on the liver at low doses. The cardiac indexes of white sesame seed low dose group decreased significantly compared with normal control group, but there was no significant difference between the other sesame supplemented groups and normal control group. The kidney indexes of the experimental groups fed on high fat diet with different levels and forms of white and black sesame decreased compared with normal control group.

The Effect of Raw, Roasted and Fermented Sesame Seeds Intake on Total Cholesterol (TC), Triacylglycerols (TAG) and Total Lipid (TL), of Atherosclerotic Rats:

Table (4) showed the effect of raw, roasted and fermented sesame seeds on serum lipids profile (TC, TAG and TL) on atherosclerotic rats. As a result of feeding high fat diet, total cholesterol increased significantly in the positive control group with mean value of 142.97±7.81 mg/dl compared with the negative control group (90.57±3.52 mg/dl). Diet supplementation with high fat with raw, roasted and fermented sesame seeds at any tested level, resulted in significant decrease in total cholesterol levels compared with the positive control group. The least significant reduction in total cholesterol was observed in raw sesame seed supplemented group (125.83 ± 5.76 mg/dl). Regarding levels of supplementation, raw and roasted sesame seeds fed groups at level 2 showed significant decreases in total cholesterol compared to level 1. It could be observed also that roasted and fermented sesame seeds fed groups at level 2 achieved values of total cholesterol comparable to that of negative control healthy group (96.17±5.83 mg/dl, 99.70±5.29 mg/dl vs. 90.57±3.52 mg/dl, respectively).

Triacylglycerol (TAG) level was significantly increased in atherosclerotic rats (+ positive control) with mean value of 166.60±10.82 mg/dl compared with that of the negative control group (66.76 ± 4.55 mg/dl). Supplementation of high fat diet with raw, roasted and fermented sesame seeds either at any tested level caused significant reduction ($P<0.05$) in triacylglycerol levels compared with positive control group. It is worth to notice that the lowest reduction in triacylglycerol levels was observed in raw sesame seeds fed group at level 1 with a mean value of 132.13-±3.10 mg/dl, while there were no significant differences between all other types of sesame supplementation at level 1 and 2.

Results in the same table (Table 4) also showed that, total lipid was significantly increased as a result of feeding atherogenic diet (+ positive control) with mean value of 586.00 ± 50.23mg/dl compared with the normal control group fed normal diet (362.67 ±24.58 mg/dl). All treated groups showed significant decreased in total lipid compared with the positive control group.

All treated groups showed significant decreased in total lipid than the positive control group. Regarding the level of supplementation, raw, roasted and fermented sesame seeds fed groups at level 2 showed slight decrease in the total lipids values compared to that of level 1 fed groups. However, the differences were not significant. The only group which had comparable values of total lipids to negative control group was the rats group fed on high fat diet supplemented with fermented sesame seeds at level 2 representing (401.33 ±68.10 and 362.67±24.58 mg/dl) ,respectively.

Our results get hand by hand with Liu *et al.* (2016) who stated that serum total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C) were elevated in the high-fat diet group compared with the normal diet group after 4, 8, and 12 weeks, respectively .

Dyslipidaemia was reported to be the most widespread marker for susceptibility to atherosclerotic heart disease (Surya *et al.,* 2017). Dyslipidaemia is a life style disorder characterized by increased levels of total cholesterol, LDL cholesterol and triglycerides and also decreased HDL cholesterol levels which is turned into cardiovascular disease, a first leading cause of death in Worldwide (Khatun *et al.,* 2019). Sesame contains considerable amounts of vitamin E, MUFA, fiber and lignans, which are thought to be associated with its lipid-lowering properties (Khalesi *et al.,* 2016). On the light of this, Nishant *et al.* (2008) reported that sesame had high content of polyunsaturated fatty acids like linoleic acid, monounsaturated fatty acids, cellulose, two unique substances (sesamin and sesame oil) and lignin, which can reduce triglycerides and cholesterol levels.

The mechanism for the hypocholesterolemic effect of sesamin in rats was described by (Kiso, 2004) who reported that the decrease in total lipids, cholesterol and triglycerides may be due to sesame seeds ingestion that regulates the transcription process of hepatic metabolizing enzymes for lipids,and increase the activity of various hepatic enzymes involved in fatty acids oxidation(Arachchige *et al.,* 2006)thereby reducing serum and liver lipids (Lim *et al.,* 2007). Moreover, Wu *et al.* (2006) observed that sesame ingestion improve blood lipids in animals.

Phytosterols are called plant sterols are compounds found in plants that have almost identical chemical structure to cholesterol and when present in diet in sufficient amounts are believed to reduce blood cholesterol, enhance the immune response and decrease risk of certain cancers(Williams, 2005). Sesame seeds contain phytosterols associated with reduced levels of blood cholesterol Wu (2007). Diverse polyphenols were present in sesame seed coat, including flavonoids (procyanidins and catechins), phenolic acids (chlorogenic acid, ferulic acid, coumaric acid, and caffeic acid) and stilbene (Elleuch *et al.*, 2007). Plant polyphenols exert cardiovascular benefits by altering the concentrations of blood lipid components (Woo *et al*., 2009)

Regarding oil content in sesame seeds, Tzang *et al.,* (2009) stated thatthe consumption of oils containing polyunsaturated fatty acids reduces triglyceride levels, probably because of increased lipase activity. In addition, Mallick *et al.* (2016) conceded that sesame seed is the rich natural sources of phytostreol which have great reducing capability for lowering the blood cholesterol, triglyceride level and total fat content of the different tissues.

Pirior studies showed that sesame lignans (sesamin and/or episesamin) reduce serum and liver cholesterol concentrations by inhibiting absorption and synthesis of cholesterol (Kang *et al.,* 2000 and Noguchi *et al.,* 2001). In addition, fiber content of sesame seed meal may stimulate binding of cholesterol with bile acids, and the inhibition of micelle formation combined with the effect of fermentation on short chain fatty acids production, mechanisms that have been proposed to explain the potential cholesterol lowering effects (Al-Harthi, 2017 and Baghban-Kanani *et al.,* 2018).

Concerning the effect of sesame lignans on blood lipids, Namiki, (2007) reported that sesame lignans lowered the cholesterol concentration in serum, especially in combination with tocopherol, due to the inhibition of absorption from the intestine and suppression of synthesis in the liver. It is worth to know that the effect of sesame lignans was extended to various effects on fatty acid metabolism involving lowering fatty acid concentration in liver and serum due to acceleration of fatty acid oxidation and suppression of fatty acid synthesis, and the controlling influence on the ratio of n-6/n-3 polyunsaturated fatty acids under excess intake of either n-6 or n-3 fatty acids in the diet. In addition, Rogi *et al.* (2011) reported that sesamin reduced the blood cholesterol level synergistically with tocopherol (a ratio of sesamin: α-tocopherol = 1:5 (w/w)) in rats fed a high-cholesterol diet and it enhanced α-tocopherol level not in the serum but in the liver.

Furthermore, Biswasand Dhar, (2010) indicated that sesame protein isolate decreases cholesterol concentration in plasma, increases HDL-cholesterol, and also decreases plasma and erythrocyte membrane lipid peroxidation with or without cholesterol fed diet in rats. Sesame protein isolate (SPI) can be produced from dehulled, defatted sesame meal. SPI consumption can reduce cardiovascular disease by reducing LDL cholesterol, triacylglycerol, and by increasing HDL cholesterol.

Although the association between increased total cholesterol and LDL-cholesterol and reduced HDL-cholesterol and the risk of CVD is well studied, elevated TAG levels have been recently considered as a single important risk factor of CVD (Nordestgaard, and Varbo, 2014).

Sirato-Yasumoto and associates, (2001) demonstrated that supplementation with lignan-rich sesame has a remarkable potentiating effect on hepatic fatty acid oxidation while down regulating the activity of lipogenic enzymes. These favorable metabolic effects of lignan-rich sesame were reported to be accompanied with a profound hypotriglyceridemic.

Triacylglycerols (TAG) lowering properties of sesame can be partially explained by its high MUFA contents (40% in sesame oil) Sankar *et al.* (2006). The American Heart Association has reported that high dietary MUFA intake is likely to decrease blood TAG concentrations Kris-Etherton, (1999). Evidence from the meta-analysis showed that a short-term intervention with a MUFA-rich diet can reduce the serum levels of TAG and HDL cholesterol Schwingshackl, & Hoffmann (2012). In addition, the high content of fiber, vitamin E and PUFA in sesame seeds, as well as the antioxidant activity of its lignans, can affect TAG generation and metabolism Sankar *et al.* (2006). It has been described that PUFA consumption reduces the risk of CVD by decreasing serum TAG levels and by modestly increasing serum HDL-cholesterol concentrations Harris *et al.* (2009).

The present results were confirmed by Zhou *et al.* (2016) they reported that white sesame have preventive effect of on dyslipidemia and cardiovascular diseases, and its biological effects may be attributed to the nutrients and active ingredients of sesame Moreover, Mohamed *et al.* (2018) reported that there was significant decrease in triglycerides values from 131.4 to 98.3 mg/dl upon oral ingestion of sesame oil after 30 days of treatment as compared with positive group (fed on fatty diet).

The Effect of Raw, Roasted and Fermented Sesame Seeds Intake on Serum Lipoprotein Fractions of Atherosclerotic Rats:

Table (5) showed the effect of raw, roasted and fermented sesame seeds intake on serum lipoprotein fractions of atherosclerotic rats. Results showed that rats fed on high fat diet (+ positive control) had significantly low value of high density lipoprotein cholesterol (HDL-C) representing 28.10 ±3.35mg/dlcompared with the negative control rats with a mean value of 53.40±7.05mg/dl. Significant improvements in HDL-C values were observed when rats were fed on high fat diet supplemented with raw (level 2), roasted (level 2) and fermented (level 1 and 2) sesame seeds compared to the positive control group. No significant differences were observed among all treated groups. HDL-C of raw roasted and fermented sesame seeds supplemented groups at level 2 were higher than that of level 1, however were not significant.

Regarding the low density lipoprotein cholesterol (LDL-C) results revealed that LDL-C was significantly increased in positive control group with a mean value of 81.55±7.13mg/dl compared with the negative control group (23.81±4.67 mg/dl). In addition, when rats were fed on high fat diet supplemented with raw, roasted and fermented sesame seeds significant reduction in LDL-C values compared with positive control group were noticed. Studying the effect of the level of sesame seeds supplementation revealed that LDL-C of raw and roasted sesame seeds (level 2) were significantly lower than that of (level 1) (64.86± 9.14mg/dl, and 51.58± 3.67mg/dl) and (58.55± 8.78mg/dl, and 35.16± 11.27mg/dl) for raw and roasted sesame seeds (level 1 and 2), respectively.

Very low-density lipoprotein cholesterol (VLDL-C) value was significantly increased in atherosclerotic rats (+ positive control) with mean value of 33.32±6.16 mg/dl compared with the negative control group (13.35 ± 2.91mg/dl).Supplementation of high fat diet with raw, roasted and fermented sesame seeds either at level 1 or level 2 caused significant reduction ($P<0.05$) in VLDL-C values compared with positive control group. It is worth to notice that the lowest reduction in VLDL-C values was observed in raw sesame seeds fed group at level 1 with a mean value of (26.44±3.80 mg/dl), while there were no significant differences between all other types of sesame supplementation at level 1 and 2 regarding VLDL-C values.

The results of serum lipoproteins cholesterol (LDL-C) of atherosclerotic rats in our study were in the same line with those reported by Hirata *et al.* (1996) who stated that daily oral intake of sesamin in hypercholesterolemic patients for 4 weeks significantly decreased total and LDL-C concentrations. In addition, Kamal-Eldin *et al.* (2000) dietary supplementation with sesamin reduced plasma and liver TC and LDL-C concentrations in hyperlipidemic rats.

Visavadiya and Narasimhacharya (2008) examined the effects of supplementation with sesame seed powder at 5% and 10% doses along with either normal or hypercholesterolemic diet for a period of 4 weeks. Administration of sesame seed powder to hypercholesterolemic rats resulted in a significant decline in plasma and hepatic total lipid and cholesterol, and plasma LDL-C whilst increasing HDL-C concentrations. They concluded that these beneficial effects of sesame seed on hypercholesteraemic rats appeared to be due to its fiber, sterol, polyphenol and flavonoid content, enhancing the fecal cholesterol excretion and bile acid production and as well as increasing the antioxidant enzyme activities.

Biswas *et al.* (2010) evaluated the effect of sesame protein isolate, fed 18% sesame protein isolate with or without 2% cholesterol in comparison with casein to rats for 28 days. The results revealed that dietary sesame protein isolate reduces plasma total cholesterol, triacylglycerol, LDL-C and increases HDL-C in both hypercholesterolemia and normocholesterolemic diet groups.

Moreover, Alipoor *et al.* (2012) reported that supplementation with 40 g/d of sesame seeds for 60 days caused significant decreases in plasma TC and LDL-C. Mallick *et al.,* (2016) reported that the effect of sesame seed extracts (ESS) on lipoprotein (LDL, triglyceride and HDL) of control and experimental animals. Circulating levels of LDL-c was significantly ($p < 0.05$) increased followed by a parallel decrease in HDL-c in different doses of ESS treated rats compared to the control groups. Nevertheless the levels were statistically similar in control and treated with ESS groups. In control rats the level of cholesterol, triglyceride, HDL, LDL was normal and the treated groups of ESS these levels were near to the control rat when compared with the control group**.**

The observed improvement in the levels of LDL-C and HDL-C as a result of raw, roasted and fermented sesame seeds supplementation may be explained by the point reported by Macarulla *et al.* (2001) that low level of plasma TC down regulates LDL-C receptors in extra-hepatic tissue which is one of the most important reasons to decreasing LDL-C and increasing HDL-C.

The Effect of Raw, Roasted and Fermented Sesame Seeds Intake on Atherogenic Index and Lipoproteins Ratio of Atherosclerotic Rats

Table (6) showed the atherogenic index and lipoproteins ratio of atherosclerotic rats supplemented with raw, roasted and fermented sesame seeds. As expected, feeding rats with high fat diet supplemented with cholesterol caused significant increase in the atherogenic index (positive control group) compared to the negative control one with a mean values of 4.09±0.29 vs. 0.71± 0.18 ,respectively. Interestingly , supplementation of high fat diet with raw, roasted or fermented sesame seeds , showed significant reduction in the atherogenic index at any or all levels of supplementation compared with the positive control group, but they still did not reach the atherogenic index level of negative control group. Regarding the level of supplementation, raw and roasted sesame seeds at level 2 showed significant reduction in the atherogenic index compared to level 1 of supplementation (1.97±0.23 vs. 2.66±0.42) for raw sesame seeds fed group and 1.33±0.36 vs. 2.37±0.37 for roasted sesame seeds fed group. On the other hand, atherogenic rats fed on fermented sesame seeds showed no significant difference between level 2 and level 1 of supplementation with a mean value of (1.37±0.09 vs.1.82±0.15).

Moreover, the lipoproteins ratio (LDL-c/ HDL-c) of positive control group showed the highest lipoproteins ratio in all groups with a mean value of 2.91±0.30 compared with the negative control group (0.46 ±0.15). Results revealed that rats fed on high fat diet supplemented with raw, roasted or fermented sesame seeds showed reduction in the LDL-c/ HDL-c ratio at all levels of intake (100 and 150 gm /kg diet) compared with the positive control group. All the forms of supplementations at level (2) caused significant improvement in the LDL-c/ HDL-c ratio compared to level (1) of supplementation. It worth to notice that atherogenic rats fed on high fat diet supplemented with roasted and fermented sesame seeds at level(2) showed remarkable improvement in LDL-c/ HDL-c ratio to the levels that were not significant with the negative control group representing (0.87±0.35, 0.90±0.06 vs. 0.46 ±0.15) ,respectively.

Atherogenic index indicates the magnitude of the potential occurrence of atherosclerosis Prangdimurti *et al.* (2007). The higher of atherogenic index, the potential occurrence of atherosclerosis and prevalence of cardiovascular disease was also higher. The total cholesterol and HDL-C levels affect atherogenic index value. Reducing total cholesterol and increasing HDL-C levels reduce the atherogenic index value, so the risk of atherosclerosis will be smaller. Total cholesterol and LDL-Cholesterol levels were positively correlated with the atherogenic index, whereas HDL-cholesterol levels were negatively correlated with the atherogenic index. The higher of HDL-C levels, the atherogenic value is lower, so the risk of atherosclerosis will be smaller (Herpandi *et al.,* 2006)

In accordance with the present study, Sa'adah *et al.* (2017) concluded that lipid-rich diet for 30 days caused an increases the total cholesterol, LDL-C levels and atherogenic index significantly ($p<0.01$) compared with control rats.

Khatun *et al.* (2019) reported that among the 3 dietary treatment groups, it was observed the significant ($p < 0.05$) decrease in the atherogenic index of plasma values in rats fed high lipid diet (HLD) + sesame seeds (SSi) groups compared to HLD group. The study also revealed improvement in atherogenic index of plasma as a result of dietary interventions with HLD+SSi which contribute to cardio-protection.

Kunutsor *et al.* (2017) stated LDL/HDL is an important parameter in detection of atherosclerotic diseases, and it was considered to be an indicator with greater predictive value than isolated parameters used independently. Aquila *et al.* (2019) reported that bioactive compounds, present in plants and certain foods, inhibit those biological processes linked to atherosclerosis onset. From the obtained results regarding LDL/HDL ratio and other lipids profile of the tested groups, it could be concluded that sesame seeds is considered as a functional food which has one or more beneficial effects in the body beyond basic nutrition that have an impact on health and reduce the risk of diseases.

The Histoplogical Examinations:

Aorta:

The histological examinations of aorta were shown in photos (1-8). Photo (1) showed that aorta of the negative control rats (fed on basal diet) had no histological changes. On the other hand, the positive control group showed mild atheromatous plaque with the necrotic core (Photo 2). Results indicated that, the atherosclerotic group of rats fed on raw sesame seeds at level 1 (Photo 3) revealed moderate regressed and fragmented atheroma. The atherosclerotic rats fed on raw sesame seeds at level 2 (Photo 4) revealed post blood clot and cardiocmyocyte suffering from severe edema dispersing the cardiac myocytes.

Results showed that, the atherosclerotic group of rats fed on roasted sesame seeds at level 1 (Photo 5) indicated moderate atheromatous plaque. The atherosclerotic rats fed on roasted sesame seeds at level 2 (Photo 6) revealed mild fragmentation of atheromatous plaque.

Data indicated that, the atherosclerotic group of rats fed on fermented sesame seeds at level 1 (Photo 7) showed few caralization of atheromatous plaque. The atherosclerotic rats fed on fermented sesame seeds at level 2 (Photo 8) showing slight fragmented thrombus.

The histological results were in the same line with the results of serum parameters and agreed with Liu *et al.* (2016) who reported that there were no pathologic changes in the aortas of normal diet rats during the course of the experiment. However, foam cells were observed following mononuclear cell infiltration in the aortas of high-fat diet (HFD) rats after 4 weeks of treatment. After 8 weeks, numerous foam cells were formed and nuclear condensation appeared in medial smooth muscle cells in HFD rats. Pahk *et al.* (2017) showed that the atherosclerotic right carotid arteries presented prominent luminal narrowing with neointimal hyperplasia, while the normal carotid arteries showed no neointimal hyperplasia.

Atherosclerosis is a chronic condition in which dyslipidemia had been contributed to its development, along with evidence proving an inflammatory cause high cholesterol diet produced marked disturbance in lipid profile and increased inflammatory markers and atherosclerotic changes in carotid artery (Ibrahim *et al.,* 2020). In the present study, atherosclerotic changes in aorta improved significantly in rats treated with all tested forms of sesame seeds with minimal improvement in level 1 tested form of sesame seeds fed groups. The reason may be that sesame seeds contain active components such as sesamin, sesamolin, and tocopherols, etc. which works as anitoxidents, anitinflamatory and antihyperlipidemic agents.

Table 1 : Chemical Composition of Raw, Roasted and Fermented Sesame Seeds (per 100 gm).

Type of sesame	Protein (%)	Carbohydrates (%)	Fat (%)	Energy (%)	Moisture (%)	Ash (%)	Fibers (%)
Raw sesame seeds	23.49	19.71	53.99	97.18	3.91	2.82	5.92
Roasted sesame seeds	28.49	13.07	55.42	96.98	2.12	3.02	7.76
Fermented sesame seeds	26.19	16.07	54.64	96.91	1.17	3.09	8.89

Each value represents the average of three determinants

Table 2 : Effect of Raw, Roasted and Fermented Sesame Seeds Intake on Feed Intake (FI), Body Weight Gain (BWG) and Feed Efficiency Ratio (FER) of Atherosclerotic Rats.

Groups	Parameters	FI (g/day)	BWG (g)	FER
Control	Negative (-)	22.56±0.82^{a}	73.53±11.62^{a}	0.05±0.007^{b}
	Positive (+)	20.66±0.84^{b}	45.17±9.76^{d}	0.03 ± 0.004^{d}
Raw sesame seeds	Level (1)*	20.20± 0.80 ^{b}	57.34±10.14^{b,c}	0.05±0.006^{b}
	level (2)**	19.42±0.76^{c}	66.23± 10.72 ^{b}	0.06±0.009^{a}
Roasted sesame seeds	Level (1)*	19.71±0.73^{c}	56.32± 10.33 ^{c}	0.05±0.005^{b}
	level (2)**	20.23±0.81^{b}	74.4± 11.39 ^{a}	0.06 ± 0.008^{a}
Fermented sesame seeds	Level (1)*	18.52±0.71^{c,d}	46.40± 9.69^{d}	0.04±0.007^{c}
	level (2)**	17.46±0.52^{d}	21.13± 5.23 ^{e}	0.02±0.005^{e}

Results are expressed as means ± SD.
Values at the same column sharing the same superscript letters are not significantly different ($P\leq 0.05$). - *level (1) = 100 gm. /kg diet - ** level (2) =150 gm. /kg diet

Table 3: Effect of Raw, Roasted and Fermented Sesame Seeds Intake on Organs Relative Weight of Atherosclerotic Rats.

Groups	Parameters	Liver (%)	Heart (%)	Kidneys (%)
Control	Negative (-)	3.36 ± 0.37^{d}	0.44 ± 0.03^{a}	0.71 ± 0.08^{c}
	Positive (+)	6.16 ± 0.68^{a}	0.53 ± 0.05^{b}	1.02 ± 0.07^{a}
Raw sesame seeds	Level (1)*	5.80 ± 0.26^{b}	0.51 ± 0.07^{b}	0.92 ±0.07^{a,b}
	level (2)**	4.64 ± 0.53^{c}	0.47±0.26^{a},^{b}	0.76 ± 0.06^{c}
Roasted sesame seeds	Level (1)*	4.80 ± 0.46^{c}	0.49 ±0.03^{b}	0.91±0.05^{a,b}
	level (2)**	4.45 ±0.42^{c,d}	0.48 ±0.02^{a,b}	0.88 ±0.09^{b,c}
Fermented sesame seeds	Level (1)*	5.03 ± 0.29^{c}	0.45 ± 0.03^{a}	0.87 ±0.11^{b,c}
	level (2)**	3.87 ±0.59^{d}	0.46 ± 0.05^{a}	0.82±0.09^{b,c}

Results are expressed as means ± SD.
Values at the same column sharing the same superscript letters are not significantly different ($P\leq 0.05$). - *level (1) = 100 gm. /kg diet - ** level (2) =150 gm. /kg diet

Table 4 : Effect of Raw, Roasted and Fermented Sesame Seeds Intake on Total Cholesterol (TC), Triacylglycerols (TAG) and Total Lipid (TL), of Atherosclerotic Rats.

Groups	Parameters	TC (mg/dl)	TAG (mg/dl)	TL (mg/dl)
control	Negative (-)	90.57±3.52 [f]	66.76 ± 4.55 [d]	362.67 ±24.58[d]
	Positive (+)	142.97±7.81 [a]	166.60±10.82 [a]	586.00 ±50.23[a]
Raw sesame seeds	Level (1)*	125.83±5.76 [b]	132.13 ±3.10 [b]	467.67 ±33.50[b]
	level (2)**	108.90±5.25[c,d]	102.23±8.26 [c]	456.33±28.16[b,c]
Roasted sesame seeds	Level (1)*	112.30±6.58 [c]	101.27±13.36 [c]	480.00±24.02[b,c]
	level (2)**	96.17±5.83[e,f]	97.37±8.05 [c]	426.67±23.62[b,c]
Fermented sesame seeds	Level (1)*	105.40±10.84[c,d,e]	107.67 ± 5.90 [c]	464.00±19.31[b,c]
	level (2)**	99.70±5.29[d,e,f]	98.47±5.01 [c]	401.33±68.10[c,d]

Results are expressed as means ± SD.
Values at the same column sharing the same superscript letters are not significantly different (P≤ 0.05). *level (1) = 100 gm. /kg diet ** level (2) =150 gm. /kg diet

Table 5 : Effect of Raw, Roasted and Fermented Sesame Seeds Intake on Serum Lipoprotein Fractions of Atherosclerotic Rats.

Groups	Parameters	HDL-C (mg/dl)	LDL-C (mg/dl)	VLDL-C (mg/dl)
Control	Negative (-)	53.40±7.05 [a]	23.81±4.67 [e]	13.35 ± 2.91[d]
	Positive (+)	28.10 ±3.35 [d]	81.55±7.13 [a]	33.32±6.16[a]
Raw sesame seeds	Level (1)*	34.53±2.48[c,d]	64.86± 9.14[b]	26.44±3.80 [b]
	level (2)**	36.87±2.98[b,c]	51.58± 3.67[c,d]	20.45±4.65 [c]
Roasted sesame seeds	Level (1)*	33.50±3.46[c,d]	58.55± 8.78[b,c]	20.25±2.67 [c]
	level (2)**	41.57±3.96[b,c]	35.16± 11.27[d]	19.47±2.61 [c]
Fermented sesame seeds	Level (1)*	37.33±2.65[b,c]	46.53± 7.62[c,d]	21.53±3.18 [c]
	level (2)**	42.10 ±2.36[b,c]	37.91± 2.80[c,d]	19.69±3.01 [c]

Results are expressed as means ± SD.
Values at the same column sharing the same superscript letters are not significantly different (P≤ 0.05)
*level (1) = 100 gm. /kg diet ** level (2) =150 gm. /kg diet
HDL-C: Serum High Density Lipoprotein Cholesterol, LDL-C: Low Density Lipoprotein Cholesterol
VLDL-C:Very Low Density Lipoprotein Cholesterol,

Table 6 : Effect of Raw, Roasted and Fermented Sesame Seeds Intake on Atherogenic Index and Lipoproteins Ratio of AI Atherosclerotic Rats.

Groups	Parameters	AI	LDL-c/HDL-c
Control	Negative (-)	0.71± 0.18 [f]	0.46 ±0.15 [f]
	Positive (+)	4.09± 0.29 [a]	2.91± 0.30 [a]
Raw sesame seeds	Level (1)*	2.66± 0.42 [b]	1.90± 0.39 [b]
	level (2)**	1.97± 0.23[c,d]	1.41± 0.22[c,d]
Roasted sesame seeds	Level (1)*	2.37± 0.37[b,c]	1.76± 0.32[b,c]
	level (2)**	1.33± 0.36 [e]	0.87± 0.35[e,f]
Fermented sesame seeds	Level (1)*	1.82± 0.15[d,e]	1.24± 0.14[d,e]
	level (2)**	1.37± 0.09 [e]	0.90± 0.06[e,f]

- Results are expressed as means ± SD.
-Values at the same column sharing the same superscript letters are not significantly different
(P≤ 0.05). - *level (1) = 100 gm. /kg diet - ** level (2) =150 gm. /kg diet
AI: Atherogenic Index HDL-C: Serum High Density Lipoprotein Cholesterol
LDL-C: Low Density Lipoprotein Cholesterol

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الملخص العربي
النشاط المضاد للأكسدة للمعاملات المختلفة لبذور السمسم على مستوى الدهون
في الفئران المصابة بتصلب الشرايين

اسماء احمد محمد, لمياء على احمد و هدى سلامة ابراهيم

تهدف هذه الدراسة الى معرفة النشاط المضاد للأكسدة للمعاملات المختلفة لبذور السمسم على مستوى الدهون في الفئران المصابة بتصلب الشرايين. تم استخدام عدد 72 فار من نوع ذكور الالبينوالبيضاء (سلالة الاسبراج داولي) و تم تقسيمهم الى مجموعتين رئيسيتين، المجموعة الاولى (المجموعة الضابطة السالبة عددها 9 فئران. تم تغذيتها على النظام الغذائي الأساسي كمجموعة ضابطه سلبية, وتم إحداث تصلب الشرايين في المجموعة الرئيسية الثانية (عدد = 63) والتي تم تقسيمها للمجموعات 2-8. المجموعة 2 مجموعة ضابطه إيجابية. وعولجت باقى المجاميع ببذور السمسم النيئة والمحمصة والمتخمرة على مستويين من الاستهلاك (100 و150 جم / كجم غذاء). في نهاية فترة التجربة (8 أسابيع) تم تسجيل كمية الغذاء المستهلك وحساب نسبة كفاءة الطعام،وتم جمع الأعضاء وكذلك عينات الدم لتقدير نسبة الدهون وأجزاءها. أظهرت النتائج أن معاملة الفئران المصابة بتصلب الشرايين ببذور السمسم النيئة والمحمصة والمتخمرة على مستويين المستخدمين أدى إلى تحسين كبير فى كل من معدل الزيادة فى الوزن, كمية الطعام المتناول, ومعدل كفاءة الطعام مقارنة بالمجموعة المصابة بتصلب الشرايين ايضا تناول بذور السمسم ادى الى تحسين معنوى فى مستوى دهون الدم المختلفة. أظهرت النتائج ايضا أن إضافة بذور السمسم أدت إلى تحسن معنوي في نتائج الدراسات النسيجية وتوافق ذلك مع التحليل البيو كيميائي. توصي الدراسة الحالية بزيادة استهلاك بذور السمسم بأشكال مختلفة لما له من تاثير ايجابى على صورة دهون الدم وتصلب الشرايين. وتشير الي أهمية الحاجة لبرامج التثقيف الغذائي لتوضيح أهمية بذور السمسم في الحد من مخاطر الإصابة بتصلب الشرايين. وايضا تنادي الدراسة لمزيد من الدراسات لتقييم الفوائد الصحية لاستهلاك بذور السمسم المتخمرة.

الكلمات المفتاحية: **بذور السمسم النىء – السمسم المحمص- فوائد السمسم المتخمر – تصلب الشرايين –– الفحص الهيستوباثولوجى.**