Evaluation the Efficacy of Combined Mixture of Spirulina Platensis and Cinnamon Extracts in Overweight Rats Fed on a Fatty Diet

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Abstract: Objective: This existing work was planned to appraise the interactive effect of both spirulina platensis and cinnamon in ameliorating the oxidative damage and the body weight increase elicited by high-fat diet (HFD) ingestion in rats with investigating their hypolipidemic activity. Methods: we utilized in this study seventy five albino ratsof male sex with body weight ranging between 130-150 g. They were randomly grouped into 5 equal sets with 15 animals in every one. All groups were fed on HFD (20 % fat) for 4 weeks to cause obesity and hyperlipidemia except the 1st one was kept as normal control. Group 2 (positive control) was remained obese without any treatments, despite groups 3, 4 and 5 were orally given S. Platensis (500 mg /kg b.wt), cinnamon aqueous extracts (400 mg/kg b.wt) and a combined mixture of S. Platensis and cinnamon extracts at the previous doses respectively after inducing hyperlipidemia for another 4 weeks. With ending of this experiment, serum lipid profile, antioxidant and histopathological tests were performed with recording body weight gain. Results: Treating of obese rats with individual and combined doses of spirulina and cinnamon extracts showed a considerable decrease in the serum triglyceride (TG), total cholesterol (TC), LDL, VLDL and tissue malondialdehyde (MDA) concentration with an elevation in the serum HDL level, tissue catalase (CAT) and superoxide dismutase (SOD) activities in comparison to obese group (positive control). Also improved data was recorded in the body weight and histopathological picture. Furthermore, our results declared that the combined group of both plant and algae exhibited better effects comparing to the separated one. Conclusion: Co-administration of S. Platensis with cinnamon exerted more potent effects against hyperlipidemia and oxidative hazards in obese rats than each one separately, that may be a future aid tool for developing a novel challenge against obesity impacts. [Ghada Ibrahim Abd El-Rahman. Evaluation the Efficacy of Combined Mixture of Spirulina Platensis and Cinnamon Extracts in Overweight Rats Fed on a Fatty Diet. Life Sci J 2018;15(7):37-46. ISSN: 1097-8135 (Print) / ISSN: 2372-613X (Online). http://www.lifesciencesite.com. 6. doi:10.7537/marslsj150718.06.

Keywords: Obesity, Spirulina platensis, High-fat diet, Antioxidant, Hypolipidemic activity, lipid profile

1. Introduction

Obesity is a rapidly growing global health problem that increases the danger for many diseases [1]. It facilitates the progress of many metabolic disorders which include diabetes mellitus, hypertension, dyslipidemia and heart disease [2]. Increased the quantity of nutritive substances (particularly fats) together with the excess of fat reserve in the organ tissues is one of the main causes of obesity [3]. Obesity is associated with ashortage in the antioxidant defense capacity with an increase in oxidative stress, due to overproduction of superoxide anion by activation of NADPH oxidase that promote the production of reactive oxygen species (ROS) [4].

Recently great attention converged on the use of natural substances for weight loss as alternative strategy for developing future effective, safe antioesity drugs with low side effects [5].

Spirulina is a cyanobacteria under the class of Cyanophyceae, Order of Oscillatoriaeae. It is also named Arthospira, with photosynthetic effects. Many species of spirulina were detected, but the most used one is Spirulina platensis (S. platensis) [6]. The high nutritive value of S. platensis make it a good provenance of numerous pharmaceutical agents with multi organ protection against many toxic chemicals. S. platensis contains high levels of multiple B vitamins and minerals (calcium, potassium, manganese, iron, magnesium, zinc) [7], in addition great amount of protein (70% dry weight), carotenoid (4000 mg/kg) [8], essential F. A, amino acids, glycolipids and potent antioxidant compounds (B carotene, vitamin C, vitamin E and selenium) [9]. So it has multiple therapeutic actions such as antiviral, immunomodulation, immunostimulant, anti-inflammatory, hepatoprotective, anti-cancer, antioxidant and lipid-lowering effects [10-15].

Cinnamomum zeylanicum L. (Cinnamon) is a natural plant belongs to the family Lauraceae, it was used for many years in Asia as traditional folk herbs to treat inflammation. It is also applied in food manufacture as antioxidant and spicy agent [16]. The cinnamon bark is one of multiple common spices used in folk and epochal medicines around world [17]. One of the important ingredients of essential oil extracted from C. zeylanicum cinnamonaldehyde that is the essential compound liable for its activity [18]. Recently, several reports have documented that
cinnamon extract has anti diabetic, anti hyperlipidemias, anti-obesity, antioxidiant and hepatoprotective actions [19-22]. Preceding studies investigated the hypolipidemic and antioxidant activities of S. platensis and cinnamon separately, however, As far as we know, this is the incipient report dealing with the joined form of algae and natural plant as an attempt to find outmedications with low side effects for controlling obesity related dyslipidemia.

2. Material and Methods

**Tested compounds and chemicals.**

Spirulina is a bright, blue-green dried powder with a characteristic smell produced by power nutritional, Jin Shun, Guangzhou, Trading Co., USA. It was obtained from Delta Trade Company, Alexandria. A dried bark of cinnamon (Cinnamomum zeylanicum L) was purchased from the local market of Agricultural Herbs, Spices and Medicinal Plants, Zagazig, Egypt. It was pulverized using an electric mixer into a fine powder and thereafter subjected to the preparation of aqueous extract. All chemicals and reagents were purchased from Sigma and El-Gomhoria Companies.

**Preparation of the Plant extracts.**

Aqueous extractsof Spirulina and cinnamon powders were obtained by maceration method. 10 g of finely-powdered substances were weighed and mixed with 100 ml of water and kept in a water bath at 60°C for two hours [23], and then the mixture was thieved through double layer of gauze and filtered by Whatman no. 1 filter paper. The rotary evaporator was applied in the concentration of the filtrate under reduced pressure, which immediately lyophilized after there.

**Animals**

The study was done on total number of 75 clinically healthy male rats (130- 150 g) collected from the Laboratory Animal’s Farm, Faculty of Veterinary Medicine, Zagazig University. The chosen animals were kept in metal cages under hygienic condition and maintained on standard balanced ration with water ad-libitum. This experiment was performed under the guidance of the National regulations of animal welfare and Institutional Animal Ethical Committee (IAEC).

**Inductance of obesity by high-fat diet supplement (HFD)**

Keeping the rats on a fat rich diet for 3-4 weeks may be sufficient to cause obesity and acute hyperlipidemia [24]. HFD is composed of standard diet with 20% added fat [25] (18% lard and 2% corn oil). Because the focus in this experiment was on dietary fat, the content of essential vitamins, minerals and protein in the feed was the same in both HF and standard diets (Table 1).

**Experimental protocol**

After one week of aclimatization, 75 albino rats (male sex) were assigned to 5 equal groups randomly (15 in each).

Group 1(normal control) was given a normal diet for 28 days, however, the remaining 4 groups were maintained on a fat rich diet for 4 weeks to induce obesity.

Group 2 was kept as obese control (positive control).

Groups 3 and 4 were orally administered with water extracts of S. Platensis dose 500 mg /kg b.wt [26] and cinnamon at a dosage of 400 mg/ kg b/wt [27] respectively dissolved in distilled water via gastric tube for another 28 days after inducing hyperlipidemia.

Group 5 was received combined doses of S. Platensis and cinnamon extracts by the same previously mentioned route and duration after induction of obesity.

Body weights of all rats in every group were recorded at the onset and the end of the experiment.

| Table 1: Composition of the high-fat diet (g/ 100g diet) used in the experiment |
|---------------------------------|---|
| **Ingredients**                | **HFD** |
| Yellow corn                    | 16    |
| Soybean meal (SBM)             | 12    |
| Ground barely                  | 20    |
| Corn gluten                    | 3     |
| Egg yolk powder                | 10    |
| Milk powder                    | 10    |
| Wheat bran                     | 5.8   |
| Lard                           | 18    |
| Corn oil                       | 2     |
| Dicalcium phosphate            | 1.5   |
| Salt                           | 0.5   |
| Mineral premix                 | 0.1   |
| Vitamin premix                 | 0.1   |
| Choline                        | 0.5   |
| Cholesterol                    | 0.5   |

**Collection of blood and tissue preparation**

At the terminus, we collected blood samples from the retro-orbital venous plexus of rats without anticoagulant on clean, sterile and chemical free centrifuge tubes for serum isolation for biochemical analysis (Lipid profile). The animals were then sacrificed and specimens from liver and kidney were rapidly collected from all groups and separated into 2 parts; the 1st part kept on -20°C until used for measuring the oxidative stress markers however, the
2nd part was preserved in 10% neutral formalin for histopathological examination.

**Serum chemical analysis**

Estimation of lipid profile included: the total cholesterol (TC) [28], triglycerides (TG) [29], high density lipoprotein cholesterol (HDL-C) [30], low density lipoprotein cholesterol (LDL-C) and very low density lipoprotein cholesterol (VLDL-C) [31] that were measured colorimetrically using commercial kits of Vitro Spectrum, Egypt on semi-automated Photometer 5010 V5+ (RIELE GmbH & Co, Berlin, Germany) related to the manufacturer’s schedule.

**Determination of lipid peroxidation and antioxidant status.**

Malondialdehyde (MDA) concentration, Superoxide dismutase (SOD) and Catalase (CAT) activities were determined in hepatic tissues by kits of Biodiagnostics-Egypt using the method depicted by [32-34] respectively.

**Histopathological examination**

Liver and kidney samples were taken from all groups, fixed at 10% buffered formalin, processed and soaked in paraffin. Sections (4–5 mm thick) were prepared, stained with hematoxylin and eosin (H–E) and examined for the pathological findings of hepatic and renal changes [35].

**Statistical Analysis**

The data of all experimental groups were completed using one-way ANOVA followed by Duncan’s test to differentiate between means with the SPSS 16.0 computer program [36]. A value of p < 0.05 was considered as statistically significant.

### 3. Results

**Alterations of oxidant and antioxidant parameters**

Hepatic levels of SOD and CAT in the rat group received HFD (GP. 2) for 4 weeks were less than those in the negative group, also tissue MDA concentration recorded a significant (P < 0.01) increase in obese animals compared to normal control. Conversely, it was found that daily dosing of obese animals with aqueous extracts of spirulina and cinnamon for 28 days evoked an elevation in the SOD and CAT enzymes in the liver tissue with a significant (P < 0.01) reduction in hepatic MDA content comparable to the positive control group (GP. 2) as shown in table (2).

### Table 2. Hepatic levels of MDA, CAT and SOD in HFD received rats after 28 days of S. Platensis and Cinnamon administration

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Parameters</th>
<th>Control</th>
<th>HFD</th>
<th>Spirulina treated group</th>
<th>Cinnamon treated group</th>
<th>Combination treated group</th>
</tr>
</thead>
<tbody>
<tr>
<td>MDA (nmol/g tissue)</td>
<td>Control</td>
<td>8.44 ± 0.46</td>
<td>21.34 ± 0.53</td>
<td>16.69 ± 0.52</td>
<td>17.46 ± 0.31</td>
<td>13.60 ± 0.55</td>
</tr>
<tr>
<td>CAT (u/g tissue)</td>
<td>Control</td>
<td>35.26 ± 0.90</td>
<td>18.89 ± 0.20</td>
<td>25.46 ± 0.98</td>
<td>27.50 ± 0.51</td>
<td>30.30 ± 0.72</td>
</tr>
<tr>
<td>SOD (u/g tissue)</td>
<td>Control</td>
<td>75.70 ± 1.43</td>
<td>58.66 ± 1.65</td>
<td>65.53 ± 1.07</td>
<td>64.43 ± 0.74</td>
<td>71 ± 0.25</td>
</tr>
</tbody>
</table>

Means within the same row having various superscripts are significantly variable (one-way ANOVA) (P≤0.05). * compared to normal control, † compared to the positive control group (HFD) **Abbreviations:** HFD: high-fat diet, MDA: Malondialdehyde, CAT: Catalase, SOD: Superoxide dismutase

### Table 3 Lipid profile of different treated groups

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Parameters</th>
<th>Control</th>
<th>HFD</th>
<th>Spirulina treated group</th>
<th>Cinnamon treated group</th>
<th>Combination treated group</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC (mg/dl)</td>
<td>Control</td>
<td>80.06 ± 1.47</td>
<td>121.16 ± 2.16</td>
<td>92.46 ± 0.99</td>
<td>94.23 ± 0.63</td>
<td>85.1 ± 0.95</td>
</tr>
<tr>
<td>TG (mg/dl)</td>
<td>Control</td>
<td>61.76 ± 1.87</td>
<td>86.06 ± 2.20</td>
<td>74.83 ± 0.98</td>
<td>76.30 ± 0.56</td>
<td>68.33 ± 0.43</td>
</tr>
<tr>
<td>HDL (mg/dl)</td>
<td>Control</td>
<td>44.86 ± 1.33</td>
<td>25.26 ± 1.45</td>
<td>32.76 ± 0.95</td>
<td>33.76 ± 1.12</td>
<td>39.30 ± 0.51</td>
</tr>
<tr>
<td>VLDL (mg/dl)</td>
<td>Control</td>
<td>12.35 ± 0.37</td>
<td>17.21 ± 0.44</td>
<td>14.96 ± 0.19</td>
<td>15.26 ± 0.11</td>
<td>13.76 ± 0.08</td>
</tr>
</tbody>
</table>

Means within the same row having various superscripts are significantly variable (one-way ANOVA) (P≤0.05). * compared to normal control, † compared to the positive control group (HFD) **Abbreviations:** HFD: high-fat diet, TG: triglyceride, LDL-C: low density lipoprotein cholesterol, HDL-C: high density lipoprotein cholesterol, VLDL-C: very low density lipoprotein cholesterol

**Anti-obesity and antihyperlipidemic activities**

Feeding of rats on fat rich diet caused a statistical (P < 0.01) increase in the total cholesterol (TC), triglyceride (TG), LDL-C and VLDL-C serum levels relative to the normal control group. This elevation was decreased in treatment groups received oral doses of spirulina and cinnamon extracts individually or together, which represented by lowering the serum TC, TG, LDL-C and VLDL-C concentrations relative to the HFD group (GP. 2). These results showed more potent effects in the combined spirulina and cinnamon group than the separated administration as given in table (3). The serum HDL-C significantly (P < 0.01) reduced in the HFD supplemented group compared with the control (GP. 1), which recorded an observable enhancement in the treatment groups

**Changes of rats body weight.**

The body weight of rats in all groups increased gradually. Table (4) illustrates a significant (P < 0.05) elevation in the final b.wt of rats received high-fat diet (HFD) comparable to the negative control. Administration of spirulina and cinnamon extracts alone or together with HFD group (GP. 2) for 4 weeks caused a significant (P < 0.05) decrease in the final body weight relative to the positive control group (obese control). This effect was better in the treated
group with both extracts than the separated one. The differences in the changes of initial b.wt of rats treated with spirulina and cinnamon extracts and control were non-significant.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Control</th>
<th>HFD</th>
<th>Spirulina treated group</th>
<th>Cinnamon treated group</th>
<th>Combination treated group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial body weight (g)</td>
<td>148.6 ± 4.41</td>
<td>153.6 ± 3.21</td>
<td>154.4 ± 3.61</td>
<td>151 ± 4.30</td>
<td>150 ± 3.53</td>
</tr>
<tr>
<td>Final body weight (g)</td>
<td>176.4 ± 2.50</td>
<td>243 ± 2.21</td>
<td>209.8 ± 1.77</td>
<td>215.6 ± 1.07</td>
<td>197.6 ± 2.50</td>
</tr>
</tbody>
</table>

Means within the same row having various superscripts are significantly variable (one-way ANOVA) (P≤0.05). *compared to normal control, †compared to the positive control group (HFD) 

Abbreviations: HFD: high-fat diet

**Figure 1:** Photomicrograph of H & E-stained liver section (400 X) of different groups. (A) The liver of negative control showing normal cellular architecture with distinct hepatic cells, sinusoidal spaces and central vein. However, rats fed with HFD only showing Centro lobular fatty change (arrows) (B). The liver of HFD fed rats treated with spirulina and cinnamon extractshowing moderate fatty change with fat vacuoles (arrows) in some hepatocytes and mild mixed inflammatory cell infiltration (arrow head) around the central vein (C, D). The hepatic parenchyma of combination treated group showingslight hydropic degeneration and fatty change (arrows) (E)

**Histopathological observation**

Microscopical examinationof H & E-stained liver section of control group (GP. 1) revealed normal cellular hepatic tissues and central vein (Fig.1 A). Conversely, hepatic tissue analysis from rats supplemented with HFD (GP. 2) for 28 days showed Centro lobular macrovesicular steatosis (fatty change) in the picture of infiltration of cells by fat vacuoles
pushing the nucleus peripheral with signet ring appearance and typically vacuolated cytoplasm (Fig.1 B). The treatment with spirulina or cinnamon extracts after induction of hyperlipidemia (GPs. 3,4) showed moderate fatty changes with fat vacuoles in some hepatocytes and mild mixed infiltration of inflammatory cell surrounding the central vein, while other hepatic cells appear normal (Fig. 1C, D) The histopathological changes in these groups were milder than those mentioned in gp. (2). The hepatic parenchyma of combination treated group (GP. 5) showed mild hydropic degeneration and fatty change (arrows), some regenerative attempts were focally noticed (Fig. 1E).

The kidney of control group (1) showed normal renal glomerular and tubular architecture (Fig. 2 A), while the renal tissue of high-fat diet feeding rats (GP. 2) showed focal accumulation of large fat vesicles intramedullary in between renal tubules compressing them and tubules showed the moderate disturbed shape, also mild peritubular mixed inflammatory filtrate was observed (Fig. 2 B). Obese rats received spirulina or cinnamon extracts for 4 weeks (GP. 3,4) showed vacuolation and hydropic degeneration of the lining epithelium of the renal tubules in form of loose adhesion between adjacent cells (Fig. 2 C, D). The co-treated group with both extracts showed mild vacuolation (arrow), the spare of renal parenchyma was mostly normal (Fig. 2 E).

Figure 2: Photomicrograph of H & E-stained kidney section of normal control showing normal renal tubules, glomeruli and bowman’s capsule (A) (300 X). The kidney of obese rats (gp.2) showing focal accumulation of large fat vesicles with signet ring appearance intramedullary in between renal tubules compressing them (arrows) (B) (400 X). Spirulina and cinnamon treated groups showing vacuolation and hydropic degeneration of the lining epithelium of the renal tubules in form of loose adhesion between adjacent cells (arrows) (C, D) (400 X). The renaltubular epithelium of co-treated group with spirulina and cinnamon extracts together showing mild vacuolation (arrow), the spare of renal parenchyma was mostly normal (E) (400 X).
4. Discussion

Suppression of antioxidant defense mechanisms with excess free radicals output, possibly has a part in an animal form of obesity [37]. This imbalance leads to oxidative stress, which is obvious from depressed hepatic SOD and CAT levels in the obese group in our study with an elevation of tissue malondialdehyde level. Reduction of enzymes of the antioxidant system in hyperlipidemic rats may be owing to rapid consumption and exhaustion of storage of these enzymes in fighting free radicals produced during the development of obesity. This observation is unison with past studies [38,39] who demonstrated that obesity is an autonomous dangerous factor for increasing lipid peroxidation and decreased activity of cytoprotective enzymes. Some researchers declared that consuming a diet with high fat calories result in down regulation of antioxidant vitamin (β-carotene and α-tocopherol) levels and several key antioxidant enzymes: Catalase, superoxide dismutases, glutathione peroxidase, heme oxidase [40]. Obesity can cause progressive and cumulative cell injury resulting from pressure of the large body mass, cell injury produces the liberation of cytokines, especially tumor necrosis factor alpha (TNF-α) which generates reactive chemical species (ROS) from the tissues that leading to lipid peroxidation [41]. Dyslipidemic changes occur in obesity could be owing to the increased triacylglycerol concentration in the liver owing to the increased influx of excess NEFAs into the liver [42]. Increase of LDL-C in high-cholesterolemic animals probably caused by the reduction in the binding capacity of LDL to its receptor or reduction in its receptor numbers [43]. The observed hypertriglyceridemia might be related to the increased triglycerides formation or absorption after giving a diethigh in fat or through higher production of hepatic very low density lipoprotein (VLDL) and reduced the uptake of triglyceride in peripheral tissues [44]. Additionally, increased dietary cholesterol absorption from the small intestine could be possible mechanism for the high level of serum cholesterol following the HFD intake [45]. For explaining the metabolic cause of decreasing the blood HDL-C in rats given HFD, [46] proposed that HFD may cause the stimulation of the hepatic lipoprotein lipase and endothelial lipase enzymes that accelerates the hydrolysis of HDL-C resulting in its low serum level. Preceding studies [47,48] are inconsistent with our findings. Feeding with enriched fat diet caused an elevation in the weight gain, this increase, perhaps due to the use of a high energy diet with saturated fats (lard) and its further accumulation in many body fat stores [49]. Alteration of lipid profile and increase of oxidative damage accompanied with obesity leading to hepato-renalis injuries that confirmed microscopically by hepatic macrovesicular lipid droplets and peritubular fatty change in renal tissue, similar observations were procured by [50,51].

In the current investigation, the dietary supplementation of overweight rats with spirulina or cinnamon extracts for 28 days decreased the oxidative damage produced by HFD via enhancement the levels of antioxidant enzymes (CAT, SOD) or by suppression of lipid peroxidation products, the results were more obvious in the combined group of two extracts that might be owing to the synergistic effect of their antioxidant components. Spirulina contains several active ingredients, particularly phenolic acids, phycocyanin, phycocyanobilin, and β-carotene, all of which show promise antioxidant activity [52,53]. Cinnamate is a phenolic compound present in cinnamon bark that accountable for its protective action and the activation of antioxidant enzymes. The antioxidant action of cinnamate is fundamentally due to its redox effects and may caused different mechanisms, as: free-radical scavenging activity, transition-metal-chelating and singlet-oxygen-quenching capacity [54]. Our findings are concomitant with the data reported by [55,56] who demonstrated the efficacy of spirulina treatment in ameliorating the antioxidant defense of experimental animals with suppressive effect on lipid peroxides accumulation and oxidative injury caused by high cholesterol diet. Concerning cinnamon, Hypercholesterolemic rats received oral dose of cinnamon extract (20mg/day) for 6 weeks showed lower levels of hepatic MDA concentration, meanwhile, the activity of SOD and CAT enzymes in hepatic tissue were elevated significantly relative to group kept without treatment [57]. Improvement of lipid profile picture upon using plant extracts was noticed in this investigation that reflect the protective action of both spirulina and cinnamon against obesity induced lipid metabolism abnormalities. However, the best findings were recorded in the combination group, suggesting the interaction of their active components to restore the lipid profile changes near to normal level. These results are compatible with [58,59] for spirulina and with [60,61] for cinnamon. The lipid lowering mechanism of spirulina may be owing to its potential to provoke the activity of lipoprotein lipase enzyme that hydrolyzes triglyceride to release F. As which can be utilized or stored [62]. Recently, it was reported that C-phycocyanin derived from spirulina produced hypocholesterolemic activity in rats where it binds to bile acids in the jejunum, this binding suppresses the absorption of cholesterol by influence on its micellar solubility [63]. Also, β-carotene and linolenic acids present in this algal lowers plasma triacylglycerol and inhibits the synthesis of hepatic fatty acids in hyperlipidemic rats [64,65]. Moreover, few previous
studies proposed that the amounts of carbohydrate and dietary fiber in spirulina are able to cause cholesterol lowering effect by increasing the bile acid pool size and fecal steroid excretion [66,67]. Another study suggested the capacity of spirulina aequous extract to activate lecithin cholesterol acyl transferase (LCAT) enzyme [26]. LCAT has a major role in the incorporation of free cholesterol into HDL and its transfer back to VLDL and LDL, which are later returned in liver cells and thus reducing the cholesterol level [68]. Correlating with such improvement in lipid profile, the hypolipidemic effect of cinnamon, possibly related to suppression of the hepatic HMG Co-A reductase activity causing the decrement of cholesterol content in the liver [69]. It was shown that cinnamon water extract regulate lipid metabolism through the stimulation of PPARγ and α (Peroxisome Proliferator-Activated Receptors) mRNA expression in the liver resulting in lower serum lipids and elevated plasma HDL-C [70]. Liver PPARα expression increased the cellular uptake of fatty acids liberated from fat tissues [71], it also increase the expression of the lipoprotein lipase gene and reduce the expression of the gene encoding for apo-C, which is an inhibitor of lipoprotein lipase producing antihyperlipidemic action [72]. According to [73], the polyphenols content of cinnamon may inhibit the absorption of cholesterol from the intestine, thus reducing its level in the serum of experimental animal models. Suppression of weight gain by spirulina or cinnamon recorded in this search are relevant to those of [74,75]. These favorable effects supporting the relief of histopathological alterations noticed in the treatment plant groups. The observable body weight decrease in obese rats received a cinnamon extract supposedly for its role in reducing the level of serum leptin/hormone [76]. In this concern, [77] mentioned that leptin is a peptide hormone released from adipose tissue into the blood in proportion to its mass. It exerts its effect on the brain to regulate food intake and energy expenditure. When body fat mass decreases, the plasma leptin levels decrease so prompting the appetite and inhibiting energy expense till fat mass is restored.

References


