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Prophylactic and Curative Effects of Barley and its Bran Against Hyperlipidemia in Albino Rats

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Abstract

The aim of this study was to investigate the prophylactic and curative effects of barley and it's bran against hyperlipidemia in albino rats. A total of 88 adult male albino rats "swiss strain" weighting about 80-100g were used in 2 main experiments. (1) The prophylactic effect of barley and bran against hyperlipidemia for 8 weeks and (2) The curative effect of barley and bran for 8 weeks after induction of hyperlipidemia (using cholesterol and cholic acid). The data revealed that there was an increase in the levels of serum total lipids, total cholesterol, triglycerides, ALT, AST, ALP and LDH, while HDL-cholesterol level was decreased after the induction of hyperlipidemia. These results suggest that barley and bran may evoke different lipidaemic responses and that barley bran has more favorable effect on blood lipids than the whole barley. Results were compared with those of Atorvastatin, a standard orally effective hypolipidemic agent.

Keywords: Hyperlipidemia, Prophylactic, Curative, Barley, Bran, Lipid Profile, Liver Function. **Introduction**

Hypercholesterolemia is a risk factor for early onset coronary heart disease. Increased consumption of dietary plant starch and non starch polysaccharides (NSP,"Fiber") and reduced consumption of total and saturated fat are known to lower plasma cholesterol⁽¹⁾.

Barley (Hordeum vulgare L.) contains relatively high concentration of the mixed-linkage ⁽¹⁻³⁾ (¹⁻⁴⁾ β –D-glucans (β -glucan). Although β –glucan occurs in all cereals, its concentration is highest in oats and barley with values ranging from 2% - 16% ⁽²⁾. Among the cereal grains, oats and barley have been reported to be the most effective in lowering serum total cholesterol and LDL-cholesterol in human and animals ⁽³⁻⁶⁾. Cholesterol-lowering ability was first ascribed to oats but more recently to barley ⁽⁶⁾. It has been hypothesized that, upon ingestion, β -glucan increases small intestinal viscosity due to its lower molecular weight and its tendency to form viscous gummy solution resulting in reduced bile acid and cholesterol or triglycerides absorption thus lowering plasma cholesterol ⁽⁷⁾ as well as altering digestive enzyme activity⁽⁸⁾. **Materials and Methods**

The barley was purchased from the Egyptian market. It was cleaned and powdered in a cyclotec mill to pass through a 60 mesh sieve. Atorvastatin was chosen as a standard hypolipidaemic agent. It was obtained from Egyptian Int. Pharm Company; each tablet contains 10mg of the active material "vastatin".

Experimental Animals

A total of 88 adult male albino rats (80-100g) were used in this study. Rats were provided from the NODCAR's Farm, Giza . they had free access to water and were fed on a standard synthetic diet for two weeks ⁽⁹⁾. Hyperlipidemia was attained to rats using cholesterol/ cholic acid mixture (3:1) mixed with the synthetic diet in a dose calculated on the basis that each rat received 0.5g of this mixture/kg b.w daily for 10 weeks. Two main experiments were conducted as follows:

International Journal of Vaccines and Immune System An Open Access Journal

The prophylactic effect against hyperlipidemia: to study the protective effect of the whole barley and bran against hyperlipidemia, a total of 40 rats were used the experiment lasted for 8 weeks. Animals were divided randomly into equal five groups (8 rats each): Group 1 fed on the standard synthetic diet and served as negative control (-ve).Group 2 was daily attained to the hyperlipidemic diet (H.L.D) and served as positive control group (+ve). Group 3 administered barley bran at a dose of 100mg/kg b.w (adde de to the H.L.D) daily. Group 4 administered barley bran at a dose of 200mg/kg b.w (added to the H.L.D).

The curative effect on hyperlipidaemic rats: in this experiment, a total of 48 rats were used. Eight rats were fed on the standard synthetic diet and served as negative control (-ve) "Group1". The other rats were subjected to the induction of experimental hyperlipidemia for 10 weeks as described before. The hyperlipidaemic rats (40rats) were divided randomly into equal 5 groups (8 rats each): The first one; Group 2 served as hyperlipidemic control (-ve control). Group 3 received barley bran at a dose of 100mg/kg b.w. (added to the diet) daily. Group 4 received 200mg/kg b.w.of barley bran (added to the diet) daily. Group 5 received whole barley at a dose of 100mg/kg b.w. (added to the diet) daily. Group 5 received whole barley at a dose of 100mg/kg b.w. Atorvastatin as a standard hypolipidemic agent (added to the diet) daily.

All doses administered to the animals were calculated according to the recommended therapeutic human dose and converted to the dose of the adult rats⁽¹⁰⁾.

Blood sampling

In the first experiment, blood samples were collected before treatment and then after 4 and 8 weeks. In the second experiment, blood samples were collected before and after induction of hyperlipidemia and then 4 & 8 weeks after administration of the different treatments.

Analysis

AACC approved methods⁽¹¹⁾ were used to analyze the test samples for protein (Kjeldahl), fat (acid hydrolysis) and ash .β-Glucan content was measured⁽¹²⁾. Moisture was determined under vacuum (16 hr, 7000 C, 25 mmHg).Total dietary fiber (TDF) and soluble fiber (SF) contents were determined⁽¹³⁾. The following parameters were assayed; serum total lipids⁽¹⁴⁾, total cholesterol⁽¹⁵⁾, HDL-cholesterol⁽¹⁶⁾, triglycerides⁽¹⁷⁾, transaminases enzymes (ALT& AST) ⁽¹⁸⁾, alkaline phosphatase (ALP)⁽¹⁹⁾, lactate dehydrogenase (LDH) ⁽²⁰⁾, total proteins⁽²¹⁾, albumin⁽²²⁾, urea⁽²³⁾ and creatinine⁽²⁴⁾.The obtained results were statistically analyzed⁽²⁵⁾.

Results

Chemical composition of Barley and Barley bran: The chemical composition of whole barley and barley bran was presented in **Table (1)**. It is obvious that the whole barley contains higher fat than bran, while fat contents were 4.1 g/100g and 3.4 g/100g. Total respectively carbohydrate amounts 51.8 g/100g and 52.1 g/100g, respectively. Barley bran contains higher amount of soluble fiber (12.5 g/100g) than whole barley (6.8 g/100g). B-Glucan concentrations were found in the same order, i.e. barley bran (13.2 g/100g) and whole barley (9.8 g/100g).

Material	Moisture	Protein	Fat	Ash	Total	Soluble	Carbo-	B-Glucan
		(TN×6.25)			dietary	fiber	hydrates	
					fiber.			
Whole barley	10.2	11.7	4.1	2.1	20.1	6.8 (34)	51.8	9.8
Barley bran	9.4	11.2	3.4	2.0	21.9	12.5 (57)	52.1	13.2

Table (1): Chemical composition of test material. (Components in g/100g)

Biochemical analysis

Prophylactic effect of Barley and Barley bran against hyperlipidemia: Table (2) revealed the effect of different treatments on serum lipid profile. It is clearly shown that the value of T. Lipids in the first group (-ve control) were not affected during the experimental period. In the (+ve control) group, where rats were fed on the hyperlipidemic diet, serum T. Lipids were significantly increased by 180.2% after 8 wks of treatment compared with the corresponding control and by 98.9%, 51.0% and 88.6% for barley bran (100, 200) and 200 mg/kg.b.w of whole barley, respectively. Serum triglycerides in the (-ve control) group were not affected during 8 weeks of treatment, while in the (+ve group), this level was increased by 144%. Barley bran in the two different doses and whole barley (200 mg/kg.b.w.) caused a decrease by 5.60, 29.5 and 10.5, respectively. Serum total cholesterol level was increased

by 225% in the (+ve control) group, while it was increased only by 4.11% in the negative control group. Barley bran in the dose of (100,200) mg/kg. b.w. and whole barley (200 mg/kg.b.w.) increased the T. Cholesterol by 36.2%, 20.8% and 37.7%, respectively. Serum HDL-cholesterol level was decreased by 19.4%, 11.4% and 17.6% in barley bran (100, 200 mg/kg.b.w) and whole barley groups, respectively. While in the (+ve control) group this value was decreased by 42.6% after 8 weeks. The risk ratio in the (+ve control) group was increased by 466%, while barley bran in the two different doses and whole barley (200 mg/kg.b.w) decreased this value only by 91.8%, 35.8% and 66.7%, respectively compared to the corresponding control.

A marked elevation in serum ALT, AST, ALP and LDH by 68.2%, 89.1%, 150% and 33.5%, respectively was observed in the +ve control group after the induction of hyperlipidemia (Table3). The

daily dose of (100,200) mg/kg.b.w. of barley bran and 200mg/ kg.b.w of whole barley decreases the levels of S-ALT, AST, LDH and ALP compared to +ve control group. **Table (4)** revealed the effect of bran and whole barley on serum total proteins, albumin, globulin and Alb / Glob. The daily dose of 200 mg/kg.b.w. of bran and whole barley caused a moderate increase in bl. urea level after 8 weeks of treatment. Both doses of barley bran and the dose of whole barley induced a slight increase in S.creatinine level after 8 weeks of treatment.

Curative effect of Barley and Barley bran on hyperlipidemic rats: In this experiment, rats were fed on the hyperlipidemic diet for 10 weeks, and then treated with the different treatments for 8 weeks. Atorvastatin was used as a reference standard hypolipidemic agent. It revealed appreciated effects on the different lipid parameters of hyperlipidemic rats after treatment for 8 weeks (Table 6). Also, this agent reduced ALT, AST, ALP and LDH levels. Bran and whole barley also decreased these levels (Table 7). Serum total protein concentration was significantly decreased by 14.8%, 18.5%, 24.2% and 25.0% in the groups of barley bran, whole barley and Atorvastatin (Table 8), respectively. The values of serum albumin were also decreased by 31.0%, 28.6%, 30.5% and 31.7% in the groups of barley bran, whole barley and Atorvastatin. The high dose only of barley bran caused a slight increase in bl.urea level after 8 weeks of treatment. There was no effect of the different treatments on serum creatinine level during 8 weeks of treatment.

Discussion

Induction of hyperlipidemia: Induction of hyperlipidemia was performed using cholesterol: cholic acid mixture at a ratio of 3: 1 ⁽²⁶⁾. In addition, saturated fats (10%) and sucrose (50%) were added to the diet. Cholic acid was used to overcome the difficulty of cholesterol absorption.

As can be seen from the data shown in **Table (5)**, very highly significant elevations were indicated in the level of serum total lipids, total cholesterol, risk ratio, triglycerides, ALT, AST, ALP, LDH and Alb/Glob ratio. While slight elevations were indicated in the level of serum creatinine and albumin after 10 weeks from the induction of hyperlipidemia. Also, highly significant reductions were indicated in the level of serum HDL-C. The level of serum total proteins and blood urea were not affected. The slight elevation in serum creatinine after induction of hyperlipidemia is statistically not significant and lies in the normal range. Elevations indicated in serum total lipids seem to be logic and runs parallel with the excess of saturated fat and sugar available in the diet. Elevations in serum total lipids were also indicated after the induction of experimental hyperlipidemia (27). The increase indicated in the level of cholesterol runs parallel with the similar elevations indicated by the previous authors. Reductions indicated in HDL-C may be important. since it stimulates the removal of cholesterol from the peripherol cells back to the liver for excretion. The increase in the level of triglycerides could be referred to the presence of excess saturated fats in the dietary intake. This excess of body needs leads to their conversion into triglycerides in the liver. These triglycerides are packaged into VLDL and released into the circulations to be delivered to various tissues for storage or production

of energy through oxidation ⁽²⁸⁾.

Elevations indicated in serum ALT, AST, ALP and LDH after the induction of hyperlipidemia may be due to the destruction of some liver parenchymal cells or by enhancement of the activity of the enzyme itself to face the damaging effect of free radicals accompanying the hyperlipidemia ⁽²⁹⁾.

In most human studies as well as experimental animals there is a positive correlation between cardiovascular disease and blood cholesterol level. Free radicals play an important role in this concept. Lipid oxidation and generation of free radicals are considered to be natural phenomenon in biological systems. The formation of reactive free radicals is mediated by a number of agents and mechanisms such as xenobiotic metabolism. The free radicals formed are highly reactive with molecular oxygen forming peroxy radicals and hydroperoxides and thus initiating a chain reaction. Pro-oxidant states cause cellular lesions in all major organs by damaging cellular components and cell function. The free radical has been implicated in the etiology of several genetic as well as acquired metabolic disorders. One of these diseases is hyperlipidaemia which favors the formation of free radicals, leading to arterial damage and platlet aggregation. Cholesterol oxidation products have received a lot of attention because of their involvement in the development of coronary artery disease (30).

Oxygen free radicals and lipid peroxidation are major factors in the etiology of atherogenesis and its associated clinical disorders, which include coronary artery disease, stroke, ischemic dementia and various other atherosclerotic disorders ⁽³¹⁾. Atherosclerosis is a vascular disease with a complex etiology ⁽³²⁾. The oxidative modification hypothesis of atherosclerosis proposes that oxidation of LDL leading to the accumulation of lipid peroxides and other oxidized radicals, is a major cause of atherosclerosis. It is now known that the level of serum LDL is positively correlated with the incidence of hyperlipidaemea and then atherosclerosis. One widely accepted theory for explaining this phenomenon is the oxidation of LDL. However, epidemiological studies have shown that the concentration of serum HDL was inversely correlated to the risk of atherosclerosis. Experimental evidences have suggested that HDL can protect LDL against oxidation. However, the HDL - cholesterol may be increased by N - acetyl cysteine suggesting the possibility that a decrease in HDL – cholesterol may be related to changes of the thiol level and / or the thiol / disulfide redox status (REDST) in the plasma. They concluded that there is a strong possibility that the changes in plasma thiol level / plasma and intracellular thiol disulphide redox status of peripheral blood mononuclear cells may play a causative role in the pathophysiology of the arteriosclerotic process and the development of coronary heart disease. This conclusion is in line with the fact that abnormally high "total homocysteine levels" which are also typically associated with an oxidative shift in REDST have been identified as an independent risk factor for CHD. The oxidative shift in REDST may therefore be a consensus risk factor common to several or all independent other risk factors (33).

Evaluation of barley and its bran: barley bran lowered the serum total cholesterol and serum triglycerides in the rats more than the whole barley did **(Table 6)**. Elevated serum HDL- Cholesterol

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levels, unlike total cholesterol levels, is reported ⁽³⁴⁾ to provide protection against heart disease. In barn fed animals, however, an interesting pattern again emerged. The different results may be due to diet, i.c. the amount of soluble fiber and β -glucan in the diet. For example, rats fed the diet containing the highest level of soluble fiber and β -glucan (diet formulated with barley bran) showed the lowest serum cholesterol levels throughout the eight- weeks test period **(Table 6)**.

The physiological effects of dietary fiber have proven to be more complex than once thought. Currently, the major nutritive effect of fiber receivins the most focus is its hypolipidaemic effect, which is more pronounced by soluble fiber such as β -glucan than non soluble fiber. The most widely held hypothesis of the mechanism by which fiber influences lipid metabolism is that it interrupts enterohepatic circulation by binding the circulating bile acids and preventing their subsequent reabsorption^(35, 36). Thus, an increased proportion of cholesterol produced by the liver is converted to bile acids, thereby making less cholesterol available for packaging into lipoproteins.

Barley reportedly contains other factors that affect blood plasma cholesterol ^(37, 38 and 39). It was reported that ⁽⁴⁰⁾ barley contains compounds that inhibit 3-hydroxy-3-methylglutaryl coenzyme A (HMG-COA) reductase in chickens, the rate-limiting enzyme in the cholesterol biosynthetic pathway. One of these compounds was isolated from high-protein barley flour (HPBF) and identified as α -tocotienol. The present authors hypothesized that the presence of dietary HPBF would partially alleviate the hypercholesterolaemia resulting from dietary cholesterol because reports indicate that various fibers moderate the increase in plasma and liver cholesterol diets ^(41, 42). Furthermore, Gallaher et al. found a significant serum lipid- lowering effect of a β -glucan rich barley fraction in hypercholesterolaemic men. These findings also indicate that the β -glucan in barley influences sterol metabolism⁽⁴³⁾.

Barley also contains lipids and phytosterols, which have both been postulated to reduce serum cholesterol ⁽⁴⁴⁾. Recently, barley oil was found to have a lipid- lowering effect similar to that of barley bran flour when added to a low-fat diet ⁽⁴⁴⁾. The authors suggested that the lipids of certain barley fractions, such as brewer's spent grain, may have lipid-lowering properties. β -glucans in barley increased intestinal viscosity and decreased plasma cholesterol of male broiler chicks fed barley and cholesterol ⁽⁴⁵⁾. In the chicken model ⁽³⁷⁾ reported a cholesterol-lowering effect in barley due to a decrease in a rate- limiting enzyme in cholesterol synthesis; subsequently, the authors identified α -tocotrienol as an inhibitor of this enzyme .However, if human subjects respond like the rats used in this study, it would suggest that the ability of soluble fiber (SF) in barley meal to lower cholesterol is negated by some mechanism (activation of β -glucanses, for example).

Elevated serum triglycerides (TG) levels are viewed by some as an independent risk factor in heart disease (34). Barley diets appeared to be strong predictors caused a reduction in serum cholesterol and serum triglycerides content in liver of rats .The viscous property of soluble β -glucan may result in reduced absorption, or reabsorption of lipids ⁽⁴⁶⁾.

 β - glucan decreased LDL- Cholesterol and increased HDL-Cholesterol. High density lipoprotein may hasten the removal of cholesterol from peripheral tissue to the liver for catabolism and excretion. Also, high levels of HDL may complete with LDL receptor sites on arterial smooth muscle cells and thus partially inhibit uptake and degradation of LDL. The increase of HDL concentration could protect LDL against oxidation in – vivo because the lipids in HDL are preferentially oxidized before those in LDL⁽⁴⁷⁾.

A considerable attention has been devoted to the role of the different natural antioxidants as inhibitors of LDL oxidation and their possible therapeutic effects to prevent hyperlipidemia and atherosclerosis. It was reported that total and LDL-Cholesterol were reduced ⁽⁴⁸⁾, both decreases being significantly correlated with soluble β -glucan content. It has been hypothesized that soluble β -glucan tends to increase intestinal viscosity due to its low molecular weight and tendency to form viscous solutions, resulting in reduced bile acid and cholesterol production ,and increased faucal fat bile acid excretion thus reducing plasma cholesterol^(48,49).

These results suggested that barley and its bran may evoke different lipidaemic responses. Thus, it seems that the bran fraction of barley which is rich in soluble fiber and β - glucan would likely exert a more favorable effect on blood lipids than any other fraction of the whole barley. **Table (2):** Prophylactic effect of whole barley and barley bran on serum lipids ($mg/dl \pm S.D$) and % variation from the corresponding control during the induction of hyperlipidemia for 8 weeks in male rats.

GROUP	TREATMENT	ITEM		Time in	tervals (Wk's)	ervals (Wk's)			
NUMBER		TIEM	0	4	% var.	8	% var.		
		T.L	293 ± 55.4	299±35.3†	2.05 ↑	301±60.9†	2.73 ↑		
	Negative control	Trig.	50.2±5.47	51.3±1.70 †	2.19 ↑	49.9±7.00 †	0.60↓		
1		T.Ch.	53.5 ±7.78	56.7±6.10 †	5.98 个	55.7±4.23†	4.11 个		
		HDL.Ch.	36.6±2.42	36.5±4.30 †	0.27↓	35.3±1.62†	3.55↓		
		T./HDL	1.46±0.12	1.55±0.27 †	6.16 个	1.58±0.09†	8.22 ↑		
	Positive control	T.L	268±53.6	723 ± 41.4***	169.8 ↑	751±53.0***	180.2 ↑		
		Trig.	54.4±7.81	65.0±1.39*	19.5 ↑	132.6±6.15***	144 ↑		
2	Positive control	T.Ch.	55.4 ± 6.71	128.1±5.24 ***	131.2 ↑	179.9±14.4***	225 ↑		
		HDL.Ch.	34.0±2.93	26.2±1.81***	22.9 ↓	19.5±2.58***	42.6↓		
		T./HDL	1.63±0.08	.0 ± 2.93 26.2 $\pm 1.81^{***}$ 22.9 \downarrow 53 ± 0.08 4.89 $\pm 0.44^{***}$ 200.0 \uparrow 3 ± 64.2 419 $\pm 79.2^{***}$ 53.5 \uparrow .0 ± 6.28 39.1 $\pm 5.95^{*}$ 21.8 \downarrow	9.23±1.20***	466 ↑			
3	Barley Bran (100 mg/kg b.w)	T.L	273 ± 64.2	419 ± 79.2***	53.5↑	543 ± 76.7***	98.9 1		
		Trig.	50.0±6.28	39.1±5.95 *	21.8↓	47.2±5.49†	5.60↓		
		T.Ch.	55.6±5.18	113.0±4.08***	103.2↑	75.7±3.99***	36.2↑		
		HDL.Ch.	37.7±2.56	27.5±2.18***	27.1↓	30.4±2.64**	19.4↓		
		T./HDL	1.47±0.06	4.10±0.49***	178.9↑	2.49±0.23***	91.8 ↑		
		T.L	251 ± 27.6	612±63.6***	143.8 个	379 ± 78.4***	51.0 个		
	Barley Bran	Trig.	57.0±9.41	42.1±9.70 *	26.1 ↓	40.2±9.40*	29.5↓		
4	(200 mg/tg h url)	T.Ch.	53.0±6.06	109.9±2.95***	107.4↑	64.0±5.95**	20.8 ↑		
	(200 mg/kg 0.w)	HDL.Ch.	35.9±2.71	25.5±2.73***	28.9↓	31.8±2.93*	11.4↓		
		T./HDL	1.48±0.07	4.31±0.58***	191.2 ↑	2.01±0.29**	35.8↑		
		T.L	281±30.5	500 ± 99.7**	77.9 ↑	530 ± 62.1***	88.6 ↑		
	Whole Barley	Trig.	48.8±6.44	40.6±8.72†	16.8↓	43.7±6.70 †	10.5↓		
5	(200 meter hard)	T.Ch.	55.4±7.67	111.5±3.84***	101.3↑	76.3±6.38***	37.7 ↑		
	(200 mg/kg b.w)	HDL.Ch.	36.3±1.92	27.2±1.65***	25.1↓	29.9±3.44**	17.6↓		
		T./HDL	1.53±0.13	4.10±0.35***	167.9 ↑	2.55 ± 0.47**	66.7 ↑		

⁺P > 0.1. ^{*} P < 0.05. ^{**} P < 0.01. ^{***} P < 0.001. T.L.: total lipids. T.C.: total cholesterol.

TG.: triglycerides. HDL-C: HDL-cholesterol. T. /HDL-C: total cholesterol / HDL-cholesterol. EGb: Ginkgo biloba extract.

Table (3): Prophylactic effect of whole barley and barley bran on serum enzymes $(U/L \pm S.D)$ and % variation from the corresponding control during the induction of hyperlipidemia for 8 weeks in male rats.

GROUP	TREATMENT	TTEM		Time inte	ervals (W	k's)	
NUMBER		TIEM	0	4	% var.	8	% var.
		ALT	32.3±5.74	32.4±3.57 †	0.31 个	32.1±5.50 †	0.62↓
1	Nagative control	AST	65.3±2.77	64.9±6.06 †	0.61 ↓	66.2±13.3†	1.38 个
	Negative control	ALP	30.3±3.22	30.9±1.98 †	1.98 个	32.8±3.89 †	8.25↑
		LDH	694±89.9	683±66.2 †	1.59↓	698±86.9 †	0.58 个
		ALT	33.7±1.53	61.7±3.48 ***	83.1 个	56.7±8.33**	68.2 ↑
2	Positive control	AST	63.3±9.80	109.8±11.4 ***	73.5 个	119.7±17.9***	89.1 ↑
2	Positive control	ALP	29.7±2.21	26.5±3.79 †	10.8↓	74.4±6.39 ***	150 个
		LDH	741±80.1	694±64.4 †	6.34 ↓	989±47.8***	33.5↑
		ALT	31.4±4.20	36.3±1.69 *	15.6 ↑	36.2±5.22*	15.3
3	Barley Bran	AST	60.2±5.04	98.9±10.8 **	64.3 个	75.7±10.0**	25.7 个
	(100 mg/kg b.w)	ALP	30.5±4.77	25.2±3.41*	17.4 ↓	34.3±6.20 †	12.5 个
		LDH	716±95.8	729±57.8 †	1.82 个	303±19.9***	57.7↓
		ALT	30.6±4.92	34.1±4.67 †	11.4 个	33.8±6.99 †	10.5 个
4	Barley Bran	AST	67.6±4.16	115.8±8.94 ***	71.3 个	68.1±12.8 †	0.74 个
4	(200 - 1 1)	ALP	31.5±5.55	41.6±5.98**	32.1 ↑	23.5±4.41 **	25.4↓
	(200 mg/kg b.w)	LDH	771±64.9	560±74.9**	27.4 ↓	472±27.1***	38.3↓
		ALT	34.8±3.07	36.5±1.37 †	4.88 ↑	41.9±6.94 **	20.4 个
5	Whole Barley	AST	60.4±6.92	90.7±2.29***	50.2 ↑	92.8±5.53 ***	53.6 个
3	(200 mg/kg b.w)	ALP	30.1±3.52	41.5±4.58**	37.9 个	43.3±9.82 **	43.8 ↑
		LDH	739±91.4	628±90.2 †	15.0↓	384±58.0***	48.0↓

⁺P > 0.1. [∗]P < 0.05. ^{∗∗}P < 0.01. ^{∗∗∗}P < 0.001. ALT: Alanine aminotransferase. AST: Aspartat aminotransferase. ALP: Alkaline phosphatase. LDH:Lactate dehydrogenase. EGb: Ginkgo biloba extract.

Table (4): Prophylactic effect of whole barley and barley bran on serum proteins, urea and creatinine ($mg/dl \pm S.D$) and % variation from the corresponding control during the induction of hyperlipidemia for 8 weeks in male rats.

GROUP	DUP TREATMENT		Time intervals (Wk's)							
NUMBER		TIEM	0	4	% var.	8	% var.			
		T.P.	6.03±0.62	6.44±0.19 †	6.80 个	6.42±0.23 †	6.47 个			
1		Alb.	3.54±0.20	3.77±0.24 †	6.50 个	3.72±0.15 †	5.08 个			
		Glob.	2.49±0.40	2.67±0.15 †	7.22 ↑	2.70±0.14 †	8.43 个			
	Negative control	Alb/Glob	1.42±0.26	1.41±0.15 †	0.70↓	1.38±0.13 †	2.82↓			
		Urea	25.2± 5.09	$24.6 \pm 1.50 \dagger$	2.38 ↓	$24.9 \pm 3.14 \dagger$	1.19↓			
		Creat.	0.39 ± 0.09	$0.40 \pm 0.02 \dagger$	2.56 ↑	$0.41\pm0.02\dagger$	5.13 个			
		T.P.	6.28±0.61	7.07±0.38*	12.6 个	6.40±0.29 †	1.91 ↑			
		Alb.	3.92±0.28	4.33±0.38*	10.5 个	4.37±0.45 †	11.5 个			
2	Desition sentes1	Glob.	2.36±0.42	2.74±0.34 †	16.1 个	2.03±0.49 †	13.9↓			
2	Positive control	Alb/Glob	1.66±0.30	1.58±0.30 †	4.82↓	2.15±0.43*	29.5 ↑			
		Urea	23.9 ± 1.59	31.1 ± 2.79***	30.1 个	$27.3 \pm 2.46^{*}$	14.2 ↑			
		Creat.	0.55 ± 0.09	$0.83 \pm 0.02^{**}$	50.9↑	0.59 ± 0.06†	7.27 ↑			
2	Barley Bran	T.P.	6.08±0.14	6.76±0.39**	11.2 1	6.40±0.27*	5.26 个			
	(100 /1 1)	Alb.	3.82±0.23	3.84±0.24 †	0.52 1	3.90±0.34 †	2.09 个			
	(100 mg/kg b.w)	Glob.	2.26±0.18	2.92±0.24 ***	29.2 1	2.50±0.35 †	10.6 个			
5		Alb/Glob	1.69±0.21	1.31±0.12**	22.5↓	1.56±0.17 †	7.69↓			
		Urea	25.6 ± 4.24	28.6 ± 3.99†	11.7 个	$27.0 \pm 3.72 \dagger$	5.47↑			
			0.49 ± 0.03	$0.61 \pm 0.03^{**}$	24.5 ↑	$0.59 \pm 0.04^{*}$	20.4 个			
		T.P.	6.54±0.20	6.84±0.39 †	4.59 个	6.67±0.43†	1.99 ↑			
		Alb.	4.15±0.22	3.85±0.26*	7.23↓	4.22±0.16 †	1.69 个			
4	Barley Bran	Glob.	2.39±0.24	2.99±0.35 **	25.1↑	2.45±0.32 †	2.51↑			
+	(200 mg/kg b.w)	Alb/Glob	1.74±0.25	1.29±0.20**	25.9↓	1.72±0.18 †	1.15↓			
		Urea	26.6 ± 3.19	$45.3 \pm 8.00^{**}$	70.3 个	$41.7 \pm 8.60^{**}$	56.8 个			
		Creat.	0.50 ± 0.05	$0.83 \pm 0.02^{***}$	66.0 个	$0.61\pm0.07^*$	22.0↑			
		T.P.	6.17±0.26	6.97±0.65*	12.9 ↑	6.43±0.47 †	4.21 ↑			
		Alb.	3.81±0.28	4.00±0.49 †	4.99 个	3.80±0.34 †	0.26↓			
5	Whale Darlary	Glob.	2.36±0.28	2.97±0.49 *	25.8 个	2.63±0.35 †	11.4 个			
5	(200 mg/kg h w)	Alb/Glob	1.61±0.36	1.35±0.30†	16.2 ↓	1.44±0.27 †	10.6↓			
	(200 mg/kg 0.w)	Urea	26.3 ± 1.65	34.9 ± 2.65***	32.7 个	$34.2 \pm 4.30^{**}$	30.0↑			
		Creat.	0.51 ± 0.03	$0.83 \pm 0.02^{***}$	62.7 1	$0.60 \pm 0.02^{*}$	17.6 ↑			

†P>0.1. * P<0.05. ** P<0.01. *** P<0.001. T.P.: Total protein. Alb.: Albumin. Glob: Globulin. Alb/ Glob: Albumin/ Globulin. Creat: Creatinine. EGb: Ginkgo biloba extract

Table (5): Arithmetic mean values \pm S.D and % changes from the corresponding control of different biochemical parameters before and after induction of hyperlipidemia in male albino rats

Parameters	Normal level	Hyperlipidemi a Level	% change	Parameters	Normal level	Hyperlipidemia Level	% change
S.T. lipids (mg /dl)	266 ± 39.7	739 ± 46.4***	178 ↑	S.T.Proteins (g/dl)	6.24 ± 0.32	$6.17 \pm 0.271 \dagger$	1.12↓
S.Triglyc.(mg /dl)	51.5±7.26	130 ± 8.51***	152↑	S.Alb.(g/dl)	3.78± 0.21	4.37 ± 0.39*	15.6 ↑
S.T.chol.(mg /dl)	55.1± 6.16	181 ± 12.9***	228↑	S.Glob.(g/dl)	2.46 ± 0.15	1.80 ± 0.22**	26.8↓
S.HDL-chol.(mg /dl)	35.7 ± 2.45	19.3 ± 0.42***	45.9↓	S.Alb. / Glob	1.54± 0.07	2.43 ± 0.26***	57.8↑
R.R (T/HDL-chol.)	1.54 ± 0.11	9.38 ± 0.41***	509.1 个	Bl. Urea (mg/dl)	25.1±3.21	26.6 ± 4.35†	5.98↑
S.ALT.(U/ml)	32.2 ± 3.70	58.1 ± 5.25***	80.4 个				
S.AST.(U/ml)	62.7 ± 6.29	117.6 ± 12.8***	87.6 1	S. Creat. (mg/dl)	0.46 ± 0.08	$0.52 \pm 0.04^{*}$	13.0↑
S.ALP. (IU/L)	30.6 ± 3.85	66.1 ± 4.61***	116 ↑	(g,)			
S. LDH.(U/I)	747 ± 75.6	986 ± 58.6***	32.0↑				

†P>0.1. * P<0.05. ** P<0.01. *** P<0.001. T.L.: total lipids. T.C.: total cholesterol.

TG: triglycerides. HDL-C: HDL-cholesterol. T. /HDL-C: total cholesterol / HDL-cholesterol. ALT: Alanine aminotransferase. AST: Aspartat aminotransferase. ALP: Alkaline phosphatase. LDH:Lactate dehydrogenase. EGb: Ginkgo biloba extract

Table (6): The Curative effect of whole barley and barley bran on serum lipids ($mg/dl \pm S.D$) and % variation from the corresponding control during the induction of hyperlipidemia for 8 weeks in male rats.

GROUP	TREATMENT		Before	After		Ti	me interv	als (Wk's)	
NUMBER		ITEM	induction of h	yperlipidemia	% var.	4	% var.	8	% var.
		T.L	293±55.4	301±45.5†	2.73↑	299±28.5†	0.66↓	298±46.2†	1.00↓
		Trig.	50.2±5.47	49.9±7.00†	0.60↓	48.9±4.38†	2.00↓	53.0±6.40†	6.21↑
1	Negative control	T.Ch.	53.5±7.78	55.7±4.23†	4.11↑	53.7±8.54†	3.59↓	56.9±6.13†	2.15↑
	-	HDL.Ch.	36.6±2.42	35.3±1.62†	3.55↓	36.6±4.60†	3.68↑	35.7±4.15†	1.13↑
		T./HDL	1.46±0.12	1.58±0.09†	8.22↑	1.47±0.12†	6.96↓	1.59±0.30†	0.63↑
		T.L	268±53.6	751±53.0***	180↑	854±44.4**	13.7↑	861±34.8**	14.6↑
		Trig.	54.4±7.81	132.6±6.15***	144↑	143.6±8.16*	8.30↑	138.7±12.1†	4.60↑
2	Positive control	T.Ch.	55.4±6.71	179.9±14.4***	225↑	188.5±9.50†	4.78↑	168.4±4.28†	6.39Ļ
		HDL.Ch.	34.0±2.93	19.5±2.58***	42.6↓	19.1±1.22†	2.05↓	20.1±0.41†	3.08↑
		T./HDL	1.63±0.08	9.23±1.20***	466↑	9.87±1.05†	6.93↑	8.38±0.19†	9.21↓
	Barley Bran	T.L	268±33.1	740±54.4***	176↑	516±52.6***	30.3↓	446±91.2***	39.7↓
3	(100 mg/kgb.w)	Trig.	49.7±4.99	131.3±7.23***	164↑	123.0±18.0†	6.32↓	99.7±10.8**	24.1↓
		T.Ch.	55.8±5.74	190.0±12.2***	241↑	148.6±17.8**	21.8↓	100.4±9.48***	47.2↓
		HDL.Ch.	35.8±4.07	19.2±3.29***	46.4↓	28.0±1.18***	45.8↑	31.5±2.21***	64.1↑
		T./HDL	1.56±0.06	9.90±0.97***	535↑	5.31±0.75***	46.4↓	3.19±0.20***	67.8↓
		T.L	288±46.1	755±47.3***	162↑	507±49.2***	32.8↓	370±67.4***	51.0↓
		Trig.	54.6±9.64	133.0±9.08***	144↑	117.5±21.3†	11.7↓	82.1±9.02***	38.3↓
4	Barley Bran	T.Ch.	53.0±3.13	178.9±18.7***	238↑	145.6±19.9**	18.6↓	84.3±8.26***	52.9↓
	(200 mg/kgb.w)	HDL.Ch.	35.9±2.09	19.6±3.69***	45.4↓	28.7±2.28**	46.4↑	33.1±2.39***	68.9 <u>†</u>
		T./HDL	1.48±0.04	9.13±1.06***	517↑	5.07±1.03***	44.5↓	2.55±0.35***	72.1↓
		T.L	261±53.8	749±77.7***	187↑	562±77.5**	25.0↓	401±42.2***	46.5↓
	Whole Barley	Trig.	55.1±6.34	128.5±6.09***	133↑	123.9±13.3†	3.58↓	88.9±5.68***	30.8↓
5	(200 mg/kgh w)	T.Ch.	53.2±6.47	175.4±10.7***	230↑	147.4±16.1**	16.0↓	93.4±6.43***	46.8 ↓
	(200 mg/kg0.w)	HDL.Ch.	35.2±3.90	19.4±3.31***	50.6↓	27.6±1.80***	42.3↑	31.7±2.32***	63.4↑
		T./HDL	1.51±0.10	9.04±1.20***	499 ↑	5.34±0.49***	40.9↓	2.95±0.15***	67.4↓
		T.L	251±35.9	746±87.7***	197↑	618±64.3*	17.2↓	443±85.2**	40.6↓
	Atorvastatin	Trig.	54.0±8.62	132.8±9.42***	146↑	118.3±7.50*	10.9↓	74.7±10.1***	43.7↓
6	(0.9mg/kgh w)	T.Ch.	55.2±5.77	179.6±12.0***	225↑	132.0±11.9***	26.5↓	73.9±9.70***	52.9↓
	(0.9111g/Kg0.W)	HDL.Ch.	34.4±3.16	19.4±2.06***	43.6↓	31.2±2.05***	60.8↑	34.4±2.74***	77.3↑
		T./HDL	1.60±0.05	9.30±1.19***	481↑	4.23±0.60***	54.5↓	2.15±0.24***	76.9↓

†P>0.1. * P<0.05. ** P<0.01. *** P<0.001. T.L.: total lipids. T.C.: total cholesterol.

TG: triglycerides. HDL-C: HDL-cholesterol. T. /HDL-C: total cholesterol / HDL-cholesterol. EGb: Ginkgo biloba extract.

GROUP	ROUP TREATMENT		Before	After		Time intervals (Wk's)				
NUMBER		ITEM	induction of	hyperlipidemia	%	4	% var.	8	%	
					var.				var.	
		ALT	32.3±5.74	32.1±5.50†	0.62↓	31.6±2.09†	1.56↓	31.4±4.80†	2.18↓	
1	Negative control	AST	65.3±2.77	66.2±13.3†	1.38↑	60.3±3.87†	8.91↓	60.3±5.88†	8.91↓	
	Regative control	ALP	30.3 ± 3.22	$32.8 \pm 3.30 \dagger$	8.25↑	$34.0\pm1.76\dagger$	3.36 个	34.1 ±4.44†	3.96↑	
		LDH	694 ± 89.9	698 ± 86.9†	0.58 个	$674 \pm 16.6 \dagger$	3.44↓	670 ± 57.5†	4.01↓	
		ALT	33.7±1.53	56.7±8.33**	68.2↑	56.9±5.88†	0.35↑	56.6±5.48†	0.18↓	
2	Desitive control	AST	63.3±9.80	119.7±17.9***	89.1↑	104.3±12.5†	12.9↓	112.7±7.73†	5.85↓	
2	Positive control	ALP	29.7 ± 2.21	74.4 ± 6.39***	150 个	$73.7 \pm 1.88 \dagger$	0.94↓	73.2 ±2.13†	1.61↓	
		LDH	741 ± 80.1	989 ± 47.8***	33.5↑	986 ± 49.1†	0.30↓	953 ±31.0†	3.64↓	
	Barley Bran	ALT	36.0±4.90	58.7±7.50***	63.1↑	48.9±3.21**	16.7↓	43.9±3.55**	25.2↓	
	(100 mg/kg h w)	AST	61.2±2.12	120.0±12.5***	96.1↑	97.0±11.4**	19.2↓	63.9±5.25***	46.7↓	
5	(100 mg/ng 0.0)	ALP	32.8 ± 4.36	65.6 ± 5.21***	100 个	62.7 ± 5.80†	4.42↓	52.0 ±5.33***	20.7↓	
		LDH	715 ± 77.4	996 ± 59.1***	39.3 个	$761 \pm 61.0^{***}$	23.6↓	690 ±61.9***	30.7↓	
		ALT	31.6±2.01	58.5±6.15***	85.1↑	45.5±6.36*	22.2↓	37.0±4.41***	36.7↓	
4		AST	61.7±3.84	120.1±10.4***	9 4.7↑	86.8±10.5***	27.7↓	63.6±6.34***	47.0↓	
4	(200 mg/lrg h m)	ALP	23.9 ± 3.09	$63.7 \pm 4.10^{***}$	120 个	54.6 ± 7.50*	14.3↓	43.6 ±4.81***	31.6↓	
	(200 mg/kg 0.w)	LDH	721 ± 78.2	979 ± 53.5***	35.8↑	731 ± 70.2***	25.3↓	692 ±79.0***	29.3↓	
		ALT	31.1±4.28	63.7±1.89***	105↑	48.3±3.38***	24.2↓	42.6±3.84***	33.1↓	
-	Whole Barley	AST	60.1±6.51	118.0±4.08***	96.3↑	98.1±6.18***	16.9↓	62.7±4.92***	46.9↓	
5	(200 mg/kg b.w)	ALP	33.0 ± 3.57	65.9 ± 6.24***	100 个	60.1± 1.20*	8.80↓	46.5 ±2.51***	29.4↓	
		LDH	740 ± 85.8	995 ± 64.3***	34.5 个	710 ± 96.9***	28.6↓	679 ±50.2***	31.8↓	
		ALT	31.3±3.79	57.0±5.33***	82.1↑	41.9±4.87***	26.5↓	38.6±4.53***	32.3↓	
6	Atorvastatin	AST	60.9±4.44	115.1±5.04***	29.0↑	90.2±5.93***	21.6↓	56.9±2.53***	50.6↓	
0	(0.9mg/kg b.w)	ALP	31.0 ±5.40	63.9 ± 8.87***	106 个	51.2±5.35**	19.9↓	35.3 ±5.40***	44.8↓	
		LDH	703 ± 88.2	992 ± 94.9**	41.1 ↑	731 ± 81.0**	26.3↓	674 ± 61.8**	32.1↓	

Table (7): The Curative effect of whole barley and barley bran on serum enzymes $(U/L \pm S.D)$ and % variation from the corresponding control during the induction of hyperlipidemia for 8 weeks in male rats.

†P > 0.1. * P < 0.05. **P < 0.01. *** P < 0.001. ALT: Alanine aminotransferase. AST: Aspartat aminotransferase. ALP: Alkaline phosphatase. LDH:Lactate dehydrogenase. EGb: Ginkgo biloba extract.

Table (8): The Curative effect of whole barley and barley bran on serum proteins, urea and creatinine $(mg/dl \pm S.D)$ and % variation from the corresponding control during the induction of hyperlipidemia for 8 weeks in male rats.

GROUP	TREATMENT		Before	After		I	ime interv	als (Wk's)	
NUMBER		ITEM	induction of h	yperlipidemia	% var.	4	% var.	8	% var.
		T.P.	6.03 ± 0.62	6.42 ± 0.23†	6.47 1	6.48±0.51†	0.93↑	6.73±0.36†	4.83↑
		Alb.	3.54 ± 0.20	$3.72 \pm 0.15 \dagger$	5.08个	3.91±0.42†	5.11↑	3.60±0.18†	3.32
1	Nogetine control	Glob.	2.49 ± 0.40	2.70 ± 0.14 †	8.43↑	2.57±0.42†	4.81↓	3.13±0.16†	15.9↑
1	Negative control	Alb/Glob	1.42 ± 0.26	$1.38 \pm 0.13 \dagger$	2.82↓	1.52±0.21†	10.1↑	1.15±0.12**	16.7↓
		Urea	25.2±5.09	24.9±3.14†	1.19↓	24.6±2.88†	1.20↓	24.3±3.28†	2.41↓
		Creat.	0.39±0.09	0.41±0.02†	5.13↑	0.44±0.02†	7.31↑	0.43±0.10†	4.88↑
		T.P.	6.28 ± 0.61	6.40 ± 0.29†	1.91↑	6.73 ± 0.53†	5.16↑	4.90 ±0.62**	7.81↑
		Alb.	3.92 ± 0.28	$4.37 \pm 0.45 \dagger$	11.5↑	$4.05 \pm 0.37 \dagger$	7.32↓	3.03 ±0.33**	30.7↓
2	Desitive control	Glob.	2.36 ± 0.42	$2.03 \pm 0.49 \dagger$	13.9↓	$2.68 \pm 0.13^{*}$	32.0↑	1.87 ±0.25†	7.88↓
2	Positive control	Alb/Glob	1.66 ± 0.30	$2.15 \pm 0.43^{*}$	29.5↑	$1.51 \pm 0.17^{*}$	29.8↓	1.62 ±0.19†	24.6↓
		Urea	23.9±1.59	27.3±2.46*	14.2↑	32.0±3.46*	17.2↑	27.0±2.57†	1.10↓
		Creat.	0.53±0.09	0.59±0.06†	7.27↑	0.42±0.06**	28.8↓	0.49±0.10†	16.9↓
	Barley Bran	T.P.	6.40 ± 0.51	$6.30 \pm 0.26 \dagger$	1.56↓	$6.53 \pm 0.52 \dagger$	3.65↑	5.37 ±0.89*	14.8↓
		Alb.	3.91 ± 0.21	$4.36 \pm 0.33^{*}$	11.5↑	3.86±0.27*	11.5↓	3.01 ±0.39***	31.0↓
	(100 mg/kg b.w)	Glob.	2.49 ± 0.39	$1.94 \pm 0.34^{*}$	22.1↓	2.67 ± 0.44**	37.6↑	2.36 ±0.39*	21.6↑
3		Alb/Glob	1.57 ± 0.18	2.25 ± 0.25**	43.3↑	1.45 ± 0.12***	35.6↓	1.28 ±0.32***	43.1↓
		Urea	23.5±3.53	26.2±4.49†	11.5↑	25.9±5.20†	1.15↓	26.7±2.11†	1.91↑
		Creat.	0.52±0.14	0.47±0.04†	9.61↓	0.45±0.03†	4.26↓	0.49±0.06†	4.26↑
		T.P.	6.17±0.62	$6.20 \pm 0.30 \dagger$	0.49个	$6.44 \pm 0.33 \dagger$	3.87↑	5.05 ±0.78**	18.5↓
		Alb.	3.83 ± 0.42	$4.34 \pm 0.42 \dagger$	13.3↑	3.96±0.30*	8.76↓	3.10 ±0.17***	28.6↓
4	Barley Bran	Glob.	2.34 ± 0.11	1.86±0.23**	20.5↓	2.48±0.19***	33.3↑	1.95 ±0.27†	1.91↑
-	$(200 \text{ m} \text{ m}^{-1}\text{ m}^{-1}\text{ m})$	Alb/Glob	1.63 ± 0.23	$2.33 \pm 0.44^{**}$	42.9↑	1.60±0.29**	31.3↓	1.59 ±0.37**	31.8↓
	(200 mg/kg b.w)	Urea	23.9±1.21	26.0±3.94†	8.79†	21.8±2.53*	16.2↓	29.3±1.93*	12.7↑
		Creat.	0.48±0.11	0.53±0.08†	10.4↑	0.44±0.03*	17.0↓	0.46±0.06†	13.2↓
		Т.Р.	6.01 ± 0.29	$6.20 \pm 0.43 \dagger$	3.16 个	$6.40 \pm 0.75 \dagger$	3.23↑	4.70±0.74**	24.2↓
		Alb.	3.73 ± 0.30	4.33 ± 0.38**	16.1 ↑	$3.84 \pm 0.32^{*}$	11.3↓	3.01±0.31***	30.5↓
5	Whole Barley	Glob.	2.28 ± 0.36	$1.87 \pm 0.27^*$	18.0↓	2.56 ± 0.30 **	36.9↑	1.69±0.40†	9.63↓
5	(200 mg/kg b.w)	Alb/Glob	1.63 ± 0.33	2.32 ± 0.41**	42.3↑	1.50 ± 0.24**	35.3↓	1.78±0.16**	23.3↓
		Urea	23.6±2.68	25.6±5.11†	8.47↑	24.3±4.39†	5.08↓	23.3±1.96†	8.98↓
		Creat.	0.51±0.05	0.50±0.08†	1.96↓	0.45±0.02†	10.0↓	0.47±0.06†	6.00↓
		T.P.	6.36 ± 0.35	$6.24 \pm 0.13 \dagger$	1.39↓	6.13±1.00†	1.76↓	4.68 ± 0.42***	25.0↓
		Alb.	3.90 ± 0.13	$4.35 \pm 0.45^{*}$	11.5 ↑	3.86±0.57†	11.3↓	2.97 ± 0.08***	31.7↓
6	Atorvastatin	Glob.	2.46 ± 0.25	$1.89 \pm 0.18^{**}$	23.2↓	2.27±0.54†	20.1↑	1.71±0.18†	9.52↓
v	(0.9mg/kg b.w)	Alb/Glob	1.58 ± 0.23	2.30 ± 0.38**	45.6↑	1.70±0.14**	26.1↓	1.74±0.11**	24.3↓
		Urea	24.6±3.20	29.5±2.35*	19.9†	33.0±4.69†	11.9↑	28.8±3.15†	2.37↓
		Creat.	0.54±0.11	0.50±0.06†	7.41↓	0.46±0.02†	\$.00↓	0.47±0.03†	6.00↓

†P > 0.1. * P < 0.05. ** P < 0.01. *** P < 0.001. T.P.: Total protein. Alb.: Albumin. Glob: Globulin. Alb/ Glob: Albumin/ Globulin. Creat: Creatinine. EGb: Ginkgo biloba extract.

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