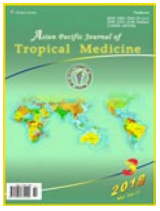

IF: 0.925

Asian Pacific Journal of Tropical Medicine

journal homepage: www.apjtm.org

doi: 10.4103/1995-7645.228435

Evaluating therapeutic potential of coriander seeds and leaves (*Coriandrum sativum* L.) to mitigate carbon tetrachloride-induced hepatotoxicity in rabbits

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ARTICLE INFO

Article history:
Received 8 October 2017
Received in revised form 10 November 2017
Accepted 4 December 2017
Available online 2 March 2018

Keywords:
Coriander seeds
Coriander leaves
Hepatoprotective potential
Hepatotoxicity
Rabbits

ABSTRACT

Objective: To evaluate the hepatic and renal protective potential of coriander seeds and leaves using animal feed model. **Methods:** Coriander seeds- and leaves-based sauces were administrated to normal (Study I) and carbon tetrachloride (2 mL/kg B.W.)-induced hepatotoxic rabbits (Study II). Hepatic and renal biomarkers like aspartate aminotransferase, alanine aminotransferase, alkaline phosphatase, superoxide dismutase and catalase were measured. **Results:** Coriander leaves-based sauce exerted more decline ($P<0.05$) in serum aspartate aminotransferase, alanine aminotransferase and alkaline phosphatase levels in the study II as 18.32%, 19.91% and 21.24%, respectively. While, hepatic superoxide dismutase and catalase levels were raised significantly ($P<0.05$) in both studies. Renal parameters also depicted positive impact by the provision of developed sauces. **Conclusions:** Coriander seeds and leaves based sauces are effective in alleviating the hepato/renal toxicity. The hepatoprotective effect of coriander leaves is more pronounced as compared to coriander seeds.

1. Introduction

Consumption of junk foods along with environmental toxicants have raised the incidence of numerous life threatening ailments like hepatic and renal toxicity as well as it can also trigger inflammatory pathways leading to various oncogenic events. The convergent scientific evidences have focused on the consumption of natural foods as therapeutic remedy against these maladies. The dietary approach towards health promotion and disease prevention has convinced the researchers to develop paradigm shift towards healthy interventions such as designer/functional foods[1].

Amongst herbs, coriander (locally known as "*dhanya*") is known for its therapeutic properties in the Indo-Pak subcontinent. Its scientific name is *Coriandrum sativum* L. Coriander seeds possess essential/volatile oil. Meta-analyses have stated that chief constitutes of coriander essential oil are alcoholic monoterpenes, amongst linalool is prominent[2]. Moreover, fresh coriander leaves and stem part contain polyphenols like phenolic acids, flavonoids (especially quercetin) and essential oil to some extent[3,4].

Various kinds of xenobiotics harm human body by the production of free radicals. Elaborated research and development in the field of pharmaceutics have revealed that reactive oxygen and nitrogen species are the root cause of numerous dysfunctions including hepatotoxicity, diabetes, cardiovascular disorders, inflammations and cancers in the human body. Normally, preset internal defense mechanism in the body is responsible to scavenge free radicals. Nevertheless, several environmental toxins and pollutants encourage the generation of reactive oxygen species to such a level where it becomes difficult for the inherent endogenous defense system to counteract their adversities. For the purpose, antioxidants from external dietary sources strengthen the endogenous defense system to mitigate free radicals-induced oxidative stress and associated ailments[5].

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How to cite this article: Muhammad Jawad Iqbal, Masood Sadiq Butt, Aamir Shehzad, Muhammad Asghar. Evaluating therapeutic potential of coriander seeds and leaves (*Coriandrum sativum* L.) to mitigate carbon tetrachloride-induced hepatotoxicity in rabbits. Asian Pac J Trop Med 2018; 11(3): 209-213.

In this context, polyphenols and linalool of coriander can reinforce enzymatic (superoxide dismutase, SOD; catalase, CAT) and non-enzymatic (glutathione, GSH) defense mechanism of the body. Alongside, participates positively in modulating liver functioning enzymes especially aspartate aminotransferase (AST) and alanine aminotransferase (ALT), thereby lowers the detrimental effects of free radicals in carbon tetrachloride-induced hepatotoxic animals. Considering aforementioned facts, the present research project was designed to elaborate therapeutic potential of coriander seeds and leaves against hepatotoxicity using animal model.

2. Materials and methods

2.1. Procurement of research material

Fresh coriander leaves and seeds were purchased from local market. Coriander leaves were washed to remove adhered dirt and impurities. Furthermore, coriander seeds were also cleaned from impurities. Afterwards, the raw materials were used to develop coriander-based sauce. Diagnostic kits used were purchased from Sigma-Aldrich, Bioassay (Bioassays Chemical Co. Germany) and Cayman Chemicals (Cayman Europe, Estonia).

2.2. Product development

In the product development phase, coriander sauces were prepared using different concentrations of coriander leaves and seeds (40% and 60%, respectively). The concentrations were selected on the basis of preliminary physicochemical and hedonic assessment.

2.3. Ethical approval

Ethics approval was given by the head of the National Institute of Food Science and Technology, University of Agriculture Faisalabad, Pakistan; by reviewing the suggestions of Animal Experimentation Ethics Committee, University of Agriculture Faisalabad. Animal experiments were conducted in accordance with the instructions for the care and use provided by the committee and instructed by the university.

2.4. Animal modeling

For efficacy trials, 60 New Zealand white rabbits were purchased and acclimatized for a period of 7 d by feeding on basal diet at animal room of National Institute of Food Science & Technology, Faculty of Food, Nutrition & Home Sciences, University of Agriculture, Faisalabad, Pakistan. During whole experimental period of 12 weeks, the animal room was maintained at a constant temperature of (23±2) ℃ and relative humidity of about (55±5)% by employing humidifier, with light and dark cycle of 12 h each (NIH Publications No. 8023, revised 1978). All animal experimental procedures were performed from 8 a.m. to 10 a.m.

The aim of animal study was to explore the hepatoprotective potential of coriander seeds and leaves sauces. Purposely, two studies were designed: study I (normal rabbits) and study II (hepatotoxic rabbits). In the study II, carbon tetrachloride was injected intraperitoneally (2 mL/kg B.W.) to induce hepatotoxicity 24 h prior to termination of trial. Each study consisted of three groups based on given diet, *i.e.*, control diet (S_0), coriander seeds sauce (S_1) and coriander leaves sauce (S_2). In all studies, each animal group was given the respective treatment through gastric tube (15 mL/kg B.W.), throughout the experimental phase. Rabbits were housed in clean large cages and fed on green leafy vegetation and allowed tap water *ad libitum*. At the end of trial blood samples were collected through cardiac puncture in normal and EDTA-coated tubes, separately[6]. Analysis of serum samples were then carried out by using Microlab-300 (Merck, Germany). Moreover, hepatic and renal antioxidant enzymes were also assessed; tissue homogenate was collected from liver and kidney tissues.

2.5. Serum specific hepatic biomarkers

Serum specific markers of liver, AST and ALT, were estimated by using Sigma kits 59-50 and 58-50, respectively, using dinitrophenylhydrazene method[7]. Furthermore, alkaline phosphatase (ALP) was estimated by Alkaline Phosphates–DGKC method[8], alongside, bilirubin was assessed following the methods described by Park *et al*.[9].

2.6. Oxidative stress biomarkers in liver tissues

Oxidative stress markers in liver tissues were evaluated by measuring the levels of tissue specific endogenous enzymes like SOD, CAT and lipid peroxidation in terms of malondialdehyde (MDA) level[10,11].

2.7. Serum specific renal biomarkers

Renal biomarkers of serum include level of urea, uric acid and creatinine. These were analyzed according to the methods described by Kassem *et al.*[12].

2.8. Oxidative stress biomarkers in kidney tissues

Tissue specific oxidative stress biomarkers of kidney are similar to hepatic tissue specific parameters, i.e., SOD, CAT and lipid peroxidation[10,11].

2.9. Statistical analysis

The findings of current scientific study were subjected to statistical analyses to find out the level of significance and efficacy of various parameters. For the purpose, statistical software Statistix 8.1 was employed[13]. Furthermore, Microsoft Excel (version 2013) was utilized for handling, summarization of data. For statistical analysis, one way ANOVA under Completely Randomized Design (CRD) was employed to assess the level of significance trailed by comparison of means via Tukey's honest significant difference (HSD) test.

3. Results

3.1. Serum specific hepatic makers

3.1.1. AST

Serum AST level was non-significantly varied in the study I (normal rabbits) from (32.33±1.52) in the S_0 control to (30.04±1.32) IU/L in the S_2 treatment. However, it momentously (P<0.05) changed in the study II (hepatotoxic rabbits). The serum AST level of hepatotoxic rabbits (study II) was found maximum in the control group (S_0), followed by the S_1 treatment and S_2 treatment (Table 1). In the study II, maximum reduction of 18.32% was noticed owing to S_2 treatment followed by S_1 treatment (14.70%).

3.1.2. ALT

Serum ALT level of normal rabbits was affected non-significantly by treatments, whilst, in hepatotoxic rabbits ALT level was significantly (P<0.05) affected by treatments. In the study II, the serum ALT level of S_0 group was higher as compared to the S_0 group of study I, indicating the acute hepatic stress. Though, the administration of S_1 and S_2 significantly (P<0.05) lowered the level of serum ALT to (85.25±4.54) and (81.02±4.92) IU/L, respectively (Table 1). The reduction of serum ALT was significant (P<0.05) in study II (15.73% in the S_1 treatment and 19.91% in the S_2 treatment).

3.1.3. ALP

Like the above mentioned parameters serum ALP level was also non-significantly effected in the study I, whilst, it significantly (P<0.05) changed in the study II owing to the provision of functional diet. In hepatotoxic rabbits it was maximum in the control group followed by the S_1 and S_2 treatments (Table 1). The percent reduction was highly significant (P<0.05) in the case of hepatotoxic rabbits (17.26% in the S_1 treatment and 21.24% in the S_2 treatment).

3.1.4. Bilirubin

Serum bilirubin level showed significant variations (P<0.05) among different diet groups in the study II by the injection of carbon tetrachloride. In the study II, the level of serum bilirubin showed a decreasing behavior and lowered owing to the consumption of S_1 and S_2 up to 17.31% and 20.19%, correspondingly (Table 1).

3.2. Tissue specific hepatic biomarkers

3.2.1. SOD

Statistical analysis (F value) indicated that in the study I the level of SOD was altered non-momentously among designed diet groups. Furthermore, the SOD level expressed significant (P<0.05) variations owing to different diet treatments in hepatotoxic (study II). It is evident from the means (Table 1) that in the study I, S_0 (control group) exhibited minimum SOD level of (264.19±13.47) U/g tissue, whilst, it get elevated to (270.28±13.40) and (275.43±12.66) U/g tissue in the S_1 and S_2 treatments, respectively. It can clearly be noticed that intra-peritoneal injection of carbon tetrachloride lowered the level of SOD to (179.64±9.05) U/g tissue in the S_0 group of study II. Treating the groups with S_1 and S_2 enhanced the level of SOD momentously to (218.97±9.10) and (231.09±12.01) U/g tissue, correspondingly (Table 1).

3.2.2. CAT

The level of catalyase in study I was affected non-significantly by administration of different treatments. However, the level of CAT significantly (P<0.05) varied due to diet treatments in the study II. It is obvious from the mean values that in hepatotoxic rabbits it was (738.53±36.18) U/g tissue in the S_0 group. However, the S_1 and S_2 elevated the level of CAT momentously (P<0.05) to (872.97±40.15) and (904.65±43.42) U/g tissue, correspondingly (Table 1). In the study II, the level of CAT showed an increasing behavior and raised significantly (P<0.05) owing to the consumption of S_1 and S_2 up to 18.20% and 22.49%, correspondingly.

3.2.3. Lipid peroxidation

Lipid peroxidation in different studies was measured by employing the TBARS assay (thiobarbituric acid reactive substances assay) which quantities the end product of lipid peroxidation (MDA). Means regarding MDA level in the study I showed that in the control group it was (36.12±1.62) nmol/(L•g tissue), while in the S_1 and S_2 groups it was (35.16±1.59) and (34.98±1.62) nmol/(L•g tissue), respectively. In the study II, maximum MDA level was measured in the S_0 group followed by the S_1 and S_2 groups (Table 1).

3.3. Renal biomarkers

3.3.1. Serum urea level

Mean values indicated that in the study I (normal rabbits) serum

Table 1

Effect of coriander seeds and leaves sauces on hepatic biomakers in normal rabbits (Study I) and hepatotoxic rabbits (Study II).

Study	Treatments	Serum-specific biomakers				Tissue-specific biomakers		
		AST (IU/L)	ALT (IU/L)	ALP (IU/L)	Bilirubin (mg/dL)	SOD levels (U/g tissue)	CAT levels (U/g tissue)	MDA level [nmol/(L•g tissue)]
I	S_0	32.33±1.52	46.58±2.45	74.02±3.69	0.76±0.03	264.19±13.47	1 070.34±44.95	36.12±1.62
	S_1	31.89±1.48	46.12±2.62	73.14±4.01	0.75±0.04	270.28±13.40	1 084.30±45.62	35.16±1.59
	S_2	30.04±1.32	46.02±2.01	72.96±3.54	0.74±0.05	275.43±12.66	1 095.16±52.56	34.98±1.62
II	S_0	58.45±2.78^a	101.16±5.08^a	155.47±7.78^a	1.04±0.05^a	179.64±9.05^c	738.53±36.18^c	49.84±2.28^a
	S_1	49.86±2.56^b	85.25±4.54^b	128.63±5.94^b	0.86±0.06^b	218.97±9.10^b	872.97±40.15^b	38.82±1.87^b
	S_2	47.74±2.25^b	81.02±4.92^c	122.45±8.16^b	0.83±0.08^b	231.09±12.01^a	904.65±43.42^a	37.05±1.46^b

S_0 = Control diet; S_1 = Coriander seeds sauce; S_2 = Coriander leaves sauce; AST = aspartate aminotransferase; ALT = alanine aminotransferase; ALP = alkaline phosphatase; SOD = superoxide dismutase; CAT = catalase; MDA = malondialdehyde. The values of study II containing similar alphabetical letters are non-statistically different, while those containing different alphabetical letters are statistically different (P<0.05).

urea level [(0.64±2.01) mg/dL] was not significantly affected in control group (S_0), while, it was (40.02±1.85) and (39.41±1.89) mg/dL in the S_1 and S_2 groups, correspondingly. Moreover, the serum urea level of hepatotoxic rabbits (study II) was found maximum in the control group (S_0), which lowered in groups taking the S_1 and S_2 (Table 2).

3.3.2. Serum uric acid level

Serum uric acid level has been considered as an essential parameter to access the extent of renal toxicity in individuals. It is evident from Table 2 that in the study II, serum uric acid level was measured maximum in the S_0 group trailed by the S_1 and S_2 groups. A significant (P<0.05) decrease of 17.39% and 21.26% was observed in the hepatotoxic rabbits (study II) in the S_1 and S_2 groups as compared to the S_0 (control diet) group.

3.3.3. Serum creatinine level

In the study I different treatments showed non-significant effect on the serum creatinine level. However, it was significantly (P<0.05) affected by treatments in the study II. The means regarding the serum creatinine level showed that the creatinine level in the control group (S_0) of study I was (0.98±0.04) mg/dL. Additionally, the S_1 and S_2 groups also exhibited almost similar levels of creatinine. In the study II, the injection of carbon tetrachloride raised the serum creatinine level up to (1.16±0.05) mg/dL in the S_0 group, though, this elevated level showed a declining trend in the groups administrated with S_1 and S_2 (Table 2).

3.3.4. Renal SOD level

It can be inferred from the statistical analysis (F value) that in the study I the level of SOD in renal tissues was altered non-momentously among designed diet groups. Furthermore, the SOD level expressed significant (P<0.05) variations owing to different diet treatments in the hepatotoxic rabbits (study II). It is evident from the means that in the study I, S_0 (control group) exhibited minimum SOD level of (287.70±14.06) U/g tissue, whilst, SOD level increased to (291.35±15.24) and (293.79±13.81) U/g tissue in the S_1 and S_2 groups, respectively (Table 2). It can clearly be noticed that intra-peritoneal injection of carbon tetrachloride lowered the level of SOD to (232.83±13.58) U/g tissue in the S_0 group of study II. Treating the groups with S_1 and S_2 enhanced the level of SOD momentously to (261.97±14.02) and (268.38±12.45) U/g tissue, correspondingly (Table 2).

3.3.5. Renal CAT levels

It is obvious from the means that in the study I, S_0 (control group) exhibited minimum CAT level of (635.25±29.22) U/g tissue, whilst, CAT level get elevated to (642.19±31.58) and (649.29±32.06) U/g tissue in the S_1 and S_2 groups, respectively (Table 2). It can clearly be noticed that intra-peritoneal injection of carbon tetrachloride lowered the level of CAT to (426.54±18.67) U/g tissue in the S_0 group of study II. Treating the groups with S_1 and S_2 raised the level of CAT significantly (P<0.05) to (464.15±22.28) and (478.80±23.59) U/g tissue, correspondingly (Table 2).

3.3.6. Renal lipid peroxidation

Means regarding MDA level in the study I showed that in the control group it was (42.25±1.94) nmol/(L•g tissue), while in the S_1 and S_2 groups it was (40.48±1.87) and (39.56±2.06) nmol/(L•g tissue), respectively. In the study II, maximum MDA level was measured in the S_0 group followed by the S_1 and S_2 groups.

4. Discussion

Liver functioning test assist to estimate the health of ones liver by evaluating the level of proteins (albumin/total protein), liver enzymes (AST, ALT and ALP) and bilirubin in blood [14]. In current investigation increment in the serum ALT level was 117% indicating the liver damage of rabbits.

This research elucidated the hepatoprotective perspectives of coriander to attenuate liver injury induced by carbon tetrachloride in rabbits. Carbon tetrachloride is a renowned hepatotoxic agent and is generally utilized to evaluate the hepatoprotective potential of various bioactive moieties and drugs. Administration of coriander leaves protects the hepatocytes from the adverse effects of carbon tetrachloride. The current results are in conformity with previous findings that demonstrated hepatoprotective potential of coriander leaves extracts in carbon tetrachloride-induced hepatotoxic rats. The serum ALT level of control group was (36.28±1.5) IU/L, which get elevated to (135.2±12.4) IU/L by intraperitoneal injection of carbon tetrachloride. Administration of coriander leaves extract decreased the level of ALT to (84.6±7.4) and (54.7±4.3) IU/L, respectively.

Kassem *et al*. noticed that serum AST, ALT and ALP levels of control rats were raised significantly by carbon tetrachloride treatment[12]. Nevertheless, incorporation of 20% and 40% coriander

Table 2

Effect of coriander seeds and leaves sauces on renal biomakers in normal rabbits (Study I) and hepatotoxic rabbits (Study II).

Study	Treatments	Serum-specific biomakers			Tissue-specific biomakers		
		Urea level (mg/dL)	Uric acid level (mg/dL)	Creatinine level (mg/dL)	Renal SOD level (U/g tissue)	Renal CAT levels (U/g tissue)	Renal MDA levels [nmol/(L•g tissue)]
I	S_0	40.64±2.01	2.54±0.12	0.98±0.04	287.70±14.06	635.25±29.22	42.25±1.94
	S_1	40.02±1.85	2.51±0.16	0.97±0.03	291.35±15.24	642.19±31.58	40.48±1.87
	S_2	39.41±1.89	2.49±0.14	0.95±0.05	293.79±13.81	649.29±32.06	39.56±2.06
II	S_0	53.61±2.56^a	4.14±0.25^a	1.16±0.05^a	232.83±13.58^b	426.54±18.67^b	54.66±2.45^a
	S_1	49.85±2.69^{ab}	3.42±0.18^{ab}	1.09±0.05^{ab}	261.97±14.02^a	464.15±22.28^{ab}	45.02±2.02^b
	S_2	47.33±2.23^b	3.26±0.19^b	1.05±0.05^b	268.38±12.45^a	478.80±23.59^a	43.89±2.34^b

S_0 = Control diet; S_1 = Coriander seeds sauce; S_2 = Coriander leaves sauce; AST = aspartate aminotransferase; ALT = alanine aminotransferase; ALP = alkaline phosphatase; SOD = superoxide dismutase; CAT = catalase; MDA = malondialdehyde. The values of study II containing similar alphabetical letters are non-statistically different, while those containing different alphabetical letters are statistically different (P<0.05).

in diet lowered the levels of AST, ALT and ALP. Coriander treatment also seems to be an effective tool to counter the lipid peroxidation resulting TBARS approached to normal. It was hypothesized that restoration of TBARS may be owing to increase in the activity of antioxidant enzymes including SOD, CAT, glutathione reductase, glutathione peroxidase and glutathione-S-transferase[16].

The findings of instant investigation are in harmony with Sreelatha *et al*.[15] who demonstrated that TBARS in control group was (1.29±0.395) nmol MDA/mg protein which increased to (1.79±0.14) nmol MDA/mg protein by carbon tetrachloride injection. Coriander stem and coriander leaf extract at a dose rate of 200 mg/kg lowered the level of TBARS to (1.43±0.23) and (1.29±0.40) nmol MDA/mg protein, respectively.

Current findings regarding the effect of coriander on levels of SOD, CAT and lipid peroxidation are in agreement with the findings of Sreelatha *et al*.[15]. SOD level of control group of rats was (75.81±1.95) mg liver protein, which lowered to (47.84±0.50) mg liver protein owing to carbon tetrachloride intoxication. A significant elevation in the level of SOD occurred by oral administration of coriander stem and coriander leaf at individual dosage of 100 and 200 mg/kg [(58.16±0.72) & (79.93±0.65) mg liver protein and (63.51±0.58) & (86.19±0.72) mg liver protein, respectively].

It has an established fact that kidneys plays an important role in regulating various essential body processes by modulating numerous chemicals. The waste products includes urea, creatinine and uric acid. Carbon tetrachloride not only causes hepatotoxicity but it also imparts nephrotoxicity as indicated by a noticeable elevation in the levels of serum urea, creatinine and uric acid[17]. Coriander consumption refurbished the endogenous antioxidant enzymes. The effect of coriander was dose depended and 40% coriander noticed to impart more pronounced renal protective effects as compared to 20% coriander[18].

It can be clinched in the nut shell that renal protective effects of coriander against carbon tetrachloride is owing to numerous mechanisms amongst the most important is the antioxidant activity the courtesy of polyphenolic constituent of coriander.

The findings of current investigation exhibited that carbon tetrachloride intoxication can damage both hepatic and renal tissues as explored by an abrupt elevation of their biomarkers. The toxicity also lowered the endogenous antioxidant enzymes, whilst, treatment with coriander considerably lowered the harmful effects of carbon tetrachloride by reserving antioxidants and scavenging free radicals. It can be established that consumption of coriander seed and leaves enriched diet can protect humans against hepato-renal toxicity induced by various xenobiotics. Furthermore, it can be concluded from the above investigation that coriander leaves possess better hepatoprotective potential as compared to coriander seeds.

Conflict of interest statement

The authors declared that they have no conflict of interest.

Acknowledgment

The authors would like to acknowledge the support of Higher Education Commission of Pakistan and University of Agriculture, Faisalabad for technical assistance.

References

[1] Siró I, Kápolna E, Kápolna B, Lugasi A. Functional food: Product development, marketing and consumer acceptance-A review. *Appetite* 2008; **51**(3): 456-467.

[2] Laribi B, Kouki K, M'Hamdi, Bettaie T. Coriander (*Coriandrum sativum* L.) and its bioactive constituents. *Fitoterapia* 2015; **103**: 9-26.

[3] Matasyoh JC, Maiyo ZC, Ngure RM, Chepkorir R. Chemical composition and antimicrobial activity of the essential oil of *Coriandrum sativum*. *Food Chem* 2009; **113**(2): 526-529.

[4] Nambiar VS, Daniel M, Guin P. Characterization of polyphenols from coriander leaves (*Coriandrum sativum*), red amaranthus (*A. paniculatus*) and green amaranthus (*A. frumentaceus*) using paper chromatography and their health implications. *J Herb Med Toxicol* 2010; **4**(1): 173-177.

[5] Valko M, Leibfritz D, Moncol J, Cronin MTD, Mazura M, Telser J. Free radicals and antioxidants in normal physiological functions and human disease. *Int J Biochem Cell Biol* 2007; **39**: 44-84.

[6] Uchida K, Satoh T, Ogura Y, Yamaga N, Yamada K. Effect of partial ileal bypass on cholesterol and bile acid metabolism in rats. *Yanago Acta Medica* 2001; **44**: 69-77.

[7] Fahmy HA, Shreif NH, Gharib OA. The protective effect of Coriandium sativum L. extract on hepato-renal toxicity induced in irradiated rats. *Eur J Med Plants* 2014; **4**(3): 196-205.

[8] Basuny AM, Gaafar AM, Arafat SM. Tomato lycopene is a natural antioxidant and can alleviate hypercholesterolemia. *Afr J Biotechnol* 2009; **8**(23): 6627-6633.

[9] Park D, Kyung J, Kim D, Hwang SY, Choi EK, Kim YB. Anti-hypercholesterolemic and anti-atherosclerotic effects of polarized-light therapy in rabbits fed a high-cholesterol diet. *Lab Anim Res* 2012; **28**(1): 39-46.

[10] Dutta M, Ghosh D, Ghosh AK, Bose G, Chattopadhyay A, Rudra S, et al. High fat diet aggravates arsenic induced oxidative stress in rat heart and liver. *Food Chem Toxicol* 2014; **66**: 262-277.

[11] Almeida EAD, Ozaki MR. Effect of pitavastatin on vascular reactivity in hypercholesterolemic rabbits. *Arq Bras Cardiol* 2014; **103**(1): 4-12.

[12] Kassem SS, Abdel-Kader MM, Al-Sayed EM, El-Din S, El-Hawary MHAZ, Haggag MM. Modulatory effects of aerial parts of *Coriandrum sativum* L. on carbon-tetrachlorid induced hepatorenal toxicity. *Global Vet* 2014; **12**(4): 523-531.

[13] Mason RL, Gunst RF, Hess JL. *Statistical design and analysis of experiments: with applications to engineering and science*. 2nd ed. Hoboken: John Wiley & Sons; 2003.

[14] American Gastroenterological Association. American Gastroenterological Association medical position statement: Evaluation of liver chemistry tests. *Gastroenterol* 2002; **123**: 1364-1366.

[15] Sreelatha S, Padma PR, Umadevi M. Protective effects of *Coriandrum sativum* extracts on carbon tetrachloride-induced hepatotoxicity in rats. *Food Chem Toxicol* 2009; **47**: 702-708.

[16] Rohrdanz E, Ohler S, Tran-Thi QH, Kahl R. The phytoestrogen daidzein affects the antioxidant enzyme system of rat hepatoma H4IIE cells. *J Nutr* 2002; **132**(3): 370-375.

[17] Makni M, Chtourou Y, Garoui EM. Carbontetrachloride-induce nephrotoxicity and DNA damage in rats. Protective role of vanillin. *Human Exp Toxicol* 2013; **31**: 844-852.

[18] Patel DK, Desal SN, Gandhi HP, DevKar RV, Ramachandran AV. Cardioprotective effects of *Coriandrum sativum* L. on isoproterenol induced myocordial necrosis in rats. *Food Chemtoxicol* 2012; **50**: 3120-3125.