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Supplementations Dietary of Quinoa Seeds Powder and their Effect on Hypercholesteremia & Oxidation in Albino Rats

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Abstract:

The main target of this research was to study the effect of dietary supplementation of quinoa seeds powder (QSP) under two different concentrations (150 and 300 g/kg diet) to give more protection against hypercholesteremia disease. Twenty (20) mature male albino rats weighing 184 ± 2 g were used in this study. The rats were divided into 4 groups (5 rats in each group) one of them used as control negative group while other three groups fed on diet containing 1.5% cholesterol plus 10 % sheep tail for 15 days to induce hypercholesteremia disease , one of these left as control positive group and other two groups fed on two doses of quinoa (150 and 300 g/kg diet) for 28 days. Body weight gain, FER and FI were estimated as well as internal organs weight . Also, lipid profile (total cholesterol, triglyceride, atherogenic index, HDL, LDL and VLDL) in addition, the oxidants (MDA) and antioxidants enzymes activities including SOD, GSH and CAT of hypercholesteremic rats were analyzed. Results indicated that treatment with quinoa seeds powder improved the previous parameters when compared to control positive group. The best treatment observed in the group administrated with quinoa (300 g/kg diet). Therefore, the study recommended that quinoa supplementation exerts significant positive effects on metabolic, hypercholesterolemia and cardiovascular.

Keywords: Quinoa- Hypercholesteremia - Oxidation- antioxidant activities- lipid profile

Introduction

Familial hypercholesterolemia (FH) is a prevalent autosomal dominant disorder of lipoprotein metabolism, caused by mutations in the genes encoding for the low-density lipoprotein (LDL) receptor, apolipoprotein B (ApoB) or proprotein convertase subtilisin/kexin-type 9 (PCSK9). Patients with FH are characterized by elevated serum LDL-cholesterol (LDL-C) levels and an increased risk for premature cardiovascular disease (CVD). LDL-C levels vary widely amongst FH patients. Because of the continuous and direct interaction between the digestive tract and foods, dietary compounds represent an interesting source of chemopreventive agents for gastrointestinal health **(Hovingh *et al.*, 2013 and Ruel *et al.*, 2018)**.

Hypercholesterolemia is defined as extravagantly high level of plasma cholesterol , and is a high risk factor for many harmful cardiovascular events. Total cholesterol levels above 200 mg/dl leads to development of peripheral vascular and coronary artery disease. High attention has been directed toward evaluating mechanisms by which hypercholesterolemia may impact vascular outcomes; these include both results of direct cholesterol lowering therapies and alternative interventions for improving vascular function **(Stapleton *et al.*, 2010)** .

Quinoa (*Chenopodium quinoa* Willd.) belongs to the family *Amaranthaceae*, native to the Andean regions. It can adapt to various types of climatic and soil. Quinoa has attracted the attention of nutrition scientists because of its high nutritional value. It is rich in proteins, dietary fiber, unsaturated fats , minerals and vitamins. It is also distinguished by its amino acid balance. Quinoa has the advantage of being a gluten-free grain making it suitable for celiac patients (**Alvarez-Jubete *et al.*, 2010 ; Filho *et al.*, 2017 and Gordillo *et al.*, 2016)**

Quinoa is easy to preparation and cook **(Filho *et al.*, 2017**).Similar to rice, its seeds are used in soups, by puffing them

to do breakfast cereal, or by grinding them to make baked products such as cookies, bread, biscuits, pasta, crisps, tortilla, and pancake **(Bhargava *et al.*, 2006).**

Reguera *et al.*, (2018) reported that the unique nutritional value of quinoa seeds depends on their high antioxidants activity. **Zhu *et al.*, (2001)** extracted six glycosylated flavonols from quinoa seeds and showed that quinoa may play an important role in inhibition of free radicals .Quinoa considered as a natural antioxidant at the cell membrane level, protecting fatty acids from damage of free radicals (**Ng *et al.*, 2007 and Ryan *et al.*, 2007) .** Quinoa seeds also play a good role in lowering blood sugar and reducing weight (**Mihaela *et al.*, 2014**).

Despite all these health benefits, quinoa is not widely used due to several reasons, such as high import costs of the grain and lack of informations about it among consumers. As we believe that further research is needed to provide more information about quinoa, so we will show the effect of dietary supplementation with quinoa seeds powder (QSP) to find out more protection against hypercholesterolemia disease .

Materials and methods

Materials

Preparation of basal diet

The basal diet was prepared according to **Reeves e*t al.*, (1993)**.

Methods

Preparation of sample

Quinoa seeds were purchased from Harraz for Food Industry and Natural Products, Bab Alkhalq, Cairo, Egypt. Quinoa seeds were well grinded for powder and then added in the above amounts to the basal diet.

Induction of experimental hypercholesterolemia

High cholesterol was induced in normal healthy male albino rats by feeding on diet containing 1.5% cholesterol plus 10% sheep tail fat for 15 days sheep according to **AIN (1993).**

iological Experiment

Twenty mature male albino rats weighing 184 ± 2 g were used in this study. The rats were divided into 4 groups (5 rats in each group) one of them used as control (-ve) while other three groups had given 1.5% cholesterol plus 10% sheep tail for 15 days , one of these left as control positive group and other two groups fed on two doses of quinoa (150 and 300 g/kg diet) for 28 days

Blood sampling collections

At the end of experiment period, blood samples were collected after 14 hours fasting from the portal vein; the rats were sacrificed under ether anesthesia. Blood samples were received into clean dry centrifuge tubes and left to clot at room temperature, then centrifuged for 10 minutes at 3000 r.p.m to separate the serum. Serum was carefully aspirated and transferred into clean covettee tubes and stored frozen at -20°C for analysis **(*Malhotra,* 2003)**.

Biological evaluation

During the experimental period, the diet consumed was recorded every day, and body weight recorded every week. The body weight gain (BWG) and feed efficiency ratio (FER) were determined according to **Chapman *et al.*, (1959)** using the following equations.

$$\textbf{B.W.G. \%} = \frac{\text{(Final weight - Initial weight)} \times 100}{\text{Initial weight}}$$

$$\textbf{FER} = \frac{\text{Body weight gain (g/day)}}{\text{Feed intake (g/day)}}$$

Relative organ weight calculated by the following formula:

$$\textbf{Relative organ weight (ROW)} = \frac{\text{Organ weight}}{\text{Total body weight}} \times 100$$

Biochemical parameters

Serum triglycerides (T.G) , total cholesterol (T.C) and high density lipoprotein cholesterol (HDL-c) were measured according to **Fossati and Principe (1982); Richmond (1973) and Allain (1974).** Low density lipoprotein cholesterol (LDL-c) was measured according to **Castelli *et al.*, (1977)**.

LDL Concentration mg/dl =LDL= TC- (VLDL+ HDL) Serum very low-density lipoprotein cholesterol (VLDL-c) was calculated as mg/dl according to **Lee and Nieman (1996*)*** equation:

$$\textbf{VLDL-C concentration mg/dl} = \frac{\textbf{T. G}}{\textbf{5}}$$

atherogenic index (AI) = $\frac{\textbf{LDL+VLDL}}{\textbf{HDL}}$

Malondialdehyde (MDA), superoxide dismutase (SOD), glutathione (GSH) and Catalase(CAT) were estimated in liver tissue according to **Ohkawa *et al.*, (1979); Kakkar *et al.*, (1984*)***; **Rotruck *et al.*, (1973) and Goth, (1991*)***, respectively .

Statistical analysis of data:

Data were statistically analyzed using a computerized program at the Scientific Computer Center, Faculty of Home Economics, Menoufia University, using ANOVA test according to **Armitage and Berry, (1987).**

Results and Discussion

Effect of quinoa on feed intake (FI) , feed efficiency ratio (FER) and body weight gain (BWG %) of hypercholesteremic rats

Data presented in Table (1) show the effect of quinoa on hypercholesterolemic rats. It is evident that the value of feed intake (FI), feed efficiency ratio (FER) and body weight gain of rats in control (+ve) was high compared to negative control group . The mean values were 18.00±1g , 0.029±0.001 g and 15.5±0.78%, respectively .

Regarding group 3 and 4, it is observed that quinoa can be used for management hypercholesterolemia and to reduce BWG especially in G4 which fed on quinoa at 300g / kg diet.

Table (1): Effect of quinoa on feed intake (FI) g , feed efficiency ratio (FER) g and body weight gain BWG(%) of hypercholestrolemic rats

Groups / Parameters	Control -ve (G1)	Control +ve (G2)	*Quinoa* 150 g/kg diet (G3)	*Quinoa*300 g/kg diet (G4)	LSD
FI (g) Mean ± SD	12^{c}±1.04	18^{a} ±1	16^{b}±1	13^{c}±1	1.8
Percent of change	- 33.3%	-	-11.11%	-27.77%	--
FER (g) Mean ± SD	0.028^{a} ±0.00	0.029^{a} ± 0.001	-0.027^{b}±0.002	-0.045^{c}± 0.005	0.008
Percent of change	-3.44 %	-	-193.0%	-255.17%	--
BWG (%) Mean ± SD	9.78^{b}±3.08	15.5^{a}±0.78	-12.6^{c}±0.77	-16.8^{d}±0.378	3.1
Percent of change	-36.9%	-	-181.29%	- 208.38%	--

Values with different letters indicate significant differences between the groups ($P \geq 0.05$), and vice versa.

LSD: least significant Differences ($P \leq 0.05$).

From this point of view, the above results coincided with the results of the researchers , **Thomas *et al.*, (2015)** they reported that quinoa consumption can decrease weight gain, improve lipid profile and improve the adverse effect of oxidative stress. These physiological effects may be due to the presence of saponins and protein in the quinoa seed.

Mihaela *et al.*, (2014) showed that diet fortified with 30% and 40% quinoa seeds can decrease the body weight, feed consumption, feed efficiency ratio, blood cholesterol and other lipids as well as improve liver and kidney functions compared to positive control group. Diet with 40% QSP reduced the adverse effect of hypercholesterolemia.

Also, **Mithila and Khanum (2015)** reported that rats fed on quinoa had little food consumption and had a decrease in weight gain as compared to control. Quinoa is one of the most nutritious

plants. Its seeds are rich in proteins , minerals, B vitamins and fibre which makes quinoa a complete and modern food to decrease weight.

Effect of quinoa on relative weight of heart, kidneys and liver of hypercholesterolemic rats

Data illustrated in Table (2) indicated the effect of treatment with quinoa on relative weight of heart, kidneys and liver of hypercholesterolemic rats .It is clear that rats fed on hypercholesterolemic diet (c+ve group) showed significant increase ($p \leq 0.05$) in relative heart,kidneys and liver weight when compared to healthy (-ve group) . Result denote that there were significant decreases in treated groups as compared to (c+ve group) .It could be noticed that rats fed on quinoa powder (300 g/kg diet) showed the lowest decrease in precedent organs as compared to (c+ve group).the percent of change for quinoa powder (300 g/kg diet) were -0.45%, -63.20% and -38.79%, respectively.

Table (2) : Effect of quinoa on relative weight of heart, kidney and liver of hypercholestrolemic rats

Groups / Parameters	Control -ve (G1)	Control +ve (G2)	*Quinoa* 150 g/kg diet (G3)	*Quinoa* 300g/kg diet (G4))	LSD
Heart (g) Mean±SD	$0.16^{c}\pm0.023$	$0.35^{a}\pm0.05$	$0.263^{b}\pm0.023$	$0.193^{c}\pm0.023$	0.062
Percent of change	-54.29%	-	-25.71%	-0.45%	-
Kidney (g) Mean ± SD	$0.393^{c}\pm0.035$	$1.063^{a}\pm0.125$	$0.533^{b}\pm0.041$	$0.393^{c}\pm0.057$	0.107
Percent of change	-63.20%	-	-50.00%	-63.20%	-
liver (g) Mean ± SD	$1.85^{d}\pm0.052$	$3.656^{a}\pm0.060$	$2.94^{b}\pm0.202$	$2.24^{c}\pm0.061$	0.235
Percent of change	-49.45%	-	-19.97%	-38.79%	-

Values with different letters indicate significant differences between the groups ($P<0.05$), and vice versa.

LSD: least significant Differences ($P<0.05$)

These results similar to **Pawel *et al.*, (2010)** findings who demonstrated that quinoa seeds can act as a moderate protective agent against potential of fructose-induced changes in rats by reducing lipid peroxidation and by enhancing the antioxidant capacity of blood (plasma) and heart, kidney, testis, lung and pancreas.

González *et al.*, (2014) showed that quinoa seeds can decrease liver, heart and kidney weight. They reported also that consumption quinoa seeds caused increase in vitamin E in the heart, liver, lungs, spleen, and kidneys and increase the antioxidant protection power of these organs in addition to their tissues.

Effect of quinoa on total cholesterol (T.C), triglyceride (T.G) and atherogenic index (A.I) of hypercholesterolemic rats

Data recorded in Table (3) show the effect of quinoa powder on total cholesterol (TC) of hypercholesterolemic rat. Control (+ve) groups showed significant increase in total cholesterol as compared to healthy rats which were 174.0±3.60mg /dl and 110 ±2 mg/dl, respectively. Feeding on quinoa led to a decrease in total cholesterol (Tc). Maximum decrease of total cholesterol recorded for group 4 which fed on quinoa at 300g/kg diet.

Regarding data illustrated in Table (4) mentioned the effect of treatments on hypercholesterolemic rats with quinoa powder, there was a significant increase of TG in hypercholesterolemic rats (control + ve group) as compared to healthy group control (– ve) which were (149.00±3.60) and (77.33±2. 51) mg /dl, respectively. All rats fed on quinoa at two doses showed significant decreases in TG as compared to control (+ve) group. It is evident that the best treatment was of groups 4 that given quinoa powder (300 g/kg diet).

Table(3): Effect of Quinoa on total cholesterol (T.C.), triglyceride (T.G.) and atherogenic index (A.I) of hypercholestrolemic rats

Groups / Parameters	Control -ve (G1)	Control +ve (G2)	*Quinoa* 150 g/kg diet (G3)	*Quinoa* 300g/kg diet (G4)	LSD
TC (mg/dl) Mean ± SD	110 ^{d}±2	174 ^{a}±3.60	144 ^{b}±3.60	123 ^{c} ±3.60	3.31
Percent of change	-36.78%	--	-17.24%	-29.21%	--
TG (mg/dl) Mean ± SD	77.33^{d}±2.51	149 ^{a}±3.60	124.33^{b}±4.50	93 ^{c}±3.60	8.039
Percent of change	-48.10%	--	-16.55%	-37.58%	--
Atherogenic Index (AI) (mg/dl) Mean ± SD	1.13^{c}±0.090	6.06^{a}±0.805	3.53^{b}±0.263	1.7^{c}±0.235	0.925
Percent of change	-81.35	--	-41.7%	-71.94%	--

Values with different letters indicate significant differences between the groups ($P<0.05$), and vice versa.

LSD: least significant Differences ($P<0.05$)

The present study is in accordance with **Farinazzi-Machado *et al.*, (2012)** they reported that daily intake of quinoa pills for 30 days significantly decreased triglycerides. Several clinical studies have indicated that quinoa consumption can lower cholesterol due to the presence of main ingredients (proteins, fibers, vitamins), tocopherol and carotenoids, minerals (iron, zinc, and magnesium), saponins, plant sterols, and polyphenols **(Abderrahim *et al.*, 2015 and Pellegrini *et al.*, 2018) . Yao and Rong (2017)** focused on the phytochemical composition of quinoa and amaranth seeds, the antioxidant and anti- inflammatory activities of hydrophilic (e.g. phenolics, betacyanins) and lipophilic (e.g. fatty acids, tocopherols, and carotenoids) nutrients, and how these contribute to the potential health benefits, especially in lowering the risk of the oxidative stress related diseases cancer, cardiovascular disease, diabetes, and obesity.

Effect of Quinoa on the serum levels of lipoproteins fractions (HDLc- LDLc and VLDLC) of hypercholesterolemic rats

To summarize the results presented in this in Table (٤) It is evident that rats fed on hypercholesteremic diet control(+ve group) indicated significant decrease in HDLc but significant increase in

LDL-c and VLDL-c as compared to normal healthy rats. Rats fed on quinoa with 300 g/kg diet showed a significant increase in HDL-c but significant decrease in LDL-c and VLDL-c levels. Treatment of quinoa with 300 g/kg diet showed the highest increase in HDLc but the highest decrease in LDLc and VLDLc as compared to control positive group.

Table (4) : Effect of quinoa on high density lipoprotein (HDL), low density lipoprotein (LDL) and very low density lipoprotein (VLDL) of hypercholestrolemic rats

Groups / Parameters	Control -ve (G1)	Control +ve (G2)	*Quinoa* 150 g/kg diet (G3)	*Quinoa* 300g/kg diet (G4)	LSD
HDL (mg/dl) Mean ± SD	$51.5^{a}\pm3.12$	$24.83^{c}\pm2.84$	$31.83^{b}\pm2.56$	$45.66^{a}\pm3.51$	6.723
Percent of change	107.4%	--	28.19%	83.89	--
LDL (mg/dl) Mean ± SD	$43.03^{d}\pm1.76$	$119.36^{a}\pm4.21$	$87.3^{b}\pm1.93$	$58.73^{c}+ 5.44$	5.49
Percent of change	-63.94	--	-26.85%	-50.79%	--
VLDL(mg/dl) Mean ± SD	$15.46^{d}\pm0.503$	$29.8^{a}\pm0.721$	$24.86^{b}\pm0.90$	$18.6\ ^{c}\pm0.721$	1.607
Percent of change	-48.12%	--	-16.57%	-37.58%	--

Values with different letters indicate significant differences between the groups ($P<0.05$), and vice versa.

LSD: least significant Differences ($P<0.05$)

These results similar to **Paśko *et al.*, (2010)** who came to same result that quinoa seeds can reduce serum TC, LDL and TG when compared to the control positive group. Quinoa seeds also can reduce serum glucose level and plasma total protein level. Fructose significantly decreased HDL level in control group but when the diet was fortified with quinoa seeds, the level of HDL increased.

Flávia *et al.*, (2012) indicated that quinoa can reduce the levels of total cholesterol, triglycerides, and LDL-c . It can be concluded that the consumption of quinoa in diet is beneficial for protecting against risk factors related to cardiovascular diseases that are among the leading causes of death in the world.

Result from **Wu *et al.*, (2015) and Lamothe *et al.*, (2015)** agreed with previous result they showed that greater consumption of fiber-rich whole grains is useful to reduce risk of type 2 and cardiovascular disease. Quinoa is an important source of dietary fiber, it contains about 2.6%-10% of the total weight of the grain. About 78% of its fiber content is insoluble and 22% soluble.

Also**, Rubén and Blanca (2017)** reported that quinoa has been found to contain numerous phytochemicals including saponins, phytosterols, phytoecdysteroids , phenolics and bioactive peptides. These compounds may exert beneficial effects on hypercholesteremia , metabolic, cardiovascular, and gastrointestinal health.

Effect of quinoa on malondialdehyde (MDA), superoxide dismutase (SOD), Glutathione (GSH) and catalase (CAT) in liver tissue of hypercholestremic rats.

Data illustrated in Table (5) showed the treatment of quinoa on hypercholesteremic rats reflected apparent increase in lipid peroxidation malondialdehyde (MDA) of control +ve group as compared to control -ve group. MDA values which were 95.50 ± 3.50 and 63.00± 3.60 nmoi/g tissue for control (+ve) and control (- ve) groups, respectively. All treated showed significant decreases in malondialdehyde as compared to control +ve, the best treatment for group 4 which fed on quinoa (300 kg/ diet) because this group caused the highest decrease in malondialdehyde which was71.66±3.50 nmol/g as compared to hypercholestremic rats. Concerning the percent decrease of control -ve group it was -34.3% as compared to control +ve group.

Regarding superoxide dismutase (SOD) data recorded in Table (6) showed that there was a significant increase in normal rats as compared to hypercholestromic rats in SOD which were 9.16 ± 1.04 and 2.96 ± 0.50 U/mg tissue, receptively. All treated group showed a significant increase in SOD as compared to control + ve group.

Concerning glutathione (GSH) , it is observed that there was a significant increase of glutathione in healthy rats (control –ve) as

compared to positive rats, values were 94.00 ±2.00 and 59.00±1.00 mg/g tissue respectively. Results denoted that there was a significant increase with all tested quinoa as compared to control positive group (control +ve).The best treatment was that of group 4 which fed quinoa 300g/kg diet .

The effect of treated groups with quinoa on CAT enzyme recorded in Table (6). The mean value of control positive group was lower than negative group (healthy rats), which were 5.00 ±1.00 and 19.50±1.80 U/g tissu, respectively and the results showed a significant difference with percent of increase 4% folds than control positive group. All treated group showed a significant increase in (CAT) enzyme as compared to control + ve groups.It is evident that the best treatment was quinoa300g/kg. diet which showed (CAT) enzyme value were 16.30 ± 1.52 U/g tissue

Table (5) : Effect of Quinoa on oxidant and antioxidant parameters in liver Tissue of hypercholestrolemic rats

Groups / Parameters	Control -ve (G1)	Control +ve (G2)	*Quinoa* 150 g/kg diet (G3)	*Quinoa* 300g/kg diet (G4)	LSD
MDA (nmoi/gtissue) Mean ± SD	63^{d}±3.60	95.5^{a}±3.5	84.5^{b}±1.80	71.66^{c}±3.05	6.569
Percent of change	-34.30%	--	-11.51%	-24.96%	--
SOD (U/mg tissue) Mean ± SD	9.16^{a}± 1.04	2.96^{d}±0.50	5.5^{c}± 0.5	7^{b}±0.5	1.497
Percent of change	2.9.45%	--	85.81%	136.48%	--
GSH (mg/g tissue) Mean ± SD	94^{a}±2	59^{d}±1	72^{c}±3	86^{b}± 2	4.75
Percent of change	59.32%	--	2203%	45.76%	--
CAT (U/g tissue) Mean ± SD	19.5^{a}±1.80	5^{c}±1	12^{b}±2	16.3^{a}±1.52	3.61
Percent of change	290%	--	140%	226%	--

Values with different letters indicate significant differences between the groups (P<0.05), and vice versa.

LSD: least significant Differences (P<0.05)

These results agree with **Pawel *et al.*, (2010)** who mentioned that quinoa seeds effected on the oxidative stress by decreasing

MDA in plasma, and increasing the activities of antioxidant enzymes. Also, **De Carvalho *et al.*, (2014)** reported a potential benefit of quinoa seeds consumption against oxidative stress**. Park *et al.*, (2017)** reported that quinoa seeds have antioxidant activity due to the presence of important active ingredients such as polysaccharides

Quinoa is an excellent source of vitamin E, the amount of γ-tocopherol was higher than the amount present in corn oil so quinoa oil has a long shelf life due to the antioxidant power of this substance. vitamin E, is very important because it acts as a natural antioxidant to protect fatty acids from damage by free radicals (**Ng *et al.*, 2007 and Ryan *et al.*, 2007)**

Zhu *et al.*, (2001) extracted six glycosylated flavonols from quinoa seeds and showed that quinoa may play an important role in inhibition of free radicals.

Conclusion:

To summarize the results presented in this section, quinoa emerges as a food of particular interest to celiac patients, as the potential cornerstone of a healthy, gluten-free diet. Furthermore, we hypothesizethat including quinoa in the diet could decrease oxidative stress, improve serum lipid profile, help to control body weight and serum glucose, and decrease cardiovascular disease and type 2 diabetes risk factors; quinoa may even prove beneficial in reversing the effects of these diseases.

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مكملات غذائية من مسحوق بذور الكينوا وتأثيرها على فرط كوليسترول الدم والأكسدة في الجرذان البيضاء

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الهدف الرئيسي من هذا البحث هو استخدام مكملات غذائية من مسحوق بذور الكينوا تحت تركيزات مختلفة (١٥٠ و٣٠٠ جم / كجم من الغذاء) لإعطاء مزيد من الحماية ضد مرض فرط كوليسترول الدم. . تم استخدام عشرون من ذكور الفئران البيضاء يتراوح وزنها ما بين ١٨٤± ٢ جرامًا في هذه الدراسة. تم تقسيم الفئران إلى ٤ مجموعات (٥ فئران في كل مجموعة) استخدمت واحدة منها كمجموعة ضابطة سالبة بينما تغذت الثلاث مجموعات الاخرى على وجبة محتوية على ١.٥٪ من الكولسترول بالإضافة إلى ١٠٪ من دهن الأغنام لمدة ١٥ يومًا وذلك للاصابة بمرض ارتفاع الكوليسترول ، تركت واحدة من هذه المجموعات كمجموعة ضابطة موجبة وتغذت المجموعتين الاخرتين على جرعتين من الكينوا (١٥٠ جم و٣٠٠جم / كجم من الوجبة) لمدة ٢٨ يوماً. تم تقدير المأخوذ من الطعام ووزن الجسم المكتسب ومعدل الاستفادة من الغذاء وكذلك وزن الاعضاء الداخلية ،كما تم تقدير الكوليسترول الكلى والترای جليسريد والليبوبروتين مرتفع الكثافة والليبوبروتين منخفض الكثافة والليبوبروتين منخفض الكثافة جدا وكذلك تم تقدير الانزيمات المؤكسدة (المالونالدهيد) وكذلك الانزيمات المضادة للاكسدة (السوبر اوكسيد ديسميوتيز والجلوتاثيون والكتايز) .وقد أظهرت النتائج أن المعاملة ببذور الكينوا قد حسّنت المعاملات السابقة وذلك بالمقارنة بالمجموعة الضابطة الموجبة وأفضل علاج لوحظ في المجموعة التي غذيت على ٣٠٠ جم/كجم من الغذاء. ولذلك، توصي الدراسة بأن مكملات الكينوا لها تأثيرات إيجابية كبيرة على التمثيل الغذائي وفرط كولسترول الدم وامراض القلب.

الكلمات المفتاحية: الكينوا - ارتفاع الكولسترول - الأكسدة - الأنشطة المضادة للأكسدة - مستوى الدهون