J Food Sci Technol (March 2016) 53(3):1690–1697
DOI 10.1007/s13197-015-2096-5

ORIGINAL ARTICLE

Antihypercholesterolemic and antioxidant effect of sterol rich methanol extract of stem of *Musa sapientum* (banana) in cholesterol fed wistar rats

Piyush Dikshit[1] · **Mool Kumar Tyagi**[1] · **Kirtikar Shukla**[1] · **Jasvindar K. Gambhir**[1] · **Rimi Shukla**[1]

Accepted: 3 November 2015 / Published online: 12 November 2015
© Association of Food Scientists & Technologists (India) 2015

Abstract *Musa sapientum* Linn. (English 'Banana' family Musaceae), is a plant with nutritive, as well as medicinal value. Antihypercholesterolemic and antioxidant effect of methanolic extract of stem of this plant was investigated in hypercholesterolemic rats. Rats were made hypercholesterolemic by feeding cholesterol (100 mg/kg/day) suspended in soya oil. Treatment groups received extract at a dose of 10, 20 and 40 mg/kg/day in addition to cholesterol orally once daily. Fasting blood samples were collected before and after 6 weeks treatment. Animals were sacrificed and liver stored at -80 °C. Total cholesterol, HDL-cholesterol and triacylglycerol were estimated in blood. Malondialdehyde, reduced glutathione, superoxide dismutase and catalase were measured in blood and liver. Total lipids, HMG CoA redutase and lipoprotein lipase were investigated in liver. Most effective dose was found to be 20 mg/kg/day. Rise in total cholesterol, LDL + VLDL-cholesterol and triacylglycerol in animals receiving only cholesterol was 179 %, 417 % and 74 % respectively, while in animals receiving 20 mg/kg dose rise in these parameters was restricted to 40 %, 106 % and 24 %. HDL-cholesterol decreased by 12 % in extract treated group, while it decreased to 36 % in untreated hypercholesterolemic rats. Malonaldialdehyde, marker of lipid peroxidation decreased while reduced glutathione and enzymes superoxide dismutase and catalase increased significantly in blood and liver ($p < 0.01$). Total lipids in liver decreased and enzymes of lipid metabolism viz. HMG CoA redutase and lipoprotein lipase were restored to near normal. Gas chromatography mass spectroscopy indicated high content of sterols in extract. Study demonstrated that methanol extract of stem of *Musa sapientum* has significant antihypercholesterolemic and antioxidant effects.

Keywords *Musa sapientum* (Msmt) · Antihypercholesterolemic · Antioxidant · Sterol · Lipoprotein lipase · Gas chromatography mass spectroscopy

Research highlights • *Musa sapientum* (English 'Banana), is a plant with nutritive, as well as medicinal value.
• Effects of methanolic extract of stem of this plant were evaluated in cholesterol fed rats.
• It was found to have significant antihypercholesterolemic and antioxidant effect.
• Extract contain phenolics, tannins, terpenoids and steroids.
• GC-MS studies indicated extract to be rich in sterols.

✉ Rimi Shukla
rimishukla@yahoo.com

[1] Department of Biochemistry, University College of Medical Sciences and GTB Hospital, University of Delhi, Delhi 110095, India

Introduction

Coronary artery disease (CAD) is one of the most important causes of death all over the world. Hypercholesterolemia contributes significantly in manifestation and developmemt of atherosclerosis and coronary artery disease (Yokozawa et al. 2003). Although several reasons such as diet rich in saturated fats, cholesterol age, family history, hypertension, life style etc. play a significant role in causing CAD, high levels of cholesterol particularly LDL-cholesterol is mainly responsible for the onset of CAD (Farias et al. 1996). Many plants decrease lipids including cholesterol in body as for example *Terminalia arjuna* (Combretaceae), *Ficus bangalensis* (Moraceae) (Gupta et al. 2001; Shukla et al. 2004) etc. *Musa sapientum* Linn. (Syn. *Musa paradisiaca* Linn.) is a herbaceous plant of Musaceae family. Different parts of this plant are in use for a wide array of human disorders. Banana fruit aids in combating diarrhea, dysentery and promotes

healing of the intestinal lesions in ulcerative colitis. Extract of the stem has antivenom activity. Fruit, inflorescence stalk, flower, root and pseudostem have antidiabetic effect (Satyavati et al. 1987; Gomathy et al. 1990; Bhaskar et al. 2011). Pectin from inflorescence stalk and fibers from banana fruit pulp have hypocholesterolemic effect in high fat diet fed animals (Gomathy et al. 1989). We have reported antidiabetic and hepatoprotective effect of central stem of *Musa sapientum* (Dikshit et al. 2012; Dikshit et al. 2011). The trunk or the pseudostem of the banana plant is not a true stem but rather a cluster of cylindrical aggregation of leaf stalk bases. The true stem begins as underground corm, which grows upward the pseudostem pushing its way through the center of the pseudostem 10 to 15 months after planting banana plant (Satyavati et al. 1987). This central part of stem is edible part of the plant and i.e. used as a food in India. It is in use for making curreys and chutneys in south India. Literature survey revealed that the central stem of banana is not being evaluated for antihypercholesterolemic and antioxidant effect. This study evaluates the antihypercholesterolemia and antioxidant effect of central stem of *Musa sapientum* in rats, made hypercholesterolemic by feeding cholesterol.

Materials and methods

Plant materials and preparation of methanol extract Stem of *Musa sapientum* Linn. was collected from the Ghaziabad, UP in January and mid February and authenticated by Dr. H. B. Singh, Scientist & Head, Raw material herbarium and Museum of the National Institute of Science Communication and Information Resources, New Delhi in the year 2008. (Voucher no.NISCAIR/RHMD/Consult/2007–08/895/79).

The upright concentric layers of leaf sheaths forming the pseudostem was peeled off from freshly cut stem of *Musa sapientum* to reveal the central pale white stem. Tiny cut pieces of this stem were mechanically crushed using a hand grinder and filtered through a sterile muslin cloth to get the juice of stem. Lyophilized stem juice was exhaustively extracted for 12 h at 40 °C with methanol using soxhelet apparatus and filtered through Whatman No.1 filter paper and dried using vacuum evaporator. The dark brown colored extract so obtained is methanol extract of *Musa sapientum* and further referred as 'Msmt' (Yield 1 %).

Animals Male Wistar rats weighing 150–200 g were housed in an air-conditioned room at temperature of 25 ± 3 °C with relative humidity 55 ± 5 units. Standard light and dark cycles were maintained through out the experimental period. Animals were fed with a standard laboratory diet and water ad libitum. Ethical clearance was obtained from Institutional Animal Ethics Committee of Animal Research (IAEC-AR) at University College of Medical Sciences and GTB Hospital, Delhi. (UCMS/IAEC/16–17/30th December 2009). Experiments were carried out as per the guidelines of the committee.

Chemicals Technical grade cholesterol powder (purity 99.4 %) was obtained from Sigma Aldrich, India. All other reagents used were of analytical grade and obtained either from Sisco Research Laboratories or Qualigens Fine Chemicals, Mumbai, India.

Treatment regimes Animals were divided into six groups of six animals each and treated for 6 weeks as follows:

Group A - Healthy rats fed with saline (0.5 ml/kg).
Group B - Rats fed with vehicle soya oil (1.5 mg/kg).
Group C -Rats fed with cholesterol suspended in soya oil (100 mg/kg). (Hypercholesterolemic control group)
Group D -Rats fed with cholesterol suspended in soya oil (100 mg/kg) + Msmt (10 mg/kg).
Group E–Rats fed with cholesterol powder suspended in soya oil (100 mg/kg) + Msmt (20 mg/kg).
Group F–Rats fed with cholesterol powder suspended in soya oil (100 mg/kg) + Msmt (40 mg/kg).

Cholesterol suspended in soya oil or Msmt in gumacacia (2 %) were given orally once daily by Orogastric intubation. Method for inducing hypercholesterolemia in animals is already standardrized in our laboratory (Shukla et al. 2004).

Collection of blood samples and tissues After 6 weeks of treatment blood samples of the overnight fasted rats were collected from retro-orbital eye plexus (Sorg and Buckner 1964) in plain vials for estimating lipid profile, malondialdehyde (MDA) and EDTA vials for estimating superoxide dismutase (SOD), reduced glutathione (GSH) and catalase (CAT) and in heparinized vials for estimating LPL.

Overnight fasted rats were anaesthetized with pentobarbital (50 mg/kg i.p.) and sacrificed by cervical dislocation (Johansen et al. 1994). Liver tissue taken out washed with cold saline and stored at-20 °C for estimating malondialdehyde (MDA), superoxide dismutase (SOD), reduced glutathione (GSH) and catalase (CAT) and HMG CoA reductase and lipoprotein lipase enzymes.

Serum lipid profile estimation and atherogenic index Total cholesterol (TC), high density lipoprotein-cholesterol (HDL-C) and triacylglycerol (TAG) were estimated in the fasting serum using kits from Accurex Biomedical Pvt. Ltd., Mumbai, India. Value of low density lipoprotein cholesterol (LDL-C) + very low density lipoprotein cholesterol (VLDL-C) was obtained by substracting value of HDL-C from TC. The atherogenic index, which is the measure of the extent of atherosclerotic lesions based on serum lipids was determined in all the

groups. It was calculated ratio of LDL-C + VLDL-C to HDL-C (Gupta et al. 2006).

Antioxidant parameters in blood Plasma MDA contents were estimated as thiobarbituric acid reactive substances in plasma (Satoh 1978). Reduced glutathione (GSH) content were assayed in erythrocytes (Beutler et al. 1963). The activity of Superoxide dismutase (SOD) in erythrocytes was determined method of as modified by (Nandi and Chatterjee 1988). This method is based on the inhibition of pyragallol autooxidation in the presence of SOD. Catalase (CAT) was assayed in red blood cells (Sinha 1972).

Antioxidant parameters in tissue A 10 % homogenate of liver tissues was prepared in ice-cold phosphate buffer (50 mM, pH 7.4). Malondialdehyde was estimated by the method of Wills (Wills 1966). The reduced glutathione (GSH) content was measured by the method described by (Ellman 1959). Catalase (CAT) activity was measured according to the method of Aebi 1984. One unit of CAT was defined as the amount of enzyme required to decompose 1 μmol of H_2O_2 in 1 min. HMG-CoA Reductase was estimated by the method of (Rao and Ramakrishnan 1975). HMG-Co and mevalonate levels in liver homogenate were estimated colorimetrically and the ratio of two parameters was taken as an index of activity of enzyme with decreased ratio indicating increased activity and conversely. Lipoprotein lipase was estimated by the determination of products of hydrolysis namely unestrified fatty acid or glycerol (Tietz and Fiereck 1972). Total lipids were extracted from tissue by the modified method of Folch et al. 1957.

Phytochemical screening and gas chromatography mass spectroscopy of methanol extract Msmt was screened for the presence of phenolic compounds, tannins, glycosides, alkaloids, flavonoids, sterols and terpenoids qualitatively (Sofowora 1993). Chemical components of Msmt were analyzed using gas chromatograph-mass spectrometer. (Shimadzu GC-MS-QO-2010 system). Msmt dissolved in methanol, was applied to Rtx-5 column (60 m × 0.25 mm i.d., film thickness 0.25 μm). Compounds were identified using Willey and NIST libraries. The relative contents of compounds were measured by their peak areas in GC chromatogram.

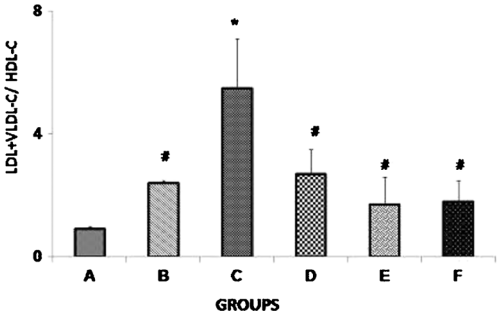

Fig. 1 Effect of 6 weeks treatment with different doses of methanol extract of stem of *Musa sapientum* (Msmt) on atherogenic index. Group A-Healthy rats, Group B- Vehicle treated rats, Group C-cholesterol fed rats, Group D,E,F are cholesterol fed rats treated with 10,20 & 40 mg/kg of methanol extract of stem of *Musa sapientum.* Values are mean ± SD of six rats in each group. • $^{*}p < 0.001$, Group C v/s Group A • $^{\#}p < 0.01$, Group C v/s Group D, E & F • $^{\#}p < 0.01$, Group B v/s Group A

Statistical analysis

Results are expressed as mean ± SD (standard deviation). Statistical analysis is done using repeated measure analysis of variance (ANOVA) followed by Tukey's test at 5 % level.

Results

Effect of Msmt treatment on lipid parameters Table 1 shows the effect of treatment with different doses of Msmt on serum lipid profile parameters. Serum total cholesterol increased by 88 % in vehicle fed group (Group B). In rats of group C, which received cholesterol suspended in soya oil rise in cholesterol level was (179 %). Group D, E and F which received treatment with Msmt at a dose of 10, 20 and 40 mg/kg respectively in addition to cholesterol suspended in

Table 1 Effect of 6 weeks treatment with different doses of methanol extract of stem of *Musa sapientum* (Msmt) on serum lipid profile of rats

	A	B	C	D	E	F
Cholesterol (mmol L^{-1})	1.41 ± 0.05	2.62 ± 0.13*	3.94 ± 0.39*	2.82 ± 0.20$^{\#}$	2.01 ± 0.15$^{\#}$	2.12 ± 0.18$^{\#}$
Triglyceride (mmol L^{-1})	0.83 ± 0.05	1.43 ± 0.09	1.45 ± 0.06*	1.23 ± 0.07$^{\#}$	1.03 ± 0.07$^{\#}$	1.04 ± 0.06$^{\#}$
HDL-C (mmol L^{-1})	0.82 ± 0.02	0.71 ± 0.05*	0.60 ± 0.07*	0.83 ± 0.05$^{\#}$	0.72 ± 0.05$^{\#}$	0.82 ± 0.05$^{\#}$
LDL + VLDL-C (mmol L^{-1})	0.64 ± 0.07	1.91 ± 0.15*	3.31 ± 0.25*	2.01 ± 0.12$^{\#}$	1.32 ± 0.15$^{\#}$	1.31 ± 0.12$^{\#}$

Group A-Healthy rats, Group B-Vehicle treated rats, Group C-cholesterol fed rats, Group D,E, F are cholesterol fed rats treated with 10,20 & 40 mg/kg of methanol extract of stem of *Musa sapientum* respectively

Values are mean ± SD of six rats in each group

• $^{*}p < 0.001$ Group C v/s Group A & Group B v/s Group A

• $^{\#}p < 0.01$ Group C v/s Group D, E & F

Table 2 Effect of 6 weeks treatment with different doses of methanol extract of stem of *Musa sapientum* (Msmt) on blood lipid peroxidation and antioxidant parameters on rats

	A	B	C	D	E	F
Malonaldialdehyde (nmol ml^{-1})	3.4 ± 0.7	4.1 ± 0.5	6.1 ± 0.4*	4.5 ± 0.3#	3.4 ± 0.3#	3.5 ± 0.7#
Reduced glutathione (mg gHb^{-1})	2.2 ± 0.5	1.9 ± 0.2	1.1 ± 0.2*	1.6 ± 0.4#	1.9 ± 0.2#	1.8 ± 0.2#
Super oxidedismutase (u $gmHb^{-1}$)	2191 ± 198	1806 ± 109**	1144 ± 109*	1489 ± 137#	1652 ± 144#	1604 ± 165#
Catalase (u $gmHb^{-1}$)	2.5 ± 0.4	2.1 ± 0.1**	0.9 ± 0.1*	1.3 ± 0.3#	1.9 ± 0.2#	1.8 ± 0.4#

Group A-Healthy rats, Group B-Vehicle treated rats, Group C-cholesterol fed rats, Group D,E,F are cholesterol fed rats treated with 10,20 & 40 mg/kg of methanol extract of stem of *Musa sapientum* respectively

Values are mean ± SD of six rats in each group

- *$p < 0.001$Group C v/s Group A
- #$p < 0.01$ Group C v/s Group D, E & F
- **$p < 0.05$ Group B v/s Group A

soya oil, there was significant fall in levels of serum total cholesterol compared to group C.

Triacylglycerol increased in group B and group C that received soya oil and cholesterol suspended in soya oil. Group D, E and F which were co-administered Msmt, along with cholesterol, there was significant fall in levels of triacylglycerol compared to group C.

HDL-C levels decreased in group C compared to healthy rats. Msmt treated group showed significant rise in levels of HDL-C ($p < 0.01$). There was no significant change in HDL-C in group B. LDL + VLDL-C increased in both group B and C, rise in these parameters was more in group C which received cholesterol in soya oil (170 %). There was significant fall in LDL + VLDL-C in Msmt treated groups.($p < 0.01$).

Improvement in lipid profile increased in dose dependent manner when dose of Msmt increased from 10 mg/kg to 20 mg/kg. Increasing dose to 40 mg/kg has no added effects. "Most effective dose of Msmt is 20 mg/kg".

Figure 1, shows effect of Msmt treatment on atherogenic index. Atherogenic index increased in vehicle treated group and cholesterol fed group compared to healthy control. Treatment with Msmt resulted in significant decrease in atherogenic index. Decrease in atherogenic index was maximum with a dose 20 mg/kg.

Effect on Msmt treatment on antioxidant parameters of blood Effect of Msmt treatment on MDA, GSH, SOD and CAT in blood is shown in Table 2. Feeding cholesterol suspended in oil increased MDA in group C. Treatment with Msmt resulted in significant fall in levels of MDA in group D, E and F ($p < 0.01$). Levels of GSH decreased in group C. Rats in group D, E and F which received Msmt treatment showed 45, 72 and 63 % increase in levels of GSH. Enzyme SOD and CAT decreased in group C (47 %, 64 % fall respectively), while treated group showed significant rise in level of SOD and CAT ($p < 0.01$). Rats in group B which were given only vehicle (soya oil) showed significant fall in levels of SOD, rise in MDA and no appreciable effect on GSH and CAT.

Effect on Msmt treatment on antioxidant parameters in liver Table 3, shows effect of Msmt treatment on MDA, GSH, SOD and CAT in liver tissues of group A, B, C and E. Among

Table 3 Effect of 6 weeks treatment with methanol extract of stem of *Musa sapientum* 20 mg/kg/day on lipid peroxidation and antioxidant parameters in liver

	A	B	C	E
Malonaldialdehyde (nmol mg $protein^{-1}$)	1.4 ± 0.2	3.3 ± 0.5*	4.4 ± 0.6*	2.2 ± 0.6#
Reduced glutathione (μmoles gm $tissue^{-1}$)	9.5 ± 0.7	8.3 ± 0.7*	2.2 ± 0.3*	5.9 ± 0.9#
Super oxidedismutase (u mg $protein^{-1}$)	2086 ± 250	1933 ± 151	1244 ± 220*	1652 ± 144#
Catalase (nmol of H_2O_2 decomposed mg of $protein^{-1}$ 60 s^{-1}.)	185 ± 20	180 ± 30	117 ± 17*	171 ± 20#

Group A-Healthy rats, Group B-Vehicle treated rats, Group C-cholesterol fed rats, Group E is cholesterol fed rats treated with 20 mg/kg/day of methanol extract

Values are mean ± SD of six rats in each group

- *$p < 0.001$Group C v/s Group A
- *$p < 0.001$ Group B v/s Group A
- #$p < 0.01$ Group C v/s Group E

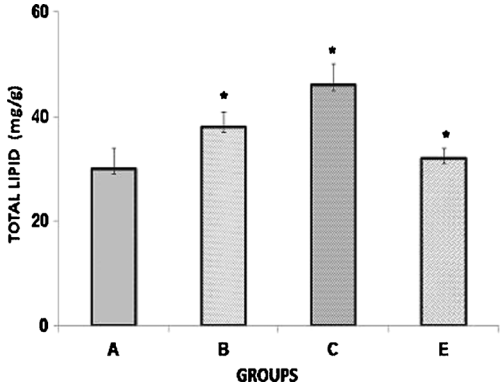

Fig. 2 Effect of 6 weeks treatment with methanol extract of stem of *Musa sapientum* 20 mg/kg/day on total lipids of liver tissue of rats. Group A- Healthy rats, Group B- Vehicle treated rats, Group C- cholesterol fed rats, Group E is cholesterol fed rats treated with 20 mg/kg of methanol extract of stem of *Musa sapientum.* Values are mean ± SD of six rats in each group. • $^{*}p < 0.001$, Group C v/s Group A • $^{*}p < 0.001$, Group C v/s Group E • $^{*}p < 0.001$, Group B v/s Group A

treatment receiving groups, liver tissues of only group E were investigated as results of studies on blood parameters indicated this group to be receiving maximum effective dose (20 mg/kg/day) MDA increased in liver of vehicle treated and cholesterol fed group as compared to healthy controls (group A). Treatment with Msmt resulted in significant fall in level of MDA in rats of group E. Levels of SOD, CAT and GSH significantly decreased in cholesterol fed group (group C). Cholesterol fed group which received treatment with Msmt there was significant rise in the levels of these parameters. In vehicle treated group levels of GSH, SOD decreased, while there was no change in values of GSH and CAT.

Effect on lipid content of liver Figure 2 shows the lipid content of tissue. Total lipid of liver of the hypercholesterolemic group was higher, compared to healthy control. Group E which received treatment with the Msmt with dose of 20 mg/kg, showed a significant decrease in the lipid content of liver.

Effect on lipid metabolizing enzymes in liver HMG Co A reductase activity increased in vehicle treated and hypercholesterolemic control group while treatment significantly decreased activity of this enzyme. Lipoprotein lipase activity was decrease in group B and C, treatment with Msmt increased activity of enzyme lipoprotein lipase in group E. (Table 4).

Phytochemical investigation and GCMS analysis of methanol extract of stem Qualitative analysis revealed that methanol extract contain phenolics, tannins, terpenoids and sterols (Table 5). Quantitative analysis showed that total phenolic content was 5 mg gallic acid equivalent/100 g of Msmt. The GC-MS studies indicated that the presence of plant sterols is very high in the methanol extract (80 %). GC-MS chromatogram of the extract shows a series of sterols with molecular weight of compounds ranging from 140 Da to 430 Da according to Willey and Nist Library (Fig. 3).

Discussion

Therapeutic relevance of natural product's extracts is of paramount importance (Patwardhan et al. 2005). The present study demonstrates that methanol extract of central stem of *Musa sapientum* has significant antihypercholesterolemic and antioxidant effect. Most effective dose Msmt was found to be 20 mg/kg. Msmt, when co-administered at this dose with cholesterol suspended in soya oil prevented rise in total cholesterol, LDL + VLDL-cholesterol, triacylgylcerol and total hepatic lipid. ($p < 0.01$) HDL-C increased by 21 %. Atherogenic index has been proposed as a marker of plasma atherogenicity as it is found to be enhanced in patients suffering from cardiovascular disorders (Tan et al. 2004). Atherogenic index decreased significantly in Msmt treated rats showing a reduction in harmful lipid pool relative to favorable one.

Mechanisms involving lowering of TC might be (i) suppression of cholesterol biosynthesis by decreasing activity HMG-CoA reductase which is the rate-limiting enzyme of cholesterol biosynthetic pathway. In the present study,

Table 4 Effect of 6 weeks treatment with methanol extract of stem of *Musa sapientum* 20 mg/kg/day on activities of enzyme of lipid metabolism in liver

	A	B	C	E
HMG Co A reductase in liver tissue (HMG Co A/mevalonate)	8.41 ± 2.2	5.3 ± 1.5**	3.2 ± 1.6*	6.2 ± 1.9$^{\#}$
Lipoprotein lipase in plasma (μmol glycerol/h/g protein)	26 ± 2.1	20 ± 1.9*	15 ± 1.4*	22 ± 1.8$^{\#}$

Group A-Healthy rats, Group B-Vehicle treated rats, Group C-cholesterol fed rats, and Group E is cholesterol fed rats treated with 20 mg/kg/day of methanol extract

Values are mean ± SD of six rats in each group

• $^{*}p < 0.001$ Group C v/s Group A & Group B v/s Group A

• $^{**}p < 0.05$ Group B v/s Group A

• $^{\#}p < 0.01$ Group C v/s Group E

Table 5 Phytochemical analysis of Methanol extract of stem of *Musa sapientum* (Msmt)

Phytochemicals	Test/Reagent	Present
Phenol	Ferric chloride test	+
Pectin	Alcoholic test	−
Glycosides	α-Naphthol test	−
Tannins	Vanillin hydrochloric acid	+
Sterols	Libermann- Burchard test	+ +

+/− Presence/Absence of compounds

HMG-CoA reductase activity was indirectly measured in terms of the ratio of HMG-CoA to mevalonate. The ratio is inversely proportional to HMG-CoA reductase activity, i.e. an increase in the ratio indicates a decrease in the enzyme activity. The rats which received cholesterol in soya oil showed increase in activity of the enzyme HMG CoA reductase compared to healthy rats. Treatment of cholesterol fed rat with Msmt resulted in decrease in the activity of HMG Co A reductase. (ii) It has been observed that plant sterol lower plasma cholesterol levels by interfering with cholesterol absorption (Batta et al. 2005). Lowering of cholesterol by Msmt may also be due to inference in cholesterol absorption by plant sterols present in Msmt.

Decrease in TAG in Msmt treated hypercholesterolemic rats may be due to increased activity of enzyme lipoprotein lipase. Others have also observed increased activity of lipoprotein lipase upon treatment of hypercholesterolmic animals with plant extracts (Patil et al. 2010; Kumar et al. 2009).

Atherosclerosis is an inflammatory process strongly affected by oxidative stress (Vogiatzi et al. 2009). Hypercholesterolemia induces oxidative stress by increasing production of oxygen free radicals, which may results in lipid peroxidation leading to increase in the formation of malondialdehyde (MDA) (Gupta et al. 2001; Shukla et al. 2004). An increase in MDA indicating decrease in antioxidant status in cholesterol fed animals is observed in present study, which is in agreement with other studies (Küskü-Kiraz et al. 2010; Ahmed et al. 2001). A decrease in rise of MDA when Msmt was co-administered with cholesterol suggested that Msmt can decrease lipid peroxidation and improve antioxidant status. More over Msmt treatment prevented decrease in GSH, which was observed in rats receiving cholesterol.

Enhanced oxidative stress may depress antioxidant defences (Dikshit et al. 2011). In the present study we observed decreased activities of antioxidant enzymes SOD and Catalase in erythrocytes and liver of rats maintained on high cholesterol diet compared to healthy controls. Simultaneous treatment of cholesterol fed rats with Msmt increased activity of SOD and catalase significantly. ($p < 0.01$) This appears to be related to effect of Msmt on decreasing cholesterol.

Important observation of the present study is that feeding soya oil alone, which was used as a vehicle in this experiment

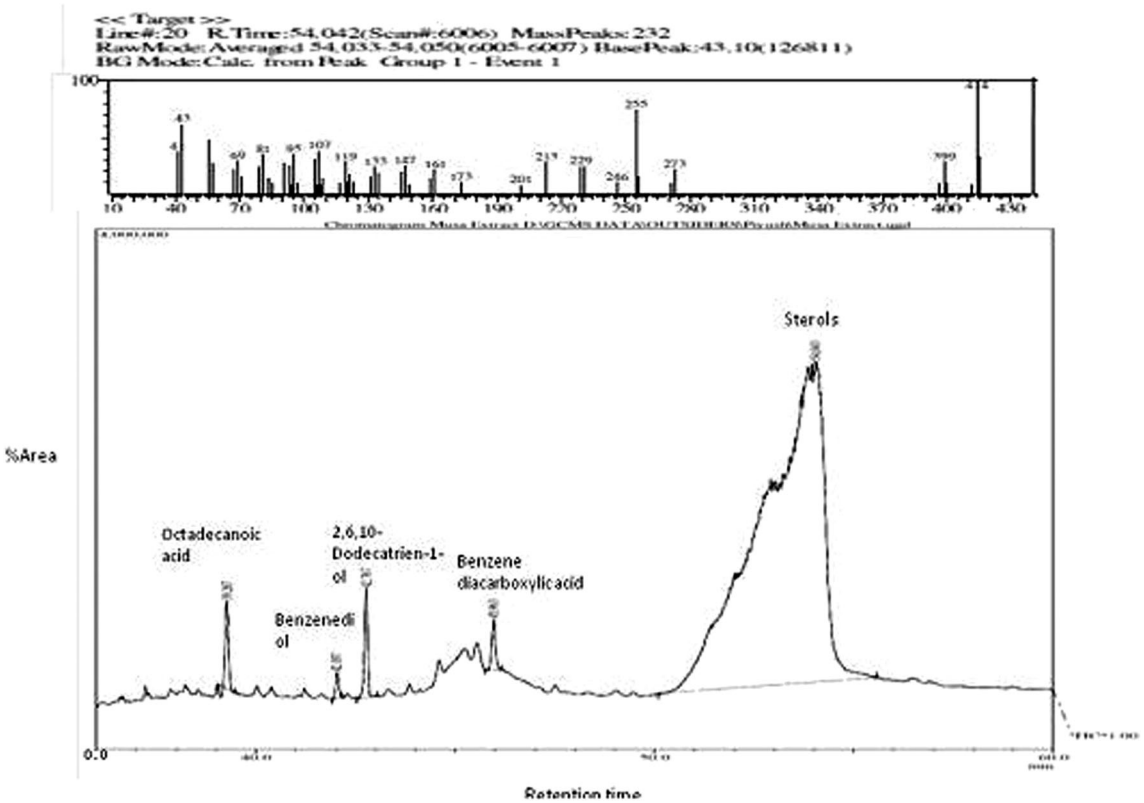

Fig. 3 Peak fragmentation & GC-MS Chromatogram of methanol extract of stem of *Musa sapientum* (Msmt)

could increase TC, TAG, LDL + VLDL-C and HMG Co A reductase activity in vehicle treated group, although rise in these parameters was much less compared to what was observed by feeding cholesterol suspended in soya oil. Feeding rats with soya oil has no effect on HDL-C. In one study, where corn oil was used as a vehicle, feeding corn oil also resulted in increase of TC, TAG and LDL + VLDL-C (Gosain et al. 2010). Rats receiving soya oil showed increased MDA and decreased SOD levels in blood and tissue but it has no significant effect on levels of 'GSH' and antioxidant enzyme 'catalase'. Results of the present study show that soya oil alone can increase serum total cholesterol, TAG and LDL + VLDL-C and induce oxidative stress, which is evident from increased levels of MDA and decreased levels of antioxidant enzyme SOD, although changes in lipid profile and antioxidant parameters are less profound in vehicle treated group.

Phytochemical studies indicated presence of phenolics, terpenoids, tannins and sterols in Msmt. A positive correlation is reported in phenolic contents and antioxidant activity (Dikshit et al. 2011). Triterpenoids compounds have been shown to possess anti-atherogenic properties (Zhang et al. 2008). GC-MS studies indicated that percentage of plant sterols is high in Msmt. Plant sterols have been shown to have antioxidant and anti-inflammatory effect (Chau et al. 2011). Sterols may interfere with intestinal absorption of fat and cholesterol and promote catabolism of cholesterol (Katan et al. 2003).

Our study demonstrated that methanol extract of central stem of *Musa sapientum* has significant hypolipidemic, antihypercholesterolemic and antioxidant effect. The mechanism by which it elicits these effects may be multiple and can be attributed to sterol content of Msmt. Further studies with the purified compound from Msmt are warranted.

Acknowledgments The authors acknowledge the Indian Council of Medical Research, New Delhi for providing financial assistance. (Grant No. - 45/26/2009/BMS/TRM).

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

Aebi H (1984) Catalase in vitro. Methods Enzymol 105:121–126

Ahmed I, Lakhani MS, Gillett M, John A, Raza H (2001) Hypotriglyceridemic and hypocholesterolemic effects of antidiabetic *momordica charantia* (karela) fruit extract in streptozotocin-induced diabetic rats. Diabetes Res Clin Pract 51(3):155–161

Batta AK, Xu G, Bollineni JS, Shefer S, Salen G (2005) Effect of high plant sterol-enriched diet and cholesterol absorption inhibitor, SCH 58235, on plant sterol absorption and plasma concentrations in hypercholesterolemic wild-type Kyoto rats. Metabolism 54(1):38–48

Beutler E, Duron O, Kelly BM (1963) Improved method for the determination of bloodglutathione. J Lab Clin Med 61:882–888

Bhaskar JJ, Salimath PV, Nandini CD (2011) Stimulation of glucose uptake by Musa sp.(cv. Elakki bale) flower and pseudostem extracts in Ehrlich ascites tumor cells. J Sci Food Agric 91(8):1482–1487

Chau VM, Phan VK, Nguyen X, Nguyen XC, Nguyen PT, Nguyen HN, le TA H, Do CT, Thuy DT, Kang HK, Jang HD, Kim YH (2011) Cytotoxic and antioxidant activities of diterpenes and sterols from the Vietnamese soft coral *Lobophytum compactum*. Bioorg Med Chem Lett 21(7):2155–2159

Dikshit P, Tyagi MK, Shukla K, Sharma S, Gambhir JK, Shukla R (2011) Hepatoprotective effect of stem of *Musa sapientum* Linn in rats intoxicated with carbon tetrachloride. Ann Hepatol 10(3):333–339

Dikshit P, Shukla K, Tyagi MK, Garg P, Gambhir JK, Shukla R (2012) Antidiabetic and antihyperlipidemic effects of the stem of *Musa sapientum* Linn. In streptozotocin-induced diabetic rats. J Diabetes 4(4):378–385

Ellman GL (1959) Tissue sulfhydryl groups. Arch Biochem Biophys 82 (1):70–77

Farias RAF, Neto MFO, Viana GSB, Rao VSN (1996) Effects of croton cajucara extract on serum lipids of rats fed a high fat diet. Phytother Res 10:697–699

Folch J, Lees M, Sloane Stanley GH (1957) A simple method for the isolation and purification of total lipids from animal tissues. J Biol Chem 226(1):497–509

Gomathy R, Vijayalekshmi NR, Kurup PA (1989) Hypolipidemic principle of the inflorescence stalk of plantain *Musa sapientum*. J Biosci 14(3):301–309

Gomathy R, Vijayalekshmi NR, Kurup PA (1990) Hypoglycemic action of the pectin present in the juice of the inflorescence stalk of plantain (*Musa sapientum*) mechanism of action. J Biosci 15:297–303

Gosain S, Ircchiaya R, Sharma PC, Thareja S, Kalra A, Deep A, Bhardwaj TR (2010) Hypolipidemic effect of ethanolic extract from the leaves of *hibiscus sabdariffa* L. in hyperlipidemic rats. Acta Pol Pharm 67(2):179–184

Gupta R, Singhal S, Goyle A, Sharma VN (2001) Antioxidant and hypocholesterolaemic effects of terminalia arjuna tree-bark powder: a randomised placebo-controlled trial. J Assoc Physicians India 49: 231–235

Gupta S, Mediratta PK, Singh S, Sharma KK, Shukla R (2006) Antidiabetic, antihypercholesterolaemic and antioxidant effect of *Ocimum sanctum* (Linn) seed oil. Indian J Exp Biol 44(4):300–304

Johansen O, Vaaler S, Jorde R, Reikerås O (1994) Increased plasma glucose levels after hypnorm anaesthesia, but not after pentobarbital anaesthesia in rats. Lab Anim 28(3):244–248

Katan MB, Grundy SM, Jones P, Law M, Miettinen T, Paoletti R, Participants SW (2003) Efficacy and safety of plant stanols and sterols in the management of blood cholesterol levels. Mayo Clin Proc 78(8):965–978

Kumar V, Singh P, Chander R, Mahdi F, Singh S, Singh R, Khanna AK, Saxena JK, Mahdi AA, Singh VK (2009) Hypolipidemic activity of *hibiscus Rosa* sinensis root in rats. Indian J Biochem Biophys 46(6): 507–510

Küskü-Kiraz Z, Mehmetçik G, Dogru-Abbasoglu S, Uysal M (2010) *Artichoke* leaf extract reduces oxidative stress and lipoprotein dyshomeostasis in rats fed on high cholesterol diet. Phytother Res 24(4):565–570

Nandi A, Chatterjee IB (1988) Assay of superoxide dismutase activity in animal tissues. J Biosci 13:305–315

Patil RH, Prakash K, Maheshwari VL (2010) Hypolipidemic effect of *celastrus paniculatus* in experimentally induced hypercholesterolemic wistar rats. Indian J Clin Biochem 25(4):405–410

Patwardhan B, Warude D, Pushpangadan P, Bhatt N (2005) Ayurveda and traditional Chinese medicine: a comparative overview. Evid Based Complement Alternat Med 2(4):465–473

Rao AV, Ramakrishnan S (1975) Indirect assessment of hydroxymethylglutaryl-CoA reductase (NADPH) activity in liver tissue. Clin Chem 21(10):1523–1525

Satoh K (1978) Serum lipid peroxide in cerebrovascular disorders determined by a new colorimetric method. Clin Chim Acta 90(1):37–43

Satyavati GV, Gupta AK, Tandon N (eds) (1987) Medicinal plants of India volume 2. Indian Council of Medical Research New Delhi pp 299–303

Shukla R, Gupta S, Gambhir JK, Prabhu KM, Murthy PS (2004) Antioxidant effect of aqueous extract of the bark of*Ficus bengalensis* in hypercholesterolaemic rabbits. J Ethnopharmacol 92(1):47–51

Sinha AK (1972) Colorimetric assay of catalase. Anal Biochem 47(2): 389–394

Sofowora EA (1993) Phytochemical Assays in "Medicinal Plants and Traditional Medicine in Africa", 3rd edn. Spectrum Books Limited, Nigeria, pp. 150–153

Sorg DA, Buckner B (1964) A simple method of obtaining venous blood from small laboratory animals. Proc Soc Exp Biol Med 115:1131–1132

Tan MH, Johns D, Glazer NB (2004) Pioglitazone reduces atherogenic index of plasma in patients with type 2 diabetes. Clin Chem 50(7): 1184–1188

Tietz NW, Fiereck EA (1972) In: Cooper, G R (ed) Standard methods of clinical chemistry, Vol. 7. Academic Press, New York, pp 19

Vogiatzi G, Tousoulis D, Stefanadis C (2009) The role of oxidative stress inatherosclerosis. Hell J Cardiol 50(5):402–409

Wills ED (1966) Mechanisms of lipid peroxide formation in animal tissues. Biochem J 99(3):667–676

Yokozawa T, Ishida A, Cho EJ, Nakagawa T (2003) The effects of *coptidis rhizoma* extract on a hypercholesterolemic animal model. Phytomedicine 10(1):17–22

Zhang Q, Chang Z, Yang J, Wang Q (2008) Antiatherogenic property of triterpenoids-enriched extract from the aerial parts of *salvia miltiorrhiza*. Phytother Res 22(8):1040–1045