Neuroprotective Effects of Purslane Seeds against Adverse Effects Induced by Experimental Hyperlipidemia on Frontal Cortex and Cerebellum in Young Male Albino Rats

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Abstract: Background. Hyperlipidemia is characterized by abnormally elevated levels of lipids and is positively associated with cerebrovascular diseases. Alzheimer's disease (AD) is a chronic brain disorder characterized by cognitive impairment, inflammation, β -amyloid deposition, and vascular damage. Recent studies have shown that high cholesterol levels are linked to the pathology of AD. Purslane seeds are medicinal plants rich in unsaturated fatty acids (omega-3), antioxidants, and fibers. They are known to have antidiabetic and antiatherogenic activities. The aim of this research is to study the structural alterations occurring in the frontal cortex and cerebellum after feeding high cholesterol diet, and the possible protective role of purslane seeds. Materials and methods. Forty male albino rats were used in the study. They were divided into three groups; control group (20 rats), hypercholesterolemic group (10 rats) who were fed the balanced diet supplemented with cholesterol at a dose of 2 gm/100 gm diet, and protected group (10 rats) who were fed the same previous hypercholesterolemic diet concomitant with purslane seed 20% (20 gm/100 ml water). After 3 months, blood samples were collected from all rats for biochemical estimation and fresh specimens were taken from the frontal cortex and cerebellum of each rat and processed for; light microscopic examination using H&E and Orcein stains. Results. Significant increase of serum triglyceride (TG), total cholesterol (TC), and low-density lipoprotein (LDL-C) levels in hyperlipidemic rats were detected. Associated structural changes in the frontal cortex of the rats were evident as pyknotic nuclei of degenerated neurons, loss of neuron, dilation and congestion of blood vessels, expanded perivascular space, and increased vacuolar spaces of neuropil. The cerebellar cortex of the rats fed on high cholesterol diet revealed pyknotic nuclei of degenerated neuron and decrease in the number of Purkinje and granule cells compared to the control group. Concomitant administration of purslane seeds revealed evident amelioration of biochemical and most of the structural changes. Conclusion. We concluded that a high cholesterol diet has deleterious biochemical changes associated with structural alteration in the frontal cortex and cerebellum and purslane seeds ameliorate most of these changes.

Keywords: High Cholesterol Diet, Neurotoxicity, Oxidative Stress, Purslane Seeds, Male Rats

1. Introduction

According to the estimates of the World Health Organization (WHO), overweight and obesity are the fifth risk factor for mortality worldwide, causing approximately 2.8 million deaths per year. Obesity is fast, becoming a medical condition of global concern, particularly due to its consistent association with increased prevalence of cardiovascular diseases, diabetes mellitus, hypertension and some forms of cancers.¹⁻³ Hypercholesterolemia (HChol) is considered as one of the most familiar metabolic disorders

and is closely associated with obesity. Studies demonstrated that HChol is significantly associated with oxidative stress and the generation of reactive oxygen species (ROS).⁴⁻⁶ It is well established that HChol induces inflammation in the brain.^{7,8} Chronic treatment of rats with cholesterol markedly increased microglial immunoreactivity and levels of several inflammatory markers in the cortex, reduced cholinergic neurons and impaired cognition.⁹ Furthermore, hypercholesterolemia in rats displays blood brain barrier (BBB) disruptions in the cortex visualized by an increased anti-rat IgG immunoreactivity.¹⁰ Also, hypercholesterolemia has been described as a risk factor for vascular dementia

(VaD) and Alzheimer's disease (AD).^{11,12} Therefore, it is necessary to search for effective approaches to control hypercholesterolemia and the associated brain complications.

Weight reduction, via dietary modulation is therefore the target of choice of many therapeutic measures. Conventional drugs promote about 5-10% loss of weight, and best, only when used in conjunction with diet, exercise, and behaviour change regimens.¹³ The reported minor and grave side effects of the drugs, as well as weight rebounds when discontinued, have necessitated a new dimensional approach into the search for anti-obesity and antihypercholesterolemic agents.¹⁴

Medicinal plants are widely used in the management of diseases all over the world. Herbal medicines have reported significant improvement in controlling body weight, without any noticeable adverse effects.¹⁵ *Portulaca oleracea* (*Portulacaceae* family), (also referred to the common; Purslane), is listed in the WHO as one of the most used medicinal plants and has been given the term global panacea.¹⁴⁻¹⁶ It is widespread as a weed and has been ranked the eighth most common plant in the world.¹⁷ *Portulaca oleracea*, or purslane, is a good source of biologically active compounds, including omega-3 fatty acids, β -carotene, amino acids, α -tocopherols, ascorbic acid, glutathione, alkaloids, antioxidant vitamins (such as vitamin A, vitamin C, and some vitamin B and carotenoids), as well as dietary minerals, such as magnesium, calcium, potassium, iron, and flavonoid compounds.¹⁸⁻²¹

Based on these issues and concerns, the aim of the present study was to investigate the structural alterations in the frontal cortex and cerebellum due to a high cholesterol diet, and to see whether purslane seeds can ameliorate this possible damage.

2. Material & Methods

2.1. Material and Subjects

This study was carried out on 40 adult male albino rats weighing about 100-150 grams (gm). Their average ages were from 3-4 months. Animals were maintained under standard housing conditions, and were allowed free access to standard laboratory food and water. Guidelines for care and use of animals approved by the Animal House Center, Faculty of Medicine, University of Alexandria, were followed. The animals were randomly divided into three groups as follows:

1. Group I: control group, which was further subdivided into two equal subgroups 10 animals each.
 - a. Subgroup Ia, received standard diet.
 - b. Subgroup Ib received purslane seeds in water orally by orogastric tube 2ml/day for three months.
2. Group II: experimental group, which included 10 rats who received high fat, high cholesterol (HFHC) diet. It consisted of a high fatty diet (standard diet together with coconut oil, palm oil and egg yolk) and cholesterol

2% for three months to induce hyperlipidemia.²²

3. Group III: protected group, which consisted of 10 rats who received simultaneously both HFHC diet and purslane seeds as in subgroup Ib for three months.

Cholesterol used in the experiment was purchased from the Oxford Chemical Company in the form of powder. It was dissolved in coconut oil.

Purslane seeds were purchased from the 'local market.' It was crushed by an electric grinder and stored at 4°C prior to its use and then was dissolved in water (20 gm/ 100 ml water).

At the end of the experimental period (3 months), rats were sacrificed after overnight fasting and the blood of each rat was taken from the abdominal aorta under ether anesthesia. The serum was separated by allowing the blood sample to be left for 15 minutes at a temperature of 25°C, then centrifuged at 3000 RPM for 20 minutes, then kept in plastic vials at -20°C. Serum was analyzed for the following biochemical parameters: triglyceride (TG), total cholesterol (TC), high-density lipoprotein-cholesterol (HDL-C) and low density lipoprotein-cholesterol (LDL-C) and determined by equations developed by Friedewald.²³

Fresh specimens were taken from the frontal cortex and cerebellum of each rat. Each specimen was fixed in 10% formal saline and processed to get paraffin sections for light microscopic examination using:

1. Haematoxylin and Eosin (H&E) stain.^{24,25}
2. Orcein stain.^{24,25}

2.2. Statistical Analysis

The results obtained were analyzed using SPSS program (version 17.0) and expressed as mean and standard deviation (SD). Statistical significance ($p < 0.05$) among the groups was determined by one-way ANOVA.

3. Results

3.1. General Appearance and Survival

Observation of rats during the experimental period revealed that HFHC diet was well tolerated by the rats and no mortality was detected. Rats of all groups exhibited normal activities and had smooth and glossy fur.

3.2. Lipid Profiles Level

Comparison between lipid profiles in different studied groups has been shown in table 1. Regarding triglyceride, it was found that there was a significant increase in the high cholesterol group than both control and high cholesterol with purslane seeds, while there was no significant difference between control and high cholesterol with purslane seeds. Total cholesterol showed a significant difference between the three groups, the highest value was found in cholesterol group, followed by high cholesterol with purslane seeds and the lowest value was in control group. HDL-C show a significant increase in control group than the other two groups, while there was no significant difference between high cholesterol group and high cholesterol with purslane

seeds. LDL-C showed a significant difference between the three groups, the highest level was in high cholesterol group followed by high cholesterol with purslane seeds then the control group.

Table 1. Comparison between lipid profiles in different studied groups.

Groups	TG	TC	HDL-C	LDL-C
Control	1.6 ± 0.26	2.9 ± 0.51	1.7 ± 0.4	0.88 ± 0.146
High cholesterol	2.96 ± 0.275	4.29 ± 0.136	1.21 ± 0.136	2.49 ± 0.224
High cholesterol+purslane seeds	1.71 ± 0.146	3.24 ± 0.132	1.48 ± 0.136	1.42 ± 0.13
ANOVA	15.62	10.25	6.21	28.9
P	0.001*	0.001*	0.017*	0.001*
P1	0.001*	0.001*	0.003*	0.001*
P2	0.136	0.023*	0.041*	0.0084*
P3	0.003*	0.002*	0.078	0.021*

P is significant if < 0.05

P1: Comparison between control group and high cholesterol group

P2: Comparison between control and high cholesterol + purslane seeds group

P3: Comparison between high cholesterol group and + purslane seeds group

TG: Triglyceride, TC: Total cholesterol, HDL-C: High density lipoprotein-cholesterol, LDL-C: Low density lipoprotein-cholesterol

3.3. Histological Results

Haematoxylin and Eosin stain:

Group I (Control Group):

H&E stained sections of the control rat showed the normal histological structure of both frontal cortex and cerebellum. The pia arachnoid was seen covering the brain surface. The frontal cortex appeared laminated with six different layers of variable thickness that are blended with each other. The amorphous

neuropil was revealed as a homogenous pale acidophilic background among the neuroglia and the neuronal cell bodies (Figure 1 a, b).

Figure 1. a, b. Photomicrographs of H&E stained control rat frontal cortex showing: 1 a: Normally arranged layers of grey matter (GM) of frontal cortex and 1 b: demonstrating the white matter (WM) containing bundles of axons and nuclei of some neurons and neuroglial cells (↑). H&E stain X200.

The cerebellum of the control rat showed the foliated tree-like appearance with the grey matter externally located. The cerebellar cortex exhibited three well demarcated layers. The nuclei of the Bergmann astrocytes that ensheath the purkinje neurons were seen in between the purkinje cells. The cerebellar glomeruli composed of complex neuronal and glial processes are seen as scattered acidophilic areas among the granule cells (Figure 2 a, b).

Figure 2. a, b. Photomicrographs of H&E stained control rat cerebellar cortex showing: normally arranged cerebellar cortical layers, molecular layer (M) with few neurons, single row of pear-shaped purkinje cell layer (P), the nuclei of the astrocytes of the purkinje layer (Bergmann cells) are revealed around the purkinje cell bodies (*) and inner granular layer with dense closely packed nuclei (G). Note the cerebellar glomeruli occupying the spaces between the granule cells (↑). H&E stain a X100 – b X400.

Group II (Hypercholesterolemic Group):

Frontal cortex of hypercholesterolemic rats showed various degrees of degenerative changes. This was proved by the many neurons and neuroglia, which appeared distorted with pyknotic nuclei and vacuolated cytoplasm compared to the

control group. The congested dilated small blood vessels were also revealed within the loose neuropil. The neuropil appeared lightly stained and vacuolated (Figure 3 a, b, c & Figure 4 a, b, c.), the grey matter of the frontal cortex revealed localized area of mononuclear cellular infiltration and numerous neuroglial

cells (Figure 4 c), and the bundles of axons in the white matter were widely separated (Figure 4 d).

The H&E stained cerebellum of hypercholesterolemic rats exhibited loosening of molecular and granular layers, but the

pattern of the folia was preserved. In addition, loss of Purkinje cells and granule cells were associated with the pyknotic nuclei of the degenerated cells, which were evident in the molecular and granular layers (Figure 5 a, b, c).

Figure 3 a, b, c. Photomicrographs of H&E stained frontal cortex of hypercholesterolemic rats showing ill-defined cortical layers, distortion and decrease the number of neurons, numerous neuroglial cells (↑) and dilated blood vessels (V). Note widely separated bundles of the axons in the white matter (WM). H&E stain a,b X200 – c X400.

Figure 4 a, b, c, d. Photomicrographs of H&E stained frontal cortex of hypercholesterolemic rats showing: a,b: ill-defined layers of grey matter (GM) of frontal cortex, distortion of neurons, dilated blood vessels (V). 4 c: showing prominent neuroglial cells and mononuclear cellular infiltration (↑). 4 d: showing widely separated bundles of the axons in white matter (WM), numerous neuroglial cells with pyknotic nuclei (↑) and dilated blood vessels (V). H&E stain X200.

Figure 5 a, b, c. Photomicrographs of H&E stained cerebellar cortex of hypercholesterolemic rats showing, distortion of purkinje cells, as well as cellular shrinkage (↑↑) or complete destruction, vacuolation of the surrounding neuropil tissue (*), and some neuroglial cells accumulated around the purkinje cells (↑). Note some destruction and decrease in the number of granule cells (**). H&E stain X200.

Group III (Protected Group):

Frontal cortex of the protected group revealed more or less the control pattern with well-arranged layer except mild dilation of the cortical blood vessels and prominent nuclei of neuroglial cells (Figure 6 a, b). The white matter of the frontal cortex revealed mild separation of the bundles of axons and many neuroglial cells (Figure 6 c, d).

Figure 6 a, b, c, d. Photomicrographs of H&E stained frontal cortex of the protected group (received purslane seeds concomitant with high cholesterol diet). *a, b:* showing more or less normal architecture of the frontal cortex except mild dilation of blood vessels (V). *b, c:* revealed numerous neuroglial (↑) cells in white matter (WM). H&E stain X200.

The H&E stained cerebellum of the protected group revealed some destruction of purkinje cells and pericellular vacuolation (Figure 7 a, b).

Figure 7 a, b. Photomicrographs of H&E stained cerebellar cortex of the protected group (received purslane seeds concomitant with high cholesterol diet) showing mild disorganization of the purkinje cell layer (P). Some purkinje cells have normal shape while others are shrunken ($\uparrow$). Note pericellular vacuolation (*). H&E stain a X200 – b X400.

Figure 8 a,b,c. Photomicrographs of orcein stained control rat frontal and cerebellar cortex showing; 8 a: normal staining (red brown) neuropil tissue and negative staining nuclei of neurons and neuroglial ($\uparrow$). 8 b: showing normal staining of bundles of axon associated with the nuclei of some neuroglial cells ($\uparrow$). 8 c: showing the characteristic three layers of cerebellar cortex. Molecular (M), Purkinje (P), and granular (G) layers. Orcein stain X200.

Orcein stain:

Orcein stained sections of the control rats frontal cortex revealed brownish red background. The neurons and neuroglia exhibited almost unstained nuclei (Figure 8 a). The white matter of the frontal cortex showing normal staining pattern of the axons associated with nuclei of neurons and neuroglial cells (Figure 8 b). Orcein stained sections of the control rats cerebellar cortex showed a normal staining pattern of the three layers (Figure 8 c).

Orcein stained sections of the frontal cortex of hypercholesterolemic rats revealed pale staining and vacuolated background, darkly stained cell bodies of neurons and neuroglia or unstained nuclei, localized area of vacuolation associated with congested blood vessels (Figure 9 a, b, c, d).

Figure 9 a, b, c, d. Photomicrographs of orcein stained frontal cortex of hypercholesterolemic rats showing 9 a: dark staining (↑↑) and few in number of neurons. 9 b, c: dilation of blood vessels (V) and negative staining of neurons. Note pale staining and vacuolation of neuropil tissue (*). 9 d: showing widely separated bundles of the axon (*) and numerous neuroglial cell nuclei (↑). Orcein stain a, b X200 - c, d X400.

Orcein stained sections of the cerebellar cortex of hypercholesterolemic rats showed pale staining of the background and loss of purkinje cells and granule cells (Figure 10 a, b).

Figure 10 a, b. Photomicrographs of orcein stained cerebellar cortex of hypercholesterolemic rats showing evident decrease in number of neurons in the three layers of cerebellar cortex associated with congested blood vessels (V). Orcein stain a X100 - b X200.

Orcein stained sections of the frontal cortex of the protected group revealed more or less normal staining pattern as compared with the control group, except mild dilation of the blood vessels (Figure 11 a, b). Orcein stained sections of cerebellar cortex of the protected group revealed mild loss of purkinje cells and granule cells (Figure 11 c).

Figure 11 a, b, c. Photomicrographs of orcein stained frontal and cerebellar cortex of the protected group (received purslane seeds concomitant with high cholesterol diet) showing 11 a, b: more or less normal orcein staining pattern except mild dilation of the blood vessels (V). 11 c: showing normal architecture of cerebellar cortex as compared with the control group. Orcein stain a, c X200 - b X400.

4. Discussion

Cholesterol is an essential component of cell membranes, which play an important role in the maintenance of cellular homeostasis and transmembrane communication within, and between cellular compartments. Cholesterol is a well-known key regulator of membrane lipid organization and fluidity, and thus homeostatic mechanisms to maintain cellular cholesterol levels in membranes are essential for life. Even though the central nervous system (CNS) represents only 2.2% of the body weight, it contains as much as 25% of total body cholesterol.²⁶⁻²⁸

The current study was performed in male rats to exclude hormonal influences, because cholesterol homeostasis of females is mediated by the hypolipidemic properties of estrogens.²⁹

In the present study cholesterol-enriched diet significantly increased TG, total cholesterol and LDL- C compared to the control group. However, it is not clear how cholesterol is able to affect brain functions, since cholesterol does not pass the BBB. However oxysterols and oxygenated derivatives of cholesterol are able to pass lipophilic membranes.³⁰⁻³²

Consumption of purslane seeds by hypercholesterolemic rats resulted in a significant decrease in lipid parameters as compared with hypercholesterolemic group. Our results suggest that purslane seeds have anti-atherogenic hypolipidemic effects which are probably mediated by unsaturated fatty acids (omega-3) present in the seeds and also the possible influence of the relatively higher fiber content of the seed. Our results are in agreement with Soltan SSA.³³ The obtained results could be attributed also to the reported antioxidant effects of purslane seeds which in turn lead to decreased free radical generation and decreased oxidative damage of the liver, the main organ involved in cholesterol biosynthesis.^{18,34} It is well known that diet plays an important role in the control of cholesterol homeostasis. It is important to have a balance of omega 3 and omega 6 in the diet. The present study also revealed an increase in HDL-C, which might be due to stimulation of pre- β HDL-C and reverse cholesterol transport. High HDL-C levels could potentially contribute to its anti-atherogenic properties, including its capacity to inhibit LDL oxidation and protect endothelial cells from the cytotoxic effects of oxidized LDL.

Histological examination of the grey matter of the frontal cortex of hypercholesterolemic rats revealed various degrees of degenerative changes as evident by distortion of layers, loss of neurons, pyknotic nuclei of degenerated cells and vacuolation of the neuropil associated with proliferation of neuroglial cells. The white matter revealed widely separated bundles of axons. The cerebellum of hypercholesterolemic rats revealed pyknotic nuclei of degenerated cells and loss of purkinje and granule cells.

Cholesterol is an essential molecule for brain homeostasis; the synthesis of cholesterol in the brain occurs mainly in oligodendrocytes and astrocytes.²⁸ While it is well known that oligodendrocytes generate cholesterol for myelination

process, it has been shown that astrocytes produce cholesterol for neuronal cells.^{35,36} Active axonal growth as well as synapse formation and remodeling requires cholesterol that cannot be provided by distant cell body of the neuron. Cholesterol for these processes may be derived primarily from astrocytes.³⁷ Astrocytes are the major glial cell population within the CNS. They play important roles in CNS homeostasis through the release of several neurotrophic factors. This function is crucial for the integrity of the neuronal cytoskeletal networks and the neuronal processes in forming connections with other cells. Brain aging, overt any neurodegenerative state, leads to inflammation, oxidative stress and cell death. Neurons are more susceptible to injury than astrocytes, as they have fewer antioxidant mechanisms and are therefore prone to excitotoxicity.³⁸ Both normally and with aging, astrocytes support neurons by providing antioxidant protection, substrates for neuronal metabolism via neurovascular coupling, and glutamate clearance. Although astrocytes are generally more resilient than neurons, severe damage also results in astrocyte dysfunction, leading to increased neuronal death.³⁹ Therefore, many recent efforts have focused on the astrocyte-neuron interaction and how astrocyte function can be improved to enhance neuronal support and survival.³⁸ A growing body of data demonstrates that astrocytes play a multifaceted and complex role in the response to neuropathologies, including neurodegenerative diseases, as they have potential to both enhance neuronal survival and regeneration and contribute to further injury.^{40,41}

Since cholesterol has structural features that make the membranes more rigid, maintaining the proper level of cholesterol is essential for neuronal membrane function, especially at the synaptic ending where membrane fluidity influences the process of neurotransmission.⁴² Cholesterol resident within the brain exists in two pools. 70 % of the total brain cholesterol is metabolically stable and is found in the myelin membranes of white matter⁴³ and 30% is found in the plasma and subcellular membranes of neurons and glial cells within the grey matter.⁴⁴ Almost all of the cholesterol in the brain is synthesized in the brain and little or none of the peripheral cholesterol crosses the BBB. Thus it has been unclear to what extent dietary cholesterol can produce increases in brain cholesterol,⁴⁵ yet hypercholesterolemia and its numerous complications are believed to play a role in promoting multiple aspects of brain pathogenesis.⁴⁶ Clinical observations strongly suggested the presence of exchange between brain and plasma compartments. On the other hand, circulating cholesterol is bound up in LDL and HDL, which enter cells by transcytosis at LDL receptors. There are some controversies regarding the effect of a high cholesterol diet on the central nervous system. It is associated with a lower risk of Parkinson's disease.^{11,34} Microvessels and BBB disruptions induced by elevated cholesterol both in vivo and in vitro which was associated with an increased risk of AD pathogenesis. There are several proposed mechanisms of hypercholesterolemia induced neurotoxicity. It has been shown that hypercholesterolemia can result in the damage to

endothelial cells of arteries and capillaries, decrease in blood flow, impairment of metabolism, and the decrease in nutritive and oxygen levels in the brain, thus increasing the possibility of cognitive impairment. It has been reported that hypercholesterolemia impairs endothelial function in brain microvessels and increase the risk of brain infarction.¹¹ These findings are in agreement with our results which revealed numerous neuroglial cells, and dilation of the blood vessels.

A great body of evidence has demonstrated that high fat diet has tight relations with vascular damage and oxidative stress so it is possible that hypercholesterolemia facilitates the development of the neurodegenerative disease through increased oxidant production. Several studies have demonstrated that oxidative stress plays an important role in the initiation and progression of atherosclerosis through stimulating inflammation and cytokines production. Inflammation is a common phenomenon in many neurodegenerative diseases.⁴⁷ In AD and VaD, increased levels of inflammatory proteins in the brain and plasma have been observed even before a clinical onset of dementia. Several studies suggest that inflammation may play a role in BBB dysfunction and cognitive decline.⁴⁸ Brain capillary endothelial cells form the structural basis of the BBB, where they restrict the passage of blood-borne proteins, many neurotoxic agents, and hydrophilic molecules while allowing diffusion of small hydrophobic molecules (O₂ and CO₂) and selective transcellular transport of nutrients and other essential components into the brain parenchyma.^{49,50} The BBB is not a static barrier, but is tightly regulated, allowing changes in vascular permeability. In health, there may be a regulated temporary increase in permeability to allow increased access of nutrients and oxygen to tissues and drug accessibility. However, in disease, an uncontrolled and prolonged increase in BBB permeability results in vasogenic edema and leakage of potentially neurotoxic plasma constituents into tissue. Many acute and chronic neurodegenerative diseases including stroke, multiple sclerosis, rheumatoid arthritis, and acquired immunodeficiency syndrome (AIDS) dementia show changes in BBB integrity.^{51,52} Activated astrocytes and microglia have been shown to increase production of pro-inflammatory cytokines. In fact, preliminary studies have shown increased expression of the pro-inflammatory cytokine tumor necrosis factor- α , pharmacological modulation of astrogliosis and microglia activation regulating the BBB integrity and modification of tight-junction proteins and assess the resulting effect on BBB integrity.⁵³

A chronic long-lasting, mild cerebrovascular damage, including inflammatory processes and oxidative stress, may cause AD. Recent studies have shown that high cholesterol levels are linked to the pathology of this disease. These findings are in agreement with the findings in the present study, which demonstrated loss of neurons and pyknotic nuclei of degenerated cells associated with congested dilated blood vessels.

Administration of purslane seeds revealed amelioration evident of most of changes present in frontal cortex and cerebellum. The neuronal activities of purslane were

investigated in adult rats by Ahmida et al.⁵⁴ Purslane was able to induce a significant decrease in calcium concentration of the brain cortex. This study concluded that the potential role of purslane for neurotransmitters which is an integral part of many neurodegenerative disorders. Moneim et al.⁵⁵ and Wang⁵⁶ had reported the neuroprotective activity of oral administration of purslane extracts. The results concluded that the degrees of brain inflammation were reduced due to administration of purslane extracts due to antibacterial, antitumor, anti-inflammatory, vasodilator and immunomodulatory effects. Furthermore, purslane is a rich source of ascorbic acid (AA) which is a famous effective antioxidant. AA is the most predominant form of vitamin C in the human body and is involved in tissue growth and repair. It is a water-soluble enzyme cofactor, abundantly present in different plants and animals. AA has a powerful antioxidant activity, which made it well known to protect tissues from oxidative injury via efficiently quenching the damaging free radicals produced by different biological processes.^{54,57-60} The antioxidant effect of purslane also mediated through omega-3 content.

5. Conclusion

After viewing our results, we found that hyperlipidemia is a highly prevalent risk factor for brain injury. Consequently, hyperlipidemia atherosclerotic lesions were developed in the cerebrovascular system, which led to brain hypoperfusion, oxidative stress and inflammation. The oxidized lipids, especially oxysterol initiated endothelial dysfunction and disruption of the BBB. The damage of the BBB and the existing cerebral ischemia induced neurodegenerative processes in the brain. Various antioxidant strategies are currently being a valuable therapeutic target in many disorders. Therefore, purslane seeds might serve as an adjuvant therapy to avoid progression of brain damage through scavenging of free radicals leading to improvement in brain injury induced by hyperlipidemia.

Conflict of Interest

None declared

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