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Evaluation of Effectiveness of Hypolipidemic Activity of Ethanolic Extract of High Dose 400 mg kg^{-1} of Leaves of *Moringa concanensis* Nimmo in Guinea Pigs

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ABSTRACT

Hyperlipidaemia is an essential hazard aspect with inside the improvement of atherosclerosis and coronary heart disease. The significance of hyperlipidemia, particularly high levels of low-density lipoprotein cholesterol in the blood, has been recognized as a contributing factor to cardiovascular disease. Herbal products contain numerous active phytochemical compounds that have demonstrated their beneficial impact on cardiovascular disease through their ability to lower lipid levels. In India, the roots of *Moringa concanensis* are traditionally employed as a remedy for obesity and hyperlipidemia. To assess the hypolipidemic activity of high-doseethanolic extract of leaves of *Moringa concanensis* nimmoin guinea pigs. Eight groups of total 48 guinea pigs, of either gender, were created at random. Feeding cholesterol powder (500 mg kg^{-1}) for 60 days caused hyperlipidaemia. As an active control group, rosuvastatin 1.5 mg kg^{-1} was used. The LMC was administered at a dose of 400 mg kg^{-1} every day for 30 days to the preventative and curative groups, for durations of 0-30 days and 31-60 days, respectively. For 30 days, distilled water and a typical food were provided to the control group. By using serological and histological parameters, the ethanolic extract of LMC was evaluated for its therapeutic and preventative effects. The introduction of cholesterol led to increased lipid levels, liver enzyme levels and observable changes in the liver and thoracic aorta tissues. However, when compared to the group that did not receive any treatment, both the preventive and therapeutic administration of a 400 mg kg^{-1} ethanolic extract of LMC exhibited a significant reduction in lipid levels ($p<0.005$) and contributed to the restoration of the normal histological structure of the liver and thoracic aorta. Due to its antioxidant properties, the ethanolic extract of LMC at a dosage of 400 mg kg^{-1} demonstrates the ability to reduce lipid levels, making it a potential treatment and preventive measure for dyslipidemia.

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Key Words
Rosuvastatin, hypercholesterolemia, cholesterol, liver enzymes, *Moringa concanensis* nimmo

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INTRODUCTION

Cardiovascular diseases (CVDs), according to the World Health Organization (WHO), encompass a range of conditions affecting the heart and blood vessels, such as coronary heart disease, cerebrovascular disease, peripheral arterial disease, rheumatic heart disease, congenital heart disease, deep vein thrombosis and pulmonary embolism. In 2016, it is estimated that CVDs were responsible for the deaths of approximately 17.9 million individuals, accounting for 31% of all global fatalities. Among these deaths, 85% were attributed to heart attacks and strokes. It is projected that the number of individuals succumbing to CVDs, particularly heart disease and stroke, will rise to approximately 23.3 million by the year 2030. The first-choice modern medication for increased LDL cholesterol is not without adverse effects, especially when used for extended periods of time. They have negative psychological consequences including sadness, memory loss and disorientation, as well as negative physical symptoms like myopathy, gastrointestinal disruption and rashes[1]. There is a need to investigate the potential of introducing efficient, secure and affordable alternatives because none of the already existing agents meet the requirements of the desired medicine. According to Hollman and Katan[2] phenolic compounds, which are abundant in plant-derived foods and drinks, have anti-cancer, anti-cardiovascular disease and anti-aging characteristics[2]. LDL oxidation, (also known as oxLDL), is thought to be a major contributor to the development of atherosclerosis and CVD[3]. Studies conducted in vivo on both humans and animals have revealed that LDL oxidation levels decrease linearly as phenolic content rises[4-6]. Therefore, attention is focused on plant-based natural compounds with anti-atherosclerotic properties that can improve human health. This can eventually prevent potential health consequences brought on by the long-term use of statins.

Herbal products offer a potentially safe approach for reducing excess calories[7]. In India, the roots of *Moringa concanensis* have been traditionally used as a folk remedy for addressing obesity and hyperlipidaemia. While studies have been conducted on the anti-inflammatory, analgesic and antimicrobial effects of *Moringa concanensis*, research regarding the hypolipidemic action of its leaves is lacking. Based on this premise, our study aims to assess the hypolipidemic activity of a high dose of *Moringa concanensis* Nimmo leaves in guinea pigs.

MATERIALS AND METHODS

The research took place at the Animal room within the Department of Pharmacology at the Government Medical College in Bhavnagar, Gujarat. The study was conducted after receiving approval (IAEC No. 49b/2016) from the Institutional Animal Ethics Committee of the same institute. The animal experiments adhered to the guidelines set forth by the Committee for the Purpose of Control and Supervision of Experiments on Animals (CPCSEA). Guinea pigs were housed in stainless-steel cages and given a 15 day period of acclimatization before the start of the experiment. Throughout the study, the experimental animals were maintained under standard conditions of light, temperature and humidity (specifically, 24±2°C, 12 hr light/dark cycle). They had access to standard laboratory feed and water ad libitum throughout the duration of the experiments.

Animal groups:

- A total of 48 guinea pigs, categorized as healthy adults weighing between 400 and 800 g, regardless of their gender, were included in the study. Each animal underwent weighing and determination of its sex. Once the animals were selected, they were placed in the animal room at the Department of Pharmacology, Government Medical College, Bhavnagar, Gujarat, for a period of 15 days to adapt to the new environment. Following the acclimatization period, the guinea pigs were divided into six groups using the following criteria
- **Group 1 (control-normal diet):** Guinea pigs in this group were given a mixture of cereals and pulses weighing a total of 50 g per animal in the morning, along with 30 g of green leafy vegetables in the evening. They were provided with distilled water for a duration of 60 days
- **Group 2 (high-fat diet):** Guinea pigs in this group were given a high-fat diet consisting of cholesterol powder (500 mg kg^{-1}) mixed with wheat and green gram flour. The animals received 40 g of this high-fat mixture in the morning, along with 30 g of green leafy vegetables in the evening. The feeding continued for 60 days
- **group 3 (extract control):** Guinea pigs in this group received a normal diet for 60 days and starting from day 31, they were also administered 200 mg kg^{-1} of ethanolic extract of *Moringa concanensis* Nimmo leaves
- **Group 4 (M.C.N. curative group):** Guinea pigs in this group were given a high-fat diet for 60 days and starting from day 31, they were administered 400 mg kg^{-1} of ethanolic extract of *Moringa concanensis* Nimmo leaves
- **group 5 (active control):** Guinea pigs in this group were given a high-fat diet for 60 days and starting from day 31, they received 1.5 mg kg^{-1} of Rosuvastatin

- **Group 6 (M.C.N. preventive group):** Guinea pigs in this group were given a high fat diet along with 400 mg kg^{-1} of ethanolic extract of *Moringa concanensis* Nimmo leaves for a duration of 30 days

Diet composition

Normal diet: In the morning, the animals were provided with a combination of cereals and pulses, consisting of 60% wheat, 35% Bengal gram and 15% peanuts, with a total weight of 50 g per animal. In the evening, they were given 30 g of green leafy vegetables each.

High fat diet: In the morning, a mixture of cholesterol powder (500 mg kg^{-1}) was combined with wheat and Bengal gram flour and then 40 g of this mixture was given to each animal as part of their normal diet. In the evening, the animals were provided with 30 g of green leafy vegetables per kilogram of their body weight. During the acclimatization period, all the animals were given a normal diet and had access to water freely.

Additionally, the animals in the high-fat diet groups (group 2, 4, 5 and 6) were also given flour made from a mixture of wheat and Bengal gram (70% wheat plus 30% Bengal gram, 10 g per animal) to help them adapt to the flour.

After fasting overnight, baseline blood samples were collected from the lateral saphenous vein in the hind paw of each animal. On day 30, another blood sample was taken. These blood samples were analyzed for liver function tests, serum lipid profiles and cardiac enzymes in our institute's Clinical Biochemistry Laboratory, which is accredited by the National Accreditation Board for Testing and Calibration Laboratories (NABL).

Following the baseline blood collection, the animals were divided into the groups mentioned above. The respective diets for each group were provided throughout the 60 day study period as previously described. During the last 30 days of the experiment, animals in group 1 received distilled water daily. Animals in groups 3, 4 and 6 were administered ethanolic extract of *Moringa concanensis* Nimmo leaves at a dose of 400 mg kg^{-1} (high dose) for 30 days. Animals in group 5 were given rosuvastatin calcium at a dose of 1.5 mg kg^{-1} for the last 30 days. The distilled water and all the drugs mentioned were administered orally through a gavages feeding tube every morning while the animals were in a fasting state to ensure maximum absorption.

At the end of the 60 day period, animals from all groups were sacrificed after blood collection from the saphenous vein while in an overnight fasting state. The collected blood samples were sent for analysis of liver function tests, serum lipid profiles and cardiac enzymes. The liver and thoracic aorta were obtained from each animal in the seven groups mentioned above for histopathological analysis. The analysis was conducted by a senior faculty member from the Pathology department of our institute, who was blinded to the experimental groups.

- **analysis of serum lipid profile:** The serum samples were examined to determine the levels of total cholesterol, HDL-C (high-density lipoprotein cholesterol), triglycerides, LDL-C (low-density lipoprotein cholesterol) and VLDL-C (very low-density lipoprotein cholesterol)
- **assessment of liver and cardiac injury:** The serum levels of alanine aminotransferase (ALT), aspartate aminotransferase (AST) and alkaline phosphatase (ALP) were analyzed to evaluate any potential liver dysfunction. Additionally, the serum level of lactate dehydrogenase (LDH) was measured as an indicator of cardiac function
- **Weighing of the animals:** The weight of each animal was recorded both before and after the study to assess any potential impact of the ethanolic extract of *Moringa concanensis* Nimmo leaves on the animals' weight

Statistical analysis: The results of all parameters were presented as Mean±SEM. To compare the differences between groups in terms of lipid profile, liver enzymes, cardiac enzymes and body weight gain at the end of the 60 day period, a one-way Analysis of Variance (ANOVA) followed by Tukey-Kramer Multiple comparison test was conducted. Within each group of animals, the mean differences in lipid profile, liver enzymes, cardiac enzymes and body weight gain at the end of the 60 days were analyzed using a paired t-test. A significance level of $p<0.05$ was considered statistically significant. The statistical calculations were performed using Graph Pad InStat, Demo version 3.06.

RESULTS

Effect of *Moringa concanensis* nimmo on serum lipid profile: The serum lipid profile values at 0, 30 and 60 days for each diet treatment group are presented in Table 1. In the group that received a high-fat diet, there was a significant increase in serum total cholesterol, triglyceride, LDL-C and VLDL-C levels ($p<0.05$) at 30 and 60 days compared to 0 days. However, there were no significant changes in serum HDL-C levels in the disease control group (Table 1). In the high-dose treatment group, there was a significant restoration of serum total cholesterol, triglyceride, LDL-C and VLDL-C levels ($p<0.05$). Although, serum HDL-C levels were also restored, the increase did not reach statistical significance compared to the disease

Table 1: The lipid parameters were compared within the groups at 0 day versus 30 day, as well as at 30 day versus 60 day. Additionally, the lipid parameters were compared between the study groups at the 60 day mark

Groups	Time period day	Total cholesterol (mg dL^{-1})	Triglycerides (mg dL^{-1})	HDL cholesterol (mg dL^{-1})	LDL cholesterol (mg dL^{-1})	VLDL cholesterol (mg dL^{-1})
Group 1	0	46.60±2.99	55.87±3.74	4.50±0.46	22.87±1.47	18.42±0.95
	30	46.30±3.00	56.50±3.68	4.50±0.53	22.50±1.45	18.77±1.00
	60	45.80±2.95	57.00±3.73	4.37±0.32	22.62±1.58	18.45±0.94
Group 2	0	41.27±2.09	58.00±3.49	4.87±0.61	22.62±1.58	17.23±0.84
	30	58.70±0.89*	67.00±4.07*	4.50±0.56	43.00±1.87*	24.13±0.94*
	60	85.20±2.85$^{\#}$	80.37±3.59$^{\#}$	5.12±0.54	61.37±1.55$^{\#}$	27.63±0.92$^{\#}$
Group 3	0	39.09±1.61	59.00±1.29	5.12±0.44	22.12±1.39	21.28±1.30
	30	39.67±1.62	58.87±1.30	4.75±0.36	21.50±1.58	20.71±1.34
	60	39.35±1.55	57.87±1.18	5.12±0.47	20.87±1.48	20.38±1.37
Group 4	0	41.45±1.52	54.00±2.50	5.87±0.35	23.12±1.68	18.28±0.82
	30	55.96±1.49*	66.62±2.00*	6.12±0.39	49.75±2.55*	24.65±1.33*
	60	50.01±1.75$^{\#\$}$	61.25±2.59$^{\#\$}$	6.87±0.51	45.25±3.15$^{\#\$}$	23.33±1.28$^{\#\$}$
Group 5	0	39.63±1.71	55.00±1.72	4.37±0.49	26.12±1.67	17.21±0.30
	30	57.55±1.09*	68.12±1.68*	5.37±0.62*	51.87±3.13*	22.53±0.66*
	60	43.00±1.06$^{\#\$}$	60.00±1.73$^{\#\$}$	7.37±0.62$^{\#\$}$	43.50±2.73$^{\#\$}$	18.02±0.34$^{\#\$}$
Group 6	0	38.45±1.56	56.62±1.95	5.25±0.49	25.75±1.75	18.60±0.94
	30	35.85±1.71*$^{\$}$	53.75±2.20*$^{\$}$	5.75±0.41	24.5±1.65*$^{\$}$	16.41±1.12*$^{\$}$

Table 2: The liver enzyme parameters were compared within the groups at 0 day versus 30 day, as well as at 30 day versus 60 day. Additionally, the liver enzyme parameters were compared between the study groups at the 60-day mark

Groups	Time period days	AST (U L^{-1})	ALP (U L^{-1})	LDH (U L^{-1})	ALT (U L^{-1})
Group 1	0	60.00±6.19	86.87±4.02	86.25±2.81	53.25±1.98
	30	61.37±6.27	86.88±4.12	86.75±2.61	53.87±2.31
	60	61.00±6.21	86.89±3.92	87.25±2.58	54.25±2.28
Group 2	0	59.37±4.41	86.37±5.15	90.00±3.74	56.12±2.19
	30	97.37±3.19*	125.62±1.97*	134.00±2.43*	92.37±2.83*
	60	124.80±2.76$^{\#}$	150.12±4.81$^{\#}$	159.00±2.40$^{\#}$	110.00±3.52$^{\#}$
Group 3	0	57.50±3.30	89.25±6.13	89.25±3.70	55.25±1.55
	30	57.00±2.24	88.87±6.50	88.00±3.80	56.00±1.72
	60	58.75±3.07	89.12±6.26	88.87±3.60	55.37±1.47
Group 4	0	60.75±4.04	89.75±4.39	94.62±3.91	54.87±2.59
	30	97.23±3.02*	131.12±1.71*	131.12±4.61*	90.12±2.25*
	60	94.87±3.10$^{\#\$}$	128.75±1.69$^{\#\$}$	126.87±4.44$^{\#\$}$	85.250±1.93$^{\#\$}$
Group 5	0	57.70±4.28	86.85±5.70	91.62±4.50	56.37±2.84
	30	93.25±3.52*	133.12±3.38*	137.12±4.40	95.87±1.46
	60	79.25±3.32$^{\#\$}$	107.00±2.65$^{\#\$}$	121.12±3.19$^{\#\$}$	79.81±1.73$^{\#\$}$
Group 6	0	58.00±3.46	84.12±5.84	89.25±3.16	53.75±2.76
	30	56.12±3.46*$^{\$}$	80.12±6.14*$^{\$}$	86.5±3.31*$^{\$}$	52.62±2.85$^{\$}$

control group at 60 days (Table 1). In the preventive high-dose group, there was a significant decrease in serum total cholesterol, triglyceride, LDL-C and VLDL-C levels but there was no statistically significant increase in HDL-C levels compared to the disease control group at 30 days (Table 1). The active control group exhibited a significant restoration in serum total cholesterol, triglyceride, LDL-C and VLDL-C levels ($p<0.05$) but the increase in serum HDL-C levels did not reach statistical significance ($p<0.05$) compared to the disease control group at 60 days (Table 1).

Effect of *Moringa concanensis* Nimmo on Liver Enzymes: There was a significant increase in AST, ALP, LDH and ALT levels ($p<0.05$) in the disease control group at 60 days compared to 30 days (Table 2). In the high-dose treatment group, there was a significant restoration of AST, ALP, LDH and ALT levels ($p<0.05$) compared to the disease control group at 60 days (Table 2). In the preventive high-dose group, the levels of AST, ALP and LDH ($p<0.05$) were significantly decreased but the level of ALT was not significantly decreased compared to the disease control group at 30 days (Table 2). The active control group showed a significant restoration in AST, ALP, LDH and ALT levels ($p<0.05$) compared to the disease control group at 60 days (Table 2).

Table 3: Comparison of body weight of guneapigs at 0 day vs 30 days vs 60days

Groups	Weight of animal (g) 0 day	30 day	60 day
Group 1	565.3±12.26	566.5±10.39	568.50±18.38
Group 2	680.0±14.56	693.0±18.57	702.00±12.06
Group 3	684.0±16.78	680.0±18.23	692.50±18.04
Group 4	660.4±17.28	661.3±17.13	661.80±17.18
Group 5	563.7±20.26	580.3±20.08	588.87±19.44
Group 6	663.3±24.70	663.3±24.70	--

Effect of *Moringa concanensis* nimmo on weight: The increase in mean body weight of all groups at the end of the 60 day period is presented in Table 3. However, the extent of weight gain did not show statistically significant differences among the groups.

Effect of *Moringa concanensis* Nimmo on liver enzymes-histopathological studies: In the disease control group, liver histopathological examination showed diffuse areas of ballooning degeneration, as well as varying degrees of macrovascular and microvascular fat deposition in hepatocytes (grade 3+, 4+). Fatty changes were observed in the mid zone and

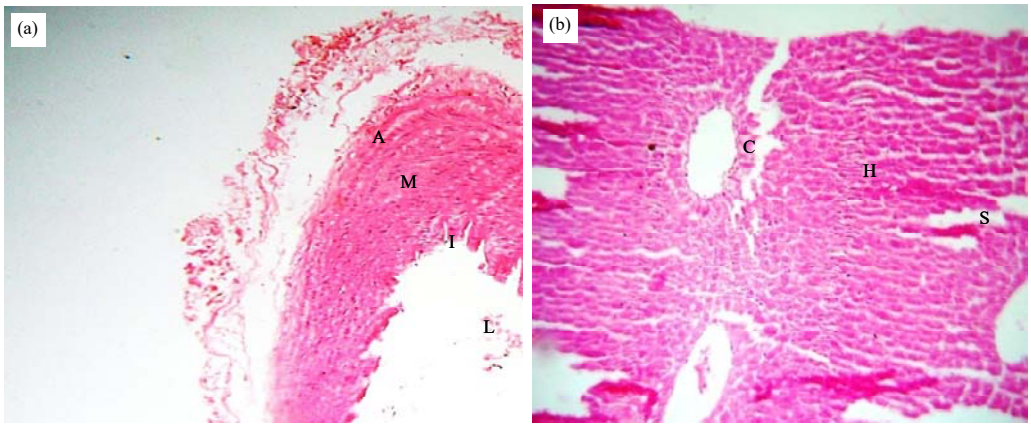

Fig. 1(a-b): Histopathology figure, Group 1: Normal diet group (a) Guinea pig normal liver; S: Sinusoid, H: Hepatocyte and C: Central vein and (b) Guinea pig normal liver; S: Sinusoid, H: Hepatocyte and C: Central vein

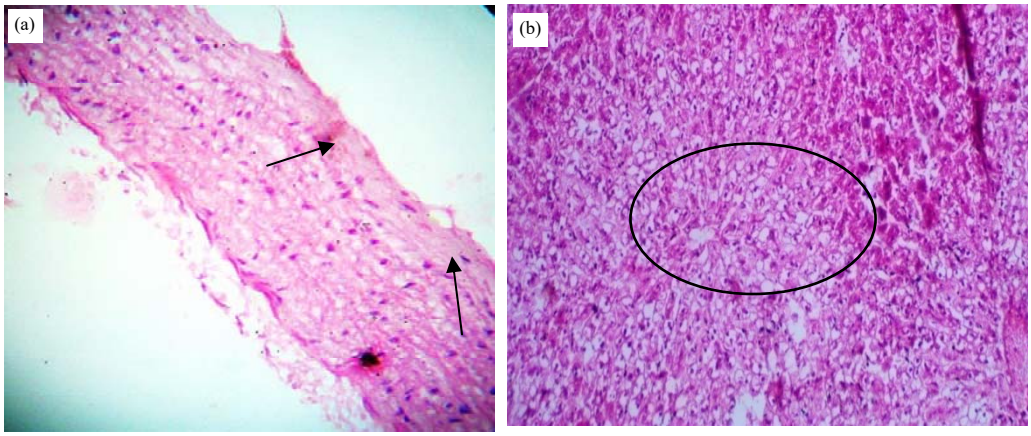

Fig. 2(a-b): Group 2: High-fat diet group, (a) Guinea pig aorta: Black arrows demonstrate foamy changes in intima and media (grade 3+) and (b) Guinea pig liver: Circle demonstrates diffuse areas of ballooning degeneration (grade 4+)

Table 4: The histopathological grading of the liver and aorta was compared between the study groups at the end of the experiment

	Liver		Aorta
Study group	Macrovascular or microvascular fat disposition grade	Degeneration grade	Fat deposition in the aorta
Group 1 (normal control)	0	0	0
Group 2 (disease control)	4.06±0.26$^{\$}$	3.37±0.18$^{\$}$	3.25±0.16$^{\$}$
Group 3 (extract control)	0	0	0
Group 4 (treatment high dose)	1.37±0.26*	1.37±0.26*	1.37±0.26*
Group 5 (active control)	0.25±0.16*	0.75±0.25*	0.50±0.18*
Group 6 (preventive high dose)	1.28±0.18*	1.28±0.18*	1.28±0.18*

periportal regions, along with congestion of the central vein and hepatic sinusoids in all animals. Histological examination of the aorta revealed focal areas of foamy changes in the tunica media and tunica intima, of varying degrees (grade 2+, 3+), compared to the normal control group. In the active control group, the *Moringa concanensis* Nimmo treatment group and the *Moringa concanensis* Nimmo preventive group, there was a restoration of macrovascular and microvascular fat deposition in the liver, as well as focal areas of foamy changes in the aorta, compared to the disease control group (Fig. 1-5).

The data are presented as Mean±SEM. Statistical significance was indicated by *p<0.05 for intra-group comparison between 0 and 30 days using paired t-test, $^{\#}$p<0.05 for intra-group comparison between 30 and 60 days using paired t-test and $^{\$}$p< 0.05 for inter-group comparison (compared to the disease control group)

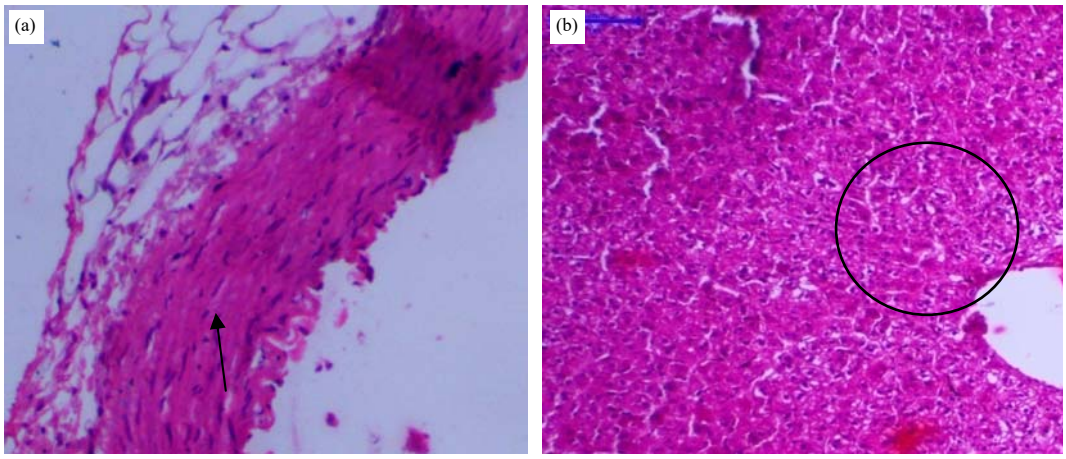

Fig. 3(a-b): Group 4 Treatment high dose group
Guinea pig aorta: Black arrows demonstratefoamy changes in intima and media (Grade 1+), Guinea pig liver: Black round demonstrateno fatty changes seen only degeneration (grade 1+) with repaired and regeneration process

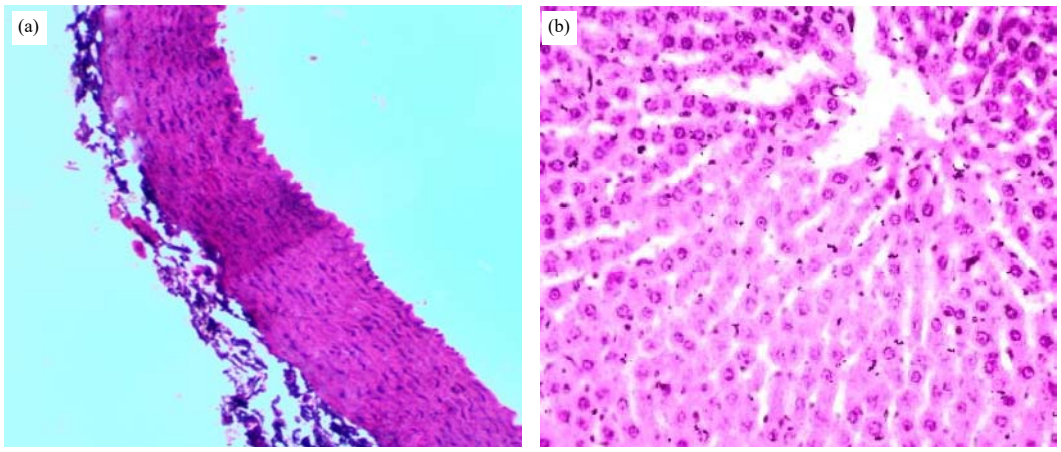

Fig. 4(a-b): Group (5) Active control group, (a) Guinea pig aorta: No histological changes seen and (b) Guinea pig liver: No histological changes seen

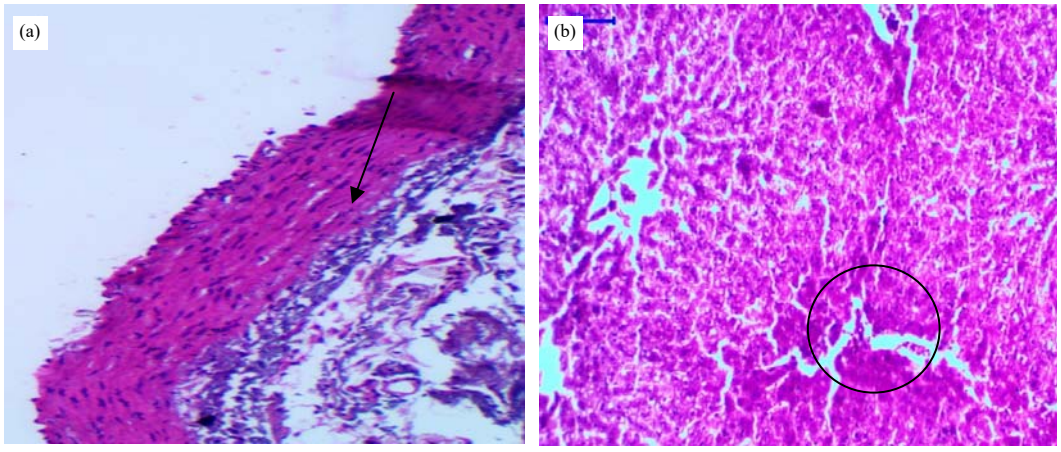

Fig. 5(a-b): Group (6) Preventive High dose, (a) Guinea pig Aorta: Black arrow demonstratefoamy changes in intima and media (grade 1+) and (b) Guinea pig liver: Black round demonstrateno fatty changes seen only degeneration (grade 1+) with repaired and regeneration process

using ANOVA followed by Tukey-Kramer Multiple comparison test. LDL refers to low-density lipoprotein, VLDL refers to very low-density lipoprotein and HDL refers to high-density lipoprotein.

The data are presented as Mean±SEM. Statistical significance was indicated by *p<0.05 for intra-group comparison between 0 and 30 days using paired t-test, #p<0.05 for intra-group comparison between 30 and 60 days using paired t-test and $p<0.05 for inter-group comparison using ANOVA followed by Tukey-Kramer Multiple comparison test. ALT represents Alanine aminotransferase, AST represents Aspartate aminotransferase, ALP represents Alkaline phosphatase and LDH represents Lactate dehydrogenase.

The data are presented as Mean±SEM. Paired t-tests were used to compare within-group differences between 0 and 30 days, as well as between 30 and 60 days. However, no statistically significant differences were observed.

The data are presented as Mean±SEM. Statistical significance was indicated by $p<0.05 compared to the normal control group and p<0.05 compared to the disease control group using the Kruskal-Wallis test followed by Dunn's multiple comparison test

DISCUSSIONS

In addition to potential cost savings, we chose guinea pigs as our diet-induced atherosclerosis model because they may be a more accurate representation of human atherosclerosis than rabbits. Guinea pigs have a lipid metabolism that is most comparable to human metabolism physiologically[8]. In addition to the results obtained from the current study, it was observed that the administration of a high-fat diet for 60 days resulted in increased serum lipid levels. Furthermore, histopathological analysis revealed the presence of middle zone degeneration and peripheral diffuse ballooning in the liver, along with lipid-related changes such as fatty deposits and hepatocellular degeneration. Similar changes were also observed in the aorta (Fig. 2a-b). This rise and the modifications to the liver's and aorta's histology were in line with other experimental investigations using high-fat diets[9,10]. Our choice of a sixty-day study period was long enough to cause lipid alterations in guinea pigs, which is supported by earlier research[11].

Numerous preclinical, clinical and epidemiological studies have demonstrated a strong association between high plasma cholesterol levels and an increased risk of developing coronary heart disease. Sedentary lifestyle has been identified as the primary contributor to the development of atherosclerosis, a lipid disorder that affects the major arteries, according to the findings of Pande *et al*.[12] and Chiuve *et al*.[13]. Additional significant factors contributing to atherosclerosis include diabetes, hypertension, smoking, glucocorticoids, dietary habits and psychological factors.

LDL-C oxidation caused foam cells and fatty streaks to develop in the arteries, which is a sign of early atherosclerosis[14]. According to several research, reducing total and LDL cholesterol levels is related with a reduction in the incidence and severity of CVD[15]. In order to address hyperlipidaemia, medications with free radical scavenging and serum cholesterol lowering activities would be sought. Despite extensive intervention, patients with hypercholesterolemia could not be adequately treated due to modern lifestyle. As a result of being a secure and affordable option, herbal medications have gained attention for the treatment of hyperlipidaemia[10].

In this study, the administration of ethanolic extract of *Moringa concanensis* Nimmo leaves at a dose of 400 mg kg^{-1} in guinea pigs resulted in the restoration of serum total cholesterol, serum triglyceride, LDL-C and VLDL-C levels in the treatment group compared to the disease control group at 60 days. Additionally, there was a decrease in serum total cholesterol, triglyceride, LDL-C and VLDL-C levels compared to the disease control group at 30 days (Fig. 1-5). High cholesterol levels pose a risk to vital organs such as the liver and heart. It has been observed that a high-fat diet significantly increases lipid accumulation in the liver, leading to hepatic steatosis and impaired liver function[10]. In our study, the disease control group exhibited elevated levels of AST, ALT, LDH and ALP compared to the normal control group, indicating compromised liver function. However, treatment with ethanolic extract of *Moringa concanensis* Nimmo leaves (400 mg kg^{-1}) significantly reduced the levels of these liver enzymes compared to the high-fat diet group (Table 2). Histological analysis of the liver revealed improved hepatocyte health and reduced lipid content in animals that received both the high-fat diet and the ethanolic extract of *Moringa concanensis* Nimmo leaves (Table 1). Medicinal plants containing ethanol have the ability to scavenge lipid peroxyl radicals, superoxide anion radicals and hydroxyl radicals[16]. The ethanolic extract of *Moringa concanensis* Nimmo leaves used in our study contained phytochemicals and flavonoids. Additionally, plant saponins, which exhibit detergent properties and facilitate intracellular histochemistry labeling, were present in the extract[16]. These saponins have been

utilized in medicine for various conditions, including hyperglycemia, antioxidant effects, anti-cancer properties, anti-inflammatory effects and weight reduction[16].

Previous studies have demonstrated that administering rosuvastatin at a dosage of 1.5 mg kg^{-1} to the high-fat diet group on a daily basis for 30 days can prevent an increase in blood levels of total cholesterol, triglycerides, LDL-C and VLDL-C, as well as fatty liver alterations caused by a high-fat diet. Moreover, it increases HDL-C levels. By the end of the 60-day period, the high-fat diet group receiving rosuvastatin exhibited higher AST and ALP levels compared to baseline, which aligns with previous findings. Thus, the protective effect of *Moringa concanensis* Nimmo leaf extract at a dose of 400 mg kg^{-1} against elevated lipid parameters was comparable to that of rosuvastatin at a dose of 1.5 mg kg^{-1}. It is worth noting that LDL-C is the primary target for treatment in clinical lipid management. Consequently, the significant decrease in LDL-C and the ratio of total cholesterol to HDL-C at the higher dose of 400 mg kg^{-1} of *Moringa concanensis* Nimmo leaf extract is an important finding of our study.

Thus, the ethanolic extract of *Moringa concanensis* Nimmo leaves shown considerable lipid lowering and antioxidant effects in the current investigation, which may be a result of their flavonoid and saponin components. Our study's limitations stemmed from the fact that we were unaware of the many mechanisms and ethanolic chemicals responsible for lipid-lowering effects.

CONCLUSION

Compared to the disease control group, both the treatment and preventive administration of 400 mg kg^{-1} ethanolic extract of *Moringa concanensis* Nimmo leaves exhibited significant reductions in lipid profile, liver enzyme parameters and histological changes in the liver and thoracic aorta. This result suggests that combining the use of *Moringa concanensis* Nimmo leaf extract with statin therapy, such as rosuvastatin, could potentially improve the management of hyperlipidemia and also mitigate the occurrence of cardiovascular disease in patients with metabolic syndrome.

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