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RESEARCH ARTICLE

# Antihyperlipidemic Activity of Ethanolic and Aqueous Extracts of *Asparagus Racemosus* and *Chlorophytum Borivilianum* Leaves in Albino Rats

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**Abstract** Hyperlipidemia is basically a risk factor for causing heart related diseases, strokes, high blood pressure, diabetes, renal disorders, etc. Herbal remedies are widely used by all sections of society, whether as traditional remedies or modern medicine. In this research work, the hyperlipidemic activity of aqueous and ethanolic extracts of *Asparagus racemosus* leaves and *Chlorophytum borivilianum* leaves was determined and the effect of these extracts on weight gain in hyperlipidemia-induced rats was determined. The aqueous and ethanolic extracts of *A. racemosus* (Leaves) and *C. borivilianum* (Leaves) were evaluated for serum lipid profile in hyperlipidemic-induced rats. It was concluded that the serum lipid profile in aqueous and ethanolic of *C. borivilianum* (Leaves) was found to be decreased than aqueous and ethanolic extract of *A. racemosus* (Leaves) when compared with standard (Rosuvastatin). The aqueous extract of *C. borivilianum* (Leaves) significantly lowered the body weight by the reduction in the serum lipid profile. Thus, in this study it was proved that aqueous extract of *C. borivilianum* (Leaves) decreased the level of hyperlipidemia in comparison to other extracts.

**Significance statement:** These studies and investigation will provide a way for other plants to be used as an important for treating various diseases. This research will help in the development of eco-friendly, cost-effective, and economic techniques for controlling hyperlipidemia and related diseases.

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**Keywords** Hyperlipidemia · Triglycerides · Hypercholesterolemia · *Chlorophytum borivilianum* · *Asparagus racemosus*

## Introduction

Hyperlipidemia is a major metabolic syndrome and a prevalent disease that combines with other prevailing diseases viz. diabetes mellitus, cardiovascular diseases, high blood pressure, etc., and thus elevated the rate of morbidity and mortality [1]. Currently, there are several lipid lowering drugs with severe side effects thus people are moving toward traditional or herbal treatments. In the majority of countries, epidemiologically observed that consumption of herbal plants, fruits and proper diet had satisfactorily decreased the concentration of hyperlipidemia. Extensively even in many developed countries it has been observed that the tendency of using herbal plants has increased. Recently, many researchers have claimed that traditional herbal plants have secondary plants constituents like flavonoids, sterols, saponins, antioxidants that may lower the concentration of lipids, inhibit LDL oxidation, improve metabolic disorder, eliminate oxygen free radicals, etc. [2]. Many clinicians and physicians have given the guidelines for the screening of "lipid profile" which is basically done by measuring the level of cholesterol and triglyceride in blood test. The guideline is recommended differently to everyone as when to start and when to stop the screening and what the frequency of screening should be told by the advisor. Some herbal extracts inhibit the deposition of lipids during adipogenesis and improve the catabolism of triglyceride rich lipoproteins. In particular, the ethanolic extracts are responsible for decreasing the serum total cholesterol, triglyceride level, LDL whereas increase in HDL level. Even this extract may improve the activity of

HMG-CoA reductase enzyme (potential role in managing serum lipid profile). It has been also proved that many herbal extracts have lipid lowering activity due to the presence of active constituents like flavonoids, saponins, sterols, glycosides, triterpenoids, etc. [3].

In recent scenarios, it has been reported that 1.8 billion people are suffering from hyperlipidemia throughout the world. In India, more than 140 million people are suffering from hyperlipidemia. According to WHO, hyperlipidemia leads to 59% cases of cardiovascular diseases and causes 4.4 million deaths every year. Thus, hyperlipidemia needs serious attention for the treatment. There are number of synthetic drugs for treating hyperlipidemia but synthetic drugs have serious adverse effects particularly liver damage and it may lead to diarrhea, nausea, gastric irritation, etc., whereas herbal practitioner aims to produce continuous improvement of disease in well- being. Herbal medicines are popular and acceptable because these are safe, rich source of therapeutic agents and easily available. The drugs obtained from different parts of various plants are biologically and pharmacologically active compounds and have various therapeutic activities [4]. The various histopathological results have been proved that *Chlorophytum borivilianum* and *Asparagus racemosus* preserved liver and myocardial tissues. This has been noticed that *C. borivilianum* leaves are able to decrease serum lipid profile in diabetic rats and normal albino rabbits. The leaves of *A. racemosus* may elevate the bile acid production, hepatic antioxidant status and excess elimination of cholesterol from the body. The leaves of *C. borivilianum* decrease the level of LDL, VLDL and triglycerides from the blood. Many practitioners have claimed that the combination of herbs improves the efficacy as well as decreases the adverse effect in the body. So, the study was conducted to investigate the phytochemicals obtained from the leaves of *C. borivilianum* and *A. racemosus* which primarily helps to overcome hyperlipidemia. In today's generation, the tendency of using synthetic drugs to lower serum lipid in hyperlipidemic patients is becoming less because of their severe adverse effects and thus the tendency of using herbal plants is being doubled. So, it becomes necessary to do furthermore research on natural methods for treating hyperlipidemia [5].

## Material and Methods

### Animal

In this research work wistar albino male rats (250–300 gm) were used and these rats were placed in polypropylene cages under normal conditions of 12 h light and (12 h dark cycles, at $20 \pm 30°$ C and humidity 30–60%). A standard palletized feeder (Amrut Pellets Rat, jaipur, India) and tap water provided with ad libitum. All the experimental procedure and protocols were approved by Institutional Animal Ethical Committee and were in accordance with the guidelines of the CPCSEA.

### Pharmacological Studies

*Studies of Acute Toxicity of Extracts*

Aqueous and ethanolic extracts from ARL: *A. racemosus* (Leaves) and CBL: *C. borivilianum* (Leaves) tested for severe toxicity study in OECD guidelines no. 423 to obtain LD50. The results proved that aqueous and ethanolic extracts, namely AEARL, EEARL, AECBL, EECBL, were class 5. Also, no toxicity was detected and recorded at 5000 mg/kg bw. Therefore, the LD50 was 5000 mg/kg; thus, the ED50 was 250 mg/kg. Therefore, 1/10th and 1/20$^{th}$, i.e., two doses of 250 and 500 mg were selected for the current study. Results are shown in Table 1.

Exfoliation was found to be protective up to a dose of 5000 mg/kg body weight. Dry extraction was set at 1% CMC at dose levels 250 mg/kg and body weight of 500 mg/kg for oral administration [6].

According to OECD guideline no. 423 the aqueous and ethanolic extracts of ARL: *A. racemosus* and CBL: *C. borivilianum* leaves were evaluated for acute toxicity study for determining $LD_{50}$. The results proved that both the extracts, i.e., AEARL, EEARL, AECBL, EECBL have belonged to category-5. Also, no toxicity was reported at 5000 mg/kg BW. Hence, $LD_{50}$ was 5000 mg/kg; therefore, $ED_{50}$ was 250 mg/kg. Therefore, 1/10th and 1/20$^{th}$, i.e., two doses of 250 and 500 mg were used. The results are shown in Table 1.

The extract was preventive up to a dose of 5000 mg/kg body weight. For oral administration, the dried extract was

**Table 1** Determination of $LD_{50}$ and $ED_{50}$ of aqueous and ethanolic extract of ARL: *A. racemosus* (Leaves) and CBL: *C. borivilianum* (Leaves)

| S/no. | No. of animals | Extract dose (mg/kg) | No. of death of animals | | | |
|---|---|---|---|---|---|---|
| | | | AEARL | EEARL | AECBL | EECBL |
| 1 | 3 | 5 | 0 | 0 | 0 | 0 |
| 2 | 3 | 50 | 0 | 0 | 0 | 0 |
| 3 | 3 | 300 | 0 | 0 | 0 | 0 |
| 4 | 3 | 2000 | 0 | 0 | 0 | 0 |
| 5 | 3 | 5000 | 0 | 0 | 0 | 0 |

suspended in 1% CMC at two different dose levels, i.e., 250 mg/kg and 500 mg/kg body weight [7].

**Anti-Hyperlipidemic Activity**

Healthy male wistar albino rat were purchased and weighing about 180–200 gms were used for research. Each animal tested was tested before surgery to detect any type of disease. The animals were kept in laboratory under supervision where they could breed, 1 week before the test. Animals kept in neat and clean cages which are separated under the controlled room temperature, i.e., $25 \pm 1°$ C & also the relative humidity, i.e., $50 \pm 15\%$; in approx. 12 h light–dark cycles. The animals eat regular food and water ad-libitum. Prior to the start of the experiment the mice were equally divided into 11 groups.

*Group I:* Control (General Control)
*Group II:* Good control (5% cholesterol diet for 3 months)
*Group III*: Normal (5% dietary cholesterol + Rosuvastatin (20 mg/kg))
*Group IV*: Test I (EEARL-250 mg/kg bw + 5% dietary cholesterol)
*Group V*: Test II (EEARL-500 mg/kg bw + 5% dietary cholesterol)
*Group VI*: Test III (AEARL-250 mg/kg bw + 5% dietary cholesterol)
*Group VII*: Test VI (AEARL-500 mg/kg bw + 5% cholesterol diet)
*Group VIII*: Test V (EECBL-2500 mg/kg bw + 5% cholesterol diet)
*Group IX*: Test VI (EECBL-500 mg/kg bw + 5% cholesterol diet)
*Group X*: Test VII (AECBL-250 mg/kg bw + 5% cholesterol diet)
*Group XI*: Test VIII (AECBL-500 mg/kg bw + 5% cholesterol diet)

**Procedure**

Rats are equally divided into eleven groups, each group consists of six animals. In which, Group I fed normally who received normal salt (5 ml/kg bw) 28 days ago orally; Group II acted as a good controller who received 5% cholesterol intake for 3 months regularly and continuously; Group III operated + as normal receiving Rosuvastatin (20 mg/kg bw; I.P route) for the last 28 days; Group IV and Group V served as a trial that received an EEARL dose of 250 and 500 mg kg bw; Group VI, Group VII operated as a trial with a dose of AEARL of 250 and 500 mg/kg bw; Group VIII, Group IX acted as a trial that received an EECBL dose of 250 and 500 mg/kg bw; Group X, Group XI performed as a trial that received an AECBL dose of 250 and 500 mg/kg bw using oral method throughout the study period and also received a 5% cholesterol intake over the past 28 days. After the study period the animals were randomly assigned to collect blood by heart piercing and the collected blood was centrifuged and serum was collected and analyzed biochemical profiles of lipid levels of serum TC, TG, HDL, LDL, VLDL, as well as antioxidant studies SOD,GSH and catalase were performed.

*Weight Gain Ratio*

During the experimental process, a high cholesterol diet and weight gain in rats was recorded on days 0, 14 and 28 for treatment. Pre-measured food pellets (approximately 30 g) are placed inside the cage hopper. The food consumed by each rat was measured by measuring the remaining food.

*Total Cholesterol Rate (TC): (CHOD-PAP Method)*

The reagents kits are intended for the determination of in-vitro quantitative cholesterol in serum/plasma [8].

$$\text{Total cholesterol mg/dl} = \text{Abs TC/Abs STD} \times 200$$

*Level of Triglycerides (TG): (GPO-Method)*

The diagnostic kit was used to measure triglycerides, followed by enzymatic end-to-end test using glycerol-3-phosphate oxidase [9].

*High-density Lipoprotein Cholesterol (HDL-C) Ratio*

A diagnostic kit was used to measure HDL cholesterol, which followed the path of Cholesterol oxidase/peroxidase (CHOD-POD) [10].

*Estimation of Creatinine*

This was done by Jaffe's method.

*Estimation of Urea and Uric Acid*

It was determined using the standard method.

*Histopathological Studies*

Tissues are immediately washed with saline and then immersed in 10% formalin solution. After repair, the heart tissue is processed with a series of alcohol-xylene and then dipped in paraffin. Parts of the serial were cut and each part was contaminated with hematoxylin and eosin. The slides were examined under a microscope and photographed.

### Statistical Analysis

The result was presented as ± SD and statistically analyzed using a single ANOVA method followed by Dunnett testing and data was computerized for statistical analysis.

## Results and Discussion

The aqueous and ethanolic extracts of ARL: *A. racemosus* (Leaves) and CBL: *C. borivilianum* (Leaves) were screened for acute toxicity study by OECD guideline no. 423 for determination of $LD_{50}$. The results showed that the aqueous and ethanolic extracts, i.e., AEARL, EEARL, AECBL, EECBL were belonging to category-5. Also, no toxicity was observed and recorded at the dose of 5000 mg/kg bw. Hence, $LD_{50}$ was 5000 mg/kg; therefore, $ED_{50}$ was 250 mg/kg. Therefore, 1/10th and 1/20$^{th}$, i.e., two doses of 250 and 500 mg were selected for present investigation. The results are presented in Table 1.

The extract was found safe up to a dose of 5000 mg/kg body weight. The dried extract was suspended in 1% CMC at dose levels 250 and 500 mg/kg body weight for oral administration.

Cholesterol powder was purchased and used with normal diet shows changes in serum cholesterol levels differ significantly between rats and humans. To clarify these confusions, a 12-week feeding study with rats was conducted to evaluate the influence of a high-fat diet on serum lipid profiles, kidney parameters, and antioxidant studies [11, 12].

The use of rats as experimental animals for hyperlipidemic activity is mainly due to the synthesis and structural similarities in humans and rats. The present study carried out inducing 5% cholesterol for the experimental induction in rats. Cholesterol will deposit in the endothelial cells and transport with lipoproteins in the bloodstream which leads to an increase in the TC, TG, LDL, VLDL levels and decreases the HDL levels in the body. It is synthesized in the liver and converted into bile acids and excreted through feces and due to hypercholesterolemia urine failure will occur due to oxidative stress [13].

Hyperlipidemic activity, i.e., high cholesterol diet-induced hyperlipidemic activity of the aqueous and ethanolic extracts of ARL: *A. racemosus* (Leaves) and CBL: *C. borivilianum* (Leaves) was determined, and results were presented. The effect of EEARL, AEARL, EECBL, and AECBL on weight gain in hyperlipidemia-induced rats was recorded and is presented in Table 2 and Fig. 1.

From the results obtained it was concluded that the weight gain in EECBL and AECBL of CBL: *C. borivilianum* (Leaves) was found significant and more satisfactory than EEARL and AEARL of ARL: *A. racemosus* (Leaves) when compared with standard.

Bodyweight can be increased due to the high cholesterol diet-induced in hyperlipidemic rats. As the dietary fat, FFAs can be synthesized into many tissues by transport of increased lipoproteins in the bloodstream absorbed from the intestine and metabolized in the liver [14–17]. The treatment, i.e., EEARL, AEARL, EECBL, and AECBL and Rosuvastatin drug significantly lower the body weight by

**Table 2** Effect of extract of *A. racemosus* (Leaves) and *C. borivilianum* (Leaves) on weight gain in hyperlipidemic-induced rats

| Group | Treatments | 0 Day | 14th Day | 28th Day |
|---|---|---|---|---|
| Group I | Normal control | 124.3 ± 0.08 | 126.1 ± 0.16 | 126.4 ± 0.10 |
| Group II | Positive control | 213.4 ± 0.10 | 226.4 ± 0.11 | 237.7 ± 0.21 |
| Group III | Standard | 198.2 ± 0.09* | 173.5 ± 0.13** | 154.1 ± 0.49* |
| Group IV | Test I EEARL 250 mg/kg bw | 205.89 ± 0.45*** | 190.54 ± 0.12** | 178.24 ± 0.78*** |
| Group V | Test II EEARL 500 mg/kg bw | 204.38 ± 0.48** | 189.45 ± 0.47** | 177.64 ± 0.15* |
| Group VI | Test III AEARL 250 mg/kg bw | 203.45 ± 0.65*** | 187.34 ± 0.21* | 176.51 ± 0.37* |
| Group VII | Test IV AEARL 500 mg/kg bw | 200.89 ± 0.31** | 182.31 ± 0.97*** | 173.84 ± 0.45*** |
| Group VIII | Test V EECBL 250 mg/kg bw | 204.52 ± 0.24 | 188.34 ± 0.32 | 175.65 ± 0.21 |
| Group IX | Test VI EECBL 500 mg/kg bw | 200.32 ± 0.21* | 180.91 ± 0.32** | 172.34 ± 0.32** |
| Group X | Test VII AECBL 250 mg/kg bw | 195.53 ± 0.50** | 175.21 ± 0.21*** | 169.02 ± 4.35*** |
| Group XI | Test VIII AECBL 500 mg/kg bw | 193.22 ± 0.87** | 174.32 ± 0.59*** | 165.06 ± 3.22*** |

All values are expressed as mean ± S.E.M ($n = 6$), Values are significant when compared with cholesterol group *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$ (one way ANOVA followed by Dunnett test)

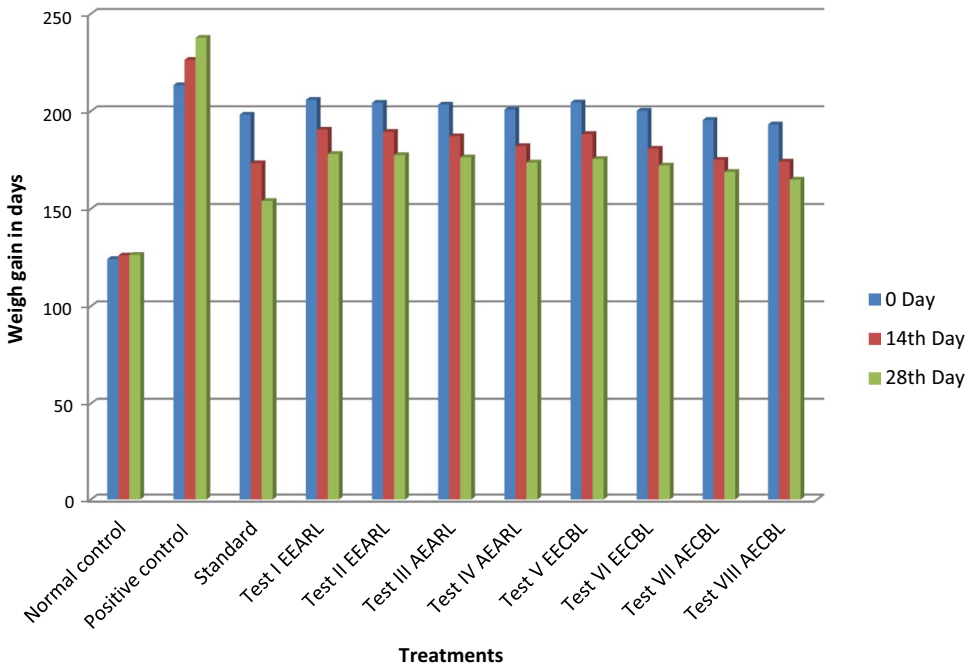



**Fig. 1** Effect of extract of *A. racemosus* (Leaves) and *C. borivilianum* (Leaves) on weight gain in hyperlipidemic-induced rats

the reduction in the LDL, VLDL levels and increase HDL levels.

Statins are a class of drugs used to lower cholesterol levels by inhibiting the enzyme HMG-CoA reductase, which plays a central role in the production of cholesterol in the liver [18, 19]. Rosuvastatin is a competitive inhibitor of HMG-CoA reductase and catalyzes the reduction in 3-hydroxy-3-methylglutarylcoenzyme A (HMG-CoA) to mevalonate, which is the rate-limiting step in hepatic cholesterol biosynthesis. Inhibition of the enzyme decreases hepatic cholesterol, increasing the expression of low-density lipoprotein receptors (LDL receptors) on hepatocytes and decreasing the amount of LDL cholesterol in the blood. Like other statins, Rosuvastatin also reduces blood levels of triglycerides and slightly increases levels of HDL cholesterol [20].

The aqueous and ethanolic extracts of ARL: *A. racemosus* (Leaves) and CBL: *C. borivilianum* (Leaves) were evaluated for serum profile, i.e., serum cholesterol, triglycerides, HDL, LDL, and VLDL in hyperlipidemic-induced rats. The results are given in Table 3 and Fig. 2.

From the results obtained it was concluded that the serum lipid profile in EECBL and AECBL of CBL: *C. borivilianum* (Leaves) was found to be decreased than EEARL and AEARL of ARL: *A. racemosus* (Leaves) when compared with standard. But the AECBL of CBL: *C. borivilianum* (Leaves) had significantly lowered the serum lipid profile in rats in comparison to other extracts.

The assessment of cholesterol function can be made by estimating the body weight and activities of various lipid profiles such as TC, TG, HDL, LDL, and VLDL; kidney parameters such as urea, creatinine, and uric acid.

TC and TG are present in dietary fat, FFAs combine with glycerol to form TG, and cholesterol is esterified by ACAT to form cholesterol esters, storing cholesterol in cells. TC and TG are generated by the liver and circulate as chylomicrons interact at capillaries of adipose tissues and muscle cells [21]. LPL hydrolyzes the TG, and FFAs are released. The elevated TC and TG levels in hyperlipidemia-induced high cholesterol diet are due to the increase in cholesterol in capillary cells. The treatment, i.e., EEARL and AEARL of ARL: *A. racemosus* (Leaves), EECBL and AECBL of CBL: *C. borivilianum* (Leaves) and Rosuvastatin drug significantly lowered the abnormal levels of TC and TG might be due to lowering of FFA (Free fatty acids) synthesis in the plasma.

LDL and VLDL are a package of TG and TC esters in the liver and are released into blood circulation. VLDL is then hydrolyzed by LPL in tissues to release fatty acids taken up by muscle cells for energy and glycerol becomes a VLDL remnant taken up by the liver by LDLR. They hydrolyzed in the liver by HL to form LDL. LDLR activity and uptake regulate plasma LDL concentration through decreasing the synthesis of HMG-CoA reductase controls the rate of de novo cholesterol synthesis by the cell. LDL and VLDL levels are increased due to the suppression of synthesis of new LDLR in the cells, activates the enzyme ACAT, free cholesterol into cholesteryl ester by cholesterol diet. The EEARL and AEARL of ARL: *A. racemosus* (Leaves), EECBL and AECBL of CBL: *C. borivilianum* (Leaves) and Rosuvastatin treatment significantly decrease the LDL and VLDL levels in the liver.

HDL is a key lipoprotein involved in reverse cholesterol transport and transfer of cholesterol esters between

**Table 3** Effect of extract of *A. racemosus* (Leaves) and *C. borivilianum* (Leaves) on serum lipid profile in hyperlipidemic-induced rats

| Group | Treatments | Serum cholesterol (mg/dL) | Triglycerides (mg/dL) | HDL-C (mg/dL) | LDL-C (mg/dL) | VLDL-C (mg/dL) |
|---|---|---|---|---|---|---|
| Group I | Normal control | 66.21 ± 0.32 | 58.11 ± 0.03 | 37.93 ± 0.21 | 17.86 ± 0.33 | 12.13 ± 0.02 |
| Group II | Positive control | 170.44 ± 0.21 | 144.2 ± 0.10 | 21.32 ± 0.11 | 117.50 ± 0.23 | 27.32 ± 0.41 |
| Group III | Standard | 110.45 ± 0.32** | 95.80 ± 0.21*** | 33.79 ± 0.11** | 48.49 ± 0.33*** | 18.70 ± 0.22*** |
| Group IV | Test I EEARL 250 mg/kg bw | 135.23 ± 0.32*** | 122.40 ± 0.31** | 28.61 ± 0.03** | 88.42 ± 0.02*** | 22.13 ± 0.32** |
| Group V | Test II EEARL 500 mg/kg bw | 134.62 ± 0.30** | 120.34 ± 0.02* | 27.40 ± 0.02*** | 87.34 ± 0.10* | 21.03 ± 0.34*** |
| Group VI | Test III AEARL 250 mg/kg bw | 133.45 ± 0.10*** | 119.68 ± .010*** | 29.32 ± 0.21** | 86.84 ± .042** | 21.02 ± 0.01** |
| Group VII | Test IV AEARL 500 mg/kg bw | 130.24 ± 0.01*** | 110.30 ± 0.03** | 30.34 ± 0.30** | 69.01 ± 0.21* | 21.00 ± 0.01* |
| Group VIII | Test V EECBL 250 mg/kg bw | 133.41 ± 0.32*** | 120.31 ± 0.01*** | 28.50 ± 0.02* | 87.42 ± 0.05** | 21.01 ± 0.02* |
| Group IX | Test VI EECBL 500 mg/kg bw | 130.24 ± 0.04** | 119.32 ± 0.06** | 29.42 ± 0.04* | 86.32 ± 0.06* | 21.02 ± 0.01* |
| Group X | Test VII AECBL 250 mg/kg bw | 126.04 ± 0.31** | 110.49 ± 0.21*** | 30.48 ± 0.61*** | 71.03 ± 0.64*** | 21.01 ± 0.01*** |
| Group XI | Test VIII AECBL 500 mg/kg bw | 122.40 ± 0.03** | 106.34 ± 0.01** | 31.20 ± 0.02*** | 69.34 ± 0.34*** | 20.09 ± 0.01*** |

All values are expressed as mean ± S.E.M ($n = 6$), Values are significant when compared with cholesterol group $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$ (one way ANOVA followed by Dunnett test)

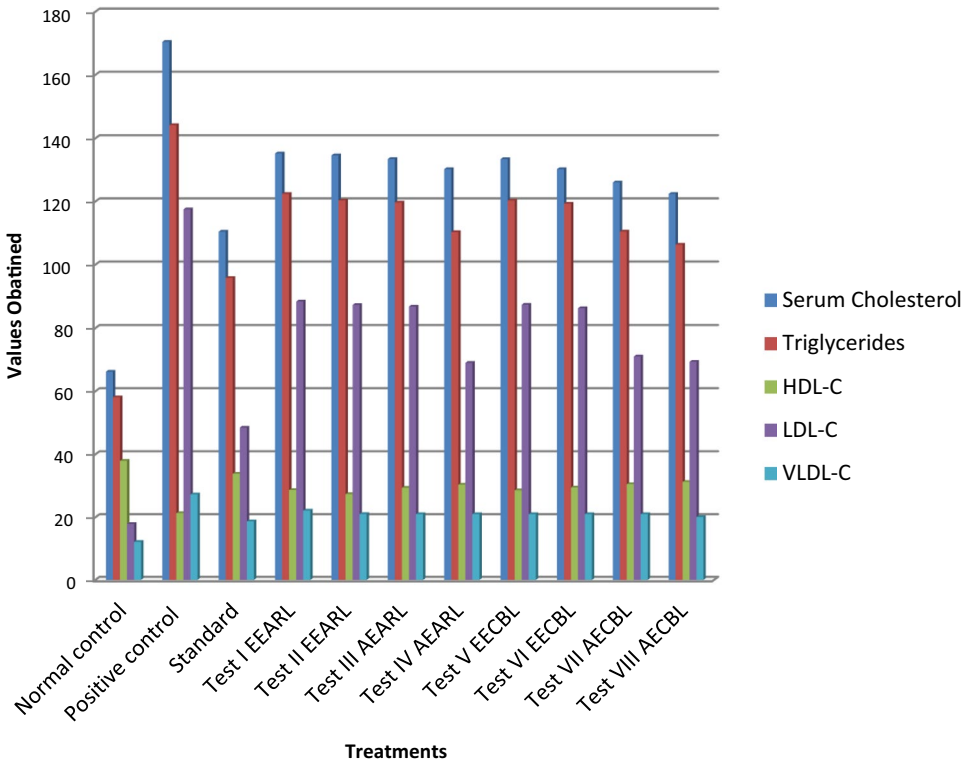



**Fig. 2** Effect of extract of *A. racemosus* (Leaves) and *C. borivilianum* (Leaves) on serum lipid profile in hyperlipidemic-induced rats

lipoproteins and secreted by the liver and intestine proceeds through a series of conversions known as the HDL cycle [22]. It attracts cholesterol from cell membranes and free cholesterol to the core of the HDL particle, inhibiting the oxidation of LDL and neutralizing the atherogenic effects of oxidizing LDL. The EEARL and AEARL of ARL: *A. racemosus* (Leaves), EECBL and AECBL of CBL: *C. borivilianum* (Leaves) and Rosuvastatin treatment significantly

**Table 4** Effect of extract of *A. racemosus* (Leaves) and *C. borivilianum* (Leaves) on serum lipid kidney biomarkers in hyperlipidemic-induced rats

| Group | Treatments | Urea (mg/dL) | Creatinine (mg/dL) | Uric acid (mg/dL) |
|---|---|---|---|---|
| Group I | Normal control | 17.1 ± 0.03 | 0.41 ± 0.10 | 2.11 ± 0.40 |
| Group II | Positive control | 18.2 ± 0.03 | 0.86 ± 0.11 | 4.82 ± 0.01 |
| Group III | Standard | 11.3 ± 0.03** | 0.42 ± 0.10*** | 1.27 ± 0.10*** |
| Group IV | Test I EEARL 250 mg/kg bw | 14.2 ± 0.30*** | 0.71 ± 0.01** | 1.78 ± 0.01*** |
| Group V | Test II EEARL 500 mg/kg bw | 13.9 ± 0.22** | 0.68 ± 0.11* | 1.75 ± 0.01*** |
| Group VI | Test III AEARL 250 mg/kg bw | 13.2 ± 0.01** | 0.66 ± 0.09*** | 1.71 ± 0.07*** |
| Group VII | Test IV AEARL 500 mg/kg bw | 13.1 ± 0.02*** | 0.65 ± 0.01*** | 1.69 ± 0.03*** |
| Group VIII | Test V EECBL 2500 mg/kg bw | 13.8 ± 0.06** | 0.64 ± 0.04* | 1.54 ± 0.04* |
| Group IX | Test VI EECBL 500 mg/kg bw | 13.5 ± 0.01** | 0.63 ± .01** | 1.48 ± 0.08*** |
| Group X | Test VII AECBL 250 mg/kg bw | 13.2 ± 0.64** | 0.62 ± 0.27** | 1.42 ± 0.34*** |
| Group XI | Test VIII AECBL 500 mg/kg bw | 12.9 ± 0.33* | 0.61 ± 0.31*** | 1.41 ± 0.37*** |

All values are expressed as mean ± S.E.M ($n = 6$), Values are significant when compared with cholesterol group *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$ (one way ANOVA followed by Dunnett test)

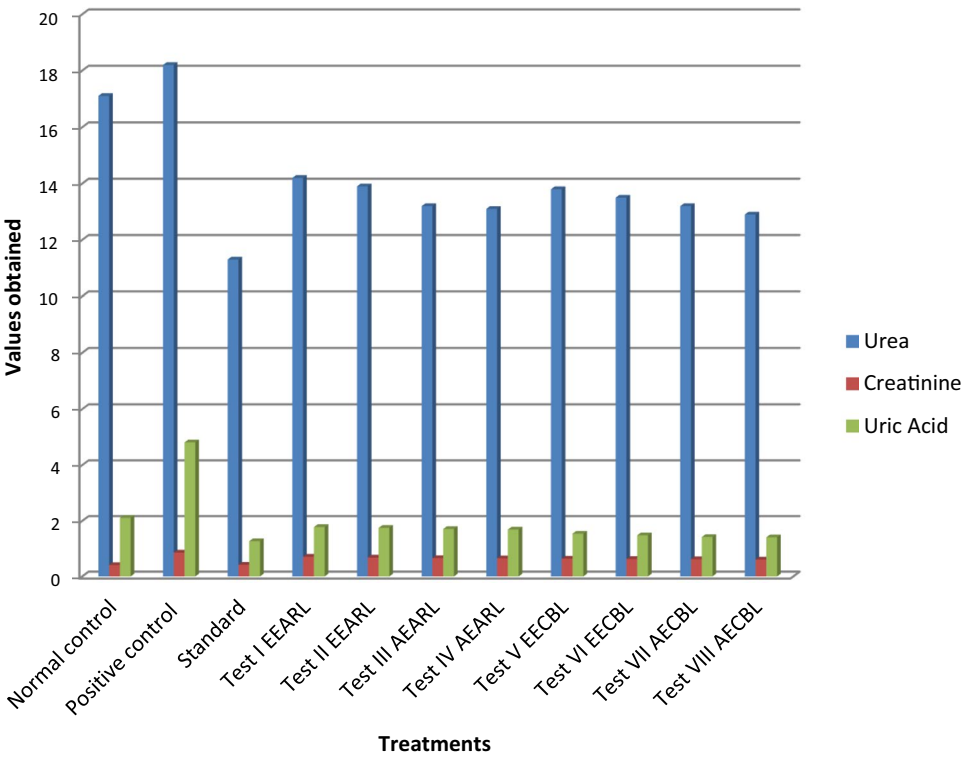



**Fig. 3** Effect of extract of *A. racemosus* (Leaves) and *C. borivilianum* (Leaves) on serum lipid kidney biomarkers in hyperlipidemic-induced rats

increase the HDL levels due to the synthesis of the liver by converting bile into bile acids and excreted through feces by decrease TC and TG levels. Flavonoids can increase HDL-C and also decrease oxidation of LDL- cholesterol. The results regarding serum lipid profile are given in Table 3 and Fig. 2.

Further hypercholesterolemia associated with oxidative modification of LDL, Protein glycation, glucose autooxidation leads to elevated oxidative stress [23]. The treatment with EEARL and AEARL of ARL: *A. racemosus* (Leaves), EECBL and AECBL of CBL: *C. borivilianum* (Leaves) and

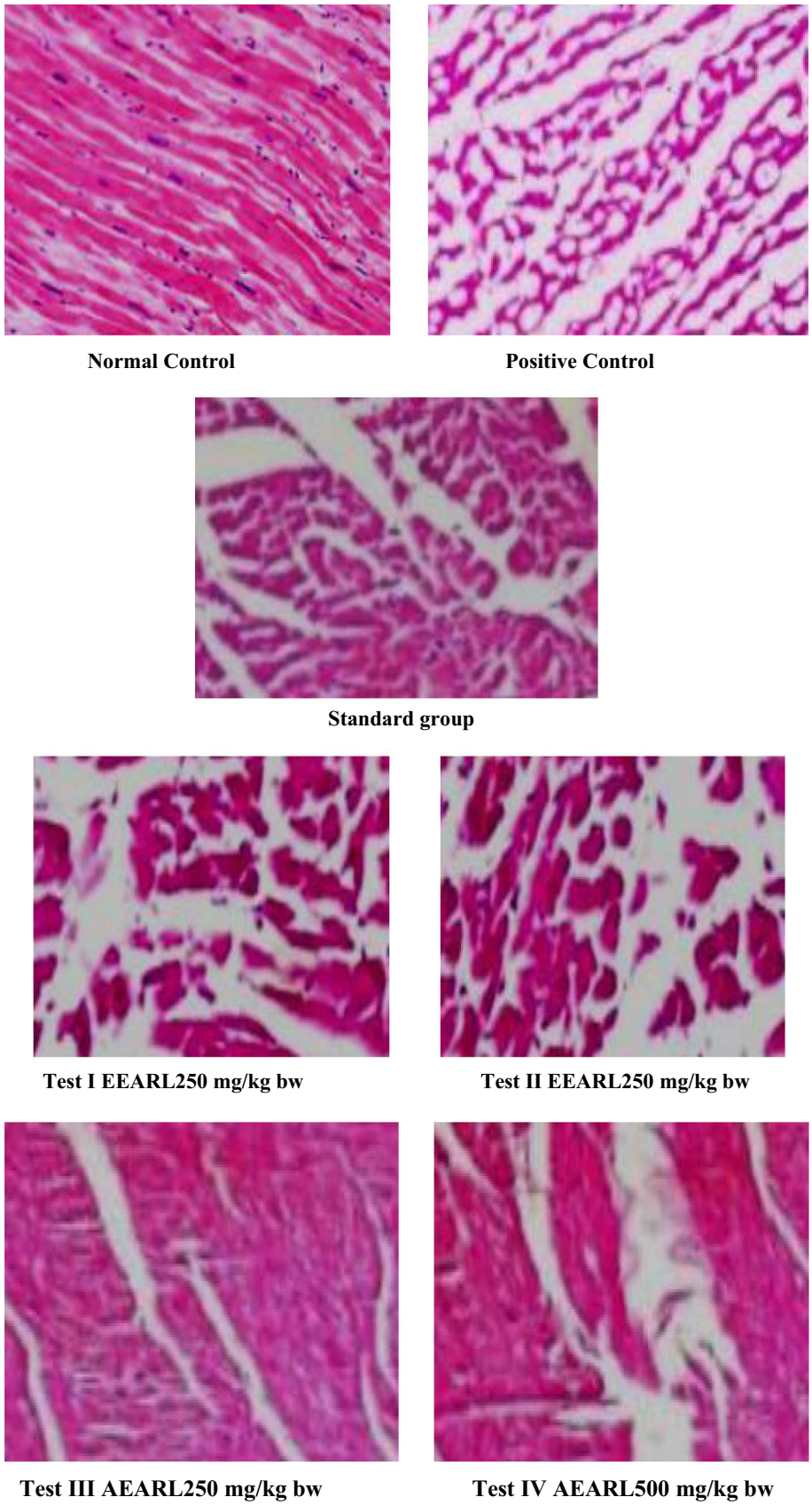
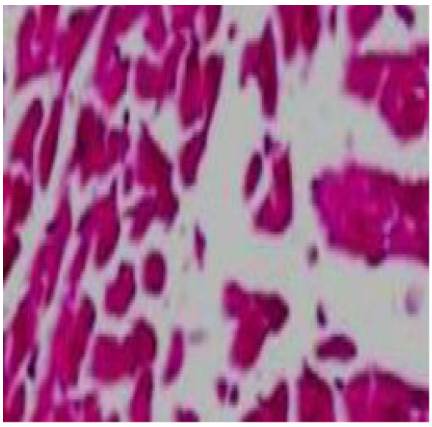


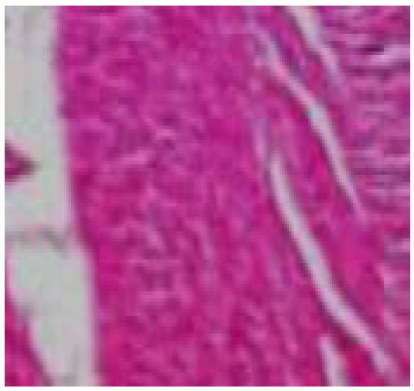

**Fig. 4** Histological studies of heart sections treated/induced with cholesterol

**Fig. 4** (continued)

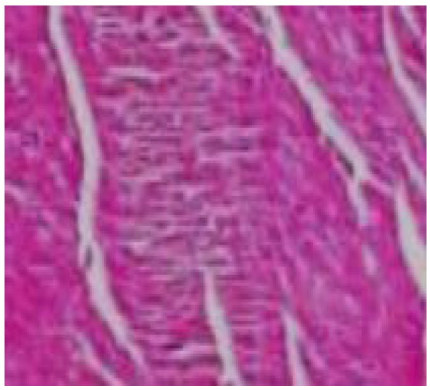


**Test V EECBL250 mg/kg bw**

**Test VI EECBL 500 mg/kg bw**



**Test VII AECBL 250 mg/kg bw**



**Test VIII AECBL 500 mg/kg bw**

Rosuvastatin significantly decrease the levels of urea, uric acid and creatinine when compare to hyperlipidemia group. The results regarding serum lipid kidney biomarkers are given in Table 4 and Fig. 3.

The declined levels of lipid peroxidation in EEARL and AEARL of ARL: *A. racemosus* (Leaves), EECBL and AECBL of CBL: *C. borivilianum* (Leaves) and rosuvastatin-treated rats contribute to the potential inhibitors of lipid peroxidation due to the presence of polyphenols like flavonoids, tannins and phenolics as they are reported to exhibit antioxidant properties.

The histological studies reveals that the heart sections treated/induced with cholesterol showed a marked fat cells in the heart which can increase the lipid peroxidation due to oxidative stress causing increase in the TC, TG, LDL, VLDL levels in positive group when compared to normal group result decreased levels of lipoproteins and showed the normal architecture of heart cells. Animals treated with Rosuvastatin showed a significant restoration of lipoproteins in the heart by maintaining ROS production, whereas group IV and IX animals treated with EECBL and AECBL of CBL: *C. borivilianum* (Leaves) and EEARL and AEARL of ARL: *A. racemosus* (Leaves) preserved the architecture of heart cells by reducing the free fatty acids exhibiting antihyperlipidemic activity. Naturally occurring flavonoids and saponins can reduce the excess production of LDL and VLDL levels and increase the HDL levels in the tissues [24]. The results of histopathological studies are presented in Fig. 4.

## Conclusion

Hyperlipidemia affects the body by giving various problems like ischemic heart disease, high blood pressure, arteries blockage, brain damage, etc., and in the market, there are several medicines for treating hyperlipidemia but these medicines have several adverse effects. So, this study may give a solution for hyperlipidemia with a new herbal formulation having no adverse effect with instant and proper treatment of hyperlipidemia [25, 26].

According to the WHO, about 80 percent of the population use herbal remedies as part of their standard of health care. Herbal plants have a global market value of about $ 0.6

billion per year and the Indian share is only 0.2%, which will grow to about 15% in the near future.

In the histological studies, animals were treated with Rosuvastatin showed effective restoration of lipoprotein in heart by maintaining ROS production while animals in group IV and IX were treated with EECBL and AECBL of CBL: *C. borivilianum* (Leaves) and EEARL and AEARL of ARL: *A. racemosus* (Leaves) maintain the formation of heart cells by decreasing free fatty acids that exhibit antihyperlipidemic activity. Natural flavonoids and saponins can decrease the high production of LDL and VLDL concentration and increase HDL levels in muscles.

Hence, these studies and investigations will also provide a pathway for other plants to be used as an important raw material for treating various diseases. This research will help in the development of eco-friendly, cost-effective, and economic techniques for controlling hyperlipidemia and related diseases [27, 28].

Hyperlipidemia affects the body by giving various problems like ischemic heart disease, heart attack, high blood pressure, arteries blockage, brain damage, etc., and in market there are number of medicines for treating hyperlipidemia but these medicines have several adverse effects. So, this study may give a solution for hyperlipidemia with a new herbal formulation having no adverse effect with instant and proper treatment of hyperlipidemia [29].

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**Declarations**

**Conflict of Interest** All authors declare no conflict of interest.

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