ORIGINAL ARTICLE

Anti-hyperlipidaemic activity of fresh and old *Guggulu* (*Commiphora wightii* (Arn.) Bhandari) in experimental animals

Kruti Yagneshkumar Vyas, Mukeshkumar Nariya[1], R Galib, Pradeep Kumar Prajapati
Department of Rasa Shastra and Bhaishajya Kalpana including Drug Research, [1]Pharmacology Laboratory, Institute for Post Graduate Teaching and Research in Ayurveda, Gujarat Ayurved University, Jamnagar, Gujarat, India

Objective: *Guggulu* (*Commiphora wightii* (Arn.) Bhandari) belong to family Burseraceae is a well-known anti-hyperlipidaemic drug. An Ayurvedic classic attributes *brihmana* (weight increasing) effect to fresh *Guggulu*, while *lekhana* (weight reducing) effect to the old one. Though anti-hyperlipidaemic activity of *Guggulu* has been studied, the actual differentiation in efficacy of *Guggulu* samples during storage period has not yet attempted in experimental animals. This prompted us to initiate a comparative anti-hyperlipidaemic activity of fresh *Guggulu* and one-year old *Guggulu* samples against cholesterol diet induced hyperlipidaemia in rats. **Materials and Methods:** Hyperlipidaemia was induced by cholesterol (0.5 ml/kg, 20% suspension in coconut oil) and hydrogenated vegetable oil (5 ml/kg). The effects of drugs were assessed on body weight, serum biochemical parameters and histological parameters. **Results:** Both drugs produced significant attenuation of relative weight of liver in cholesterol-fed animals. Fresh sample of *Guggulu* provided better effect in lowering serum cholesterol (15.34%), triglyceride (34.72%), very low density lipoprotein (34.7%) and low density lipoprotein (18.66%) and non-significant increase in serum HDL-cholesterol while old sample of *Guggulu* provided mild effect in lowering serum triglyceride (6.47%), VLDL (6.49%) and LDL (29.50%) and non-significant increase in serum HDL-cholesterol in comparison with control group. **Conclusion:** From the present study, it is concluded that fresh *Guggulu* produced pronounced hyperlipidaemic effect than the old one in experimental animals, which may be due the presence of higher concentration of Z-guggulsterone and E-guggulsterone.

Key words: Anti-hyperlipidaemia, *Commiphora wightii*, Guggulsterone, *Guggulu*

INTRODUCTION

Hyperlipidaemia is the term used to denote raised serum levels of any one of total cholesterol, low-density lipoprotein (LDL), triglycerides, or both total cholesterol and triglyceride (combined hyperlipidaemia). The abnormal levels of triglyceride and/or cholesterol in plasma are consequent to excess of substrate leading to more production, defective transport, delayed peripheral clearance, and reduced utilisation of lipoproteins or their intermediaries, or combinations of these abnormalities leads to cardio vascular diseases (CVDs) and cerebrovascular accidents (CVA). Cardio vascular diseases are the number one cause of death globally.[1] An estimated 7.3 million deaths were reported due to coronary heart disease and 6.2 million due to stroke.[2] Conventional systems of medicine do have drugs to combat this situation but are known to develop certain adverse drug reactions (ADRs). Considering this situation; leads are being searched from other systems of medicine.

Guggulu (*Commiphora wightii* (Arn.) Bhandari) belong to family Burseraceae is a popular herb classified as *Tridoshahar* in Indian Ayurvedic medicine that is used to treat several ailments. History revealed that *Guggulu* has prime place in Vedas, Samhitas, Nighantus and in Rasa classics.[3] It is used in various disease conditions like *Kustha* (skin diseases), *Medoroga* (lipid disorders), *Aamavata* (rheumatic arthritis), *Sandhigata Vata* (osteoarthritis), *Gulma* (Abdominal lump), *Shotha* (odema) etc.[4] *Guggulu* has a wide range of useful properties in indigenous medicine. The lipid lowering activity of *Guggulu* was first reported and an active lipid lowering agent, a standardised fraction from ethyl acetate extract of *Guggulu* gum containing guggulsterone mixed with some other steroids, diterpene, esters and higher alcohols named as 'Guggulipid' was developed.[5-7]

Ayurvedic classics mentioned that clinical properties of fresh and old *Guggulu* are different. Old *Guggulu* is said to be *lekhana* (weight reducing) in comparison with

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Address for correspondence: Dr. Kruti Yagneshkumar Vyas, Department of Rasa Shastra and Bhaishajya Kalpana including Drug Research, Institute for Post Graduate Teaching and Research in Ayurveda, Gujarat Ayurved University, Jamnagar - 361 008, Gujarat, India.
E-mail: vyas_krt@yahoo.co.in
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brihmana (weight increasing) effect to fresh *Guggulu*.[8] This implies on the storage for specific time period and imparts certain changes in the properties of drug. In Ayurveda, it is indicated that some drugs should be used in fresh condition like *Guduchi, Vasa* etc., *Guggulu* is placed under this category.[9] However, some author contraindicates the use of old *Guggulu* in diseased condition.[10] Multiple experimental and clinical trials were done on this plant but experiments on fresh and old samples have not been evaluated till date, which prompted us to initiate comparative anti-hyperlipidaemic efficacy of fresh and old *Guggulu* in albino rats.

MATERIALS AND METHODS

Drug

Guggulu cultivated at Dwaraka Forest Range, Gujarat was collected from Gujarat State Forest Development Corp. Ltd., Vadodara during February 2011 (Batch no. B 05, code-148600). This sample was preserved under identical conditions to make it old. Though, specific time period is not mentioned for *Guggulu* to become old; the sample stored for one year is considered as old based on the general terminology.[11] Another sample of fresh *Guggulu* was collected in the same manner during February 2012 (Batch no. B 01, code-128500). Both the samples were purified by following classical procedure mentioned in Ayurvedic Formulary of India.[12]

Animals

Wistar strain albino rats of either sex, weighing 160 ± 20 g were used for the experiment. The animals were maintained under standard conditions of temperature (22 ± 02°C), humidity (50-60%) and exposed to 12 h light and dark cycles. All animals were exposed to the same environmental conditions and were maintained on standard diet and water *ad libitum*. The experimental protocol was approved by the Institutional Animal Ethics Committee (IAEC/12/2012/12MD) and conducted as per the guidelines of Committee for the Purpose of Control and Supervision on Experiments on Animals, India.

Dose fixation and schedule

The human dose considered in the present study is 2 gm/day.[13] Rat dose was calculated on basis of body surface area ratio by referring to table of Paget and Barnes (1964).[14] Suspension of the test drugs was made by suspending in lukewarm water and administered orally with the help of oral rat feeding cannula.

Anti-hyperlipidaemic activity

Protocol designed in earlier works has been followed in present study with some modifications as per experimental need.[15] Wistar albino rats of either sex were divided into four groups of six animals each. Group (I) was kept as normal control (NC), which received distilled water in a dose of 10 ml/kg body weight of rats. Group (II) of animals kept as cholesterol-control group, which received distilled water in the dose of 10 ml/kg body weight of rats in addition to hyperlipidaemic diet. Group (III) and (IV) were kept as drug-treated groups and received fresh *Guggulu* (180 mg/kg) and old *Guggulu* (180 mg/kg) orally in addition to hyperlipidaemic diet.

The drug suspension was administered to respective groups at morning hours daily for 21 days. The control and cholesterol-control groups received distilled water as vehicle, daily for 21 days. The hyperlipidaemic diet was administered to Group II to IV to induce hyperlipidaemia. Hyperlipidaemic diet includes cholesterol suspension in coconut oil and hydrogenated vegetable oil. Cholesterol extra pure powder (Batch No. P-935883, SRL, Mumbai) made in to 20% suspension in coconut oil and administered (5 ml/kg) orally at morning hours for 21 consecutive days after one hour of drug administration. Hydrogenated vegetable oil (Vanaspati ghee - 'Raag' brand, Adani Wilmar Ltd., Gujarat) administered at the dose of 5 ml/kg body weight of rat in evening hours.

On the 22nd day, after overnight fasting, the rats were weighed again and blood was collected from retro-orbital puncture under light ether anaesthesia using capillary tubes; serum was separated and used for estimation of different serum biochemical parameters. An auto analyser was used for the analysis of serum total cholesterol[16], high-density lipoprotein (HDL)-cholesterol[17], triglyceride[18], very low density lipoprotein (VLDL)-cholesterol, low density lipoprotein (LDL)-cholesterol, serum glutamic pyruvic transaminase (SGOT)[19], serum glutamic oxaloacetic transaminase (SGPT)[20] and alkaline phosphatase.[21] The rats were sacrificed and important organs like liver, kidney, heart and aorta were excised out. The extraneous tissues were cleaned off and the weight of organs were noted down except for aorta and further stored in 10% formalin solution for histopathological study.[22]

Statistical analysis

The data are expressed as mean ± standard error of mean for six rats per experimental group. Student's *t*-test was used to compare the unpaired data to determine significant difference between groups at $P < 0.05$.

RESULTS

Progressive gain in body weight was observed by the end of treatment in all the groups. Hyperlipidaemic diet increases the weight of rats compared with normal

control (69.41%). Weight gain was observed in fresh *Guggulu* and old *Guggulu* treated rats as well, but lesser (20.83% and 14.37% respectively) in comparison with cholesterol-control group [Table 1]. Significant increase in liver weight (28.68%) and non-significant increase in kidney weight (4.55%) were found in cholesterol-fed group compared to normal control rats. Both test drugs showed significant decrease in liver weight ($P < 0.05$) and non-significant decrease in kidney weight in comparison to cholesterol-control group. The test drugs show almost same values as seen in control group [Table 2].

Cholesterol-fed rats showed increase in total cholesterol level (20.90%) compared to normal control rats. Fresh *Guggulu* exhibited 15.34% decrease in cholesterol level while old *Guggulu* did not affect cholesterol level compared with cholesterol control group. Further cholesterol-fed rats showed significant increase in triglyceride level ($P < 0.05$) compared to normal control rats. Fresh *Guggulu* showed 34.72% decrease in triglyceride level while old *Guggulu* produced mild decrease in comparison to cholesterol-control group [Table 3].

Cholesterol-fed animals showed significant decrease in HDL-cholesterol and increase in VLDL ($P < 0.05$) and two fold increases in LDL-cholesterol compared to normal control rats. Both the test drugs produced marked increase in HDL-cholesterol and decrease in LDL-cholesterol and VLDL-cholesterol; however, the effect was statistically non-significant in comparison with cholesterol control group [Table 4].

Cholesterol-fed rats exhibited non-significant increase in SGPT (35.37%), SGOT (5.20%) and significant increase in alkaline phosphatase level (56.13%) compared to normal control rats. Fresh *Guggulu* showed non-significant reversal in SGOT, SGPT and alkaline phosphatase level while old *Guggulu* did not affect the above parameters in comparison with cholesterol control group [Table 5].

Table 1: Effect of test drugs on body weight of albino rats in anti-hyperlipidaemic study

Groups	Body weight (g)		Change in body weight (g)	% changes
	Initial	Final		
NC	177.33±5.90	194.33±4.66	17.00±5.6	-
CC#	160.80±9.60	189.60±11.58	28.80±4.27	69.41↑
FG@	163.20±2.80	186.00±4.14	22.80±3.87	20.83↑
OG@	154.66±5.28	179.33±4.58	24.66±3.08	14.37↑

Data: Mean±SEM, ↑ – Increase, ↓ – Decrease, #compared to normal control group, @compared to cholesterol control group

Table 2: Effect of test drugs on relative weight of liver, heart and kidneys of ratsin anti-hyperlipidaemic study

Groups	Relative weight of organs (g/100 g body weight)					
	Liver	% change	Heart	% change	Kidney	% change
NC	3.27±0.17	-	0.304±0.01	-	0.681±0.02	-
CC#	4.20±0.28*	28.68↑	0.303±0.01	0.32↓	0.712±0.01	4.55↑
FG@	3.52±0.06@	16.24↓	0.310±0.01	2.31↑	0.706±0.03	0.84↓
OG@	3.52±0.10@	16.36↓	0.303±0.02	-	0.668±0.01	6.17↓

Data: Mean±SEM, ↑ - Increase, ↓ - Decrease, #compared to normal control group, @compared to cholesterol control group, *P<0.05 when compared to normal control group, @P<0.05 when compared to cholesterol control group

Table 3: Effect of test drugs on serum cholesterol and triglyceride level of rats in anti-hyperlipidaemic study

Groups	Cholesterol (mg/dl)	% change	Triglyceride (mg/dl)	% change
NC	48.66±4.76	-	84.66±05.68	-
CC#	58.83±6.09	20.90↑	172.50±16.57*	15.34↑
FG@	49.80±3.12	15.34↓	112.60±29.42	34.72↓
OG@	61.33±5.89	4.20↑	161.33±28.95	6.47↓

Data: Mean±SEM, ↑ - Increase; ↓ - Decrease, #compared to normal control group, @ compared to cholesterol control group, *P<0.05 when compared to normal control group

Table 4: Effect of test drugs on serum HDL, LDL and VLDL of rats in anti-hyperlipidaemic study

Groups	HDL (mg/dl)	% change	LDL (mg/dl)	% change	VLDL (mg/dl)	% change
NC	39.16±1.85	-	2.76±1.81	-	19.30±2.81	-
CC#	29.50±2.12*	24.66↓	6.00±1.32	54.00↑	34.50±3.31*	78.75↑
FG@	34.40±1.36	14.24↑	4.88±1.22	18.66↓	22.52±5.88	34.70↓
OG@	34.83±2.30	18.06↑	4.23±0.39	29.50↓	32.26±5.79	6.49↓

Data: Mean±SEM, ↑ - Increase; ↓ - Decrease, #compared to normal control group, @compared to cholesterol control group, *P<0.05 when compared to normal control group. HDL – High-density lipoprotein, LDL – Low density lipoprotein, VLDL – Very low density lipoprotein

Table 5: Effect of test drugs on SGOT, SGPT and alkaline phosphatase of rats in anti-hyperlipidaemic study

Groups	SGPT (IU/L)	% change	SGOT (IU/L)	% change	ALP (IU/L)	% change
NC	49.00±7.04	-	156.83±12.9	-	269.00±46.84	-
CC#	58.80±5.62	-	165.00±8.52	-	613.20±54.79*	-
FG@	56.80±4.03	3.40↓	151.20±19.49	8.36↓	470.20±80.82	23.32↓
OG@	58.33±4.71	0.79↓	160.33±4.24	2.83↓	592.67±59.00	3.34↓

Data: Mean±SEM, ↑ - Increase; ↓ - Decrease, #compared to normal control group, @compared to cholesterol control group, *P<0.05 compared to normal control group. SGOT – Serum glutamic pyruvic transaminase, SGPT – Serum glutamic oxaloacetic transaminase

In addition to the above, histopathological studies have shown marked cell infiltration, oedema and fatty degenerative changes in heart [Figure 1] and kidney [Figure 2], accumulation of fat globules and hepatic degenerative changes in liver [Figure 3] of cholesterol-fed rats in comparison to normal control rats. The rats from fresh and old *Guggulu*-treated groups showed almost normal cytoarchitecture of heart, micro fatty changes in liver and mild fatty changes and oedema in kidney. The changes observed in drug-treated groups were mild in comparison to cholesterol-control group. The overall impression suggests that fresh *Guggulu* produced pronounced effect than old *Guggulu* sample in cholesterol-fed animals.

DISCUSSION

High cholesterol diet is regarded as an important factor in the development of cardiac diseases as it leads to development of hyperlipidaemia, atherosclerosis and ischaemic heart disease.[23] Lowering elevated plasma lipid levels is highly effective in reducing coronary artery disease (CAD) mortality and other cardiovascular system (CVS) events. Diet and drug therapy for hypercholesterolaemia is clearly indicated for individuals with existing CAD, as well as for individuals with multiple risk factors for cardiovascular diseases.[24] Thus there is a scope for the introduction of effective hypolipidaemic drugs into existing therapeutic armamentarium.

Numbers of studies have been carried out on anti-hyperlipidaemic effect of *Guggulu*,[3,5-7,25] but actual differentiation on efficacy of *Guggulu* samples during storage period has not yet attempted in experimental animals. This impelled to initiate a comparative anti-hyperlipidaemic activity of fresh *Guggulu* and one year old *Guggulu* samples against cholesterol diet induced hyperlipidaemia. In Ayurvedic classics, old *Guggulu* and fresh *Guggulu* have accredited with different efficacy in human beings. Possibly, the physico-chemical profiles of both the samples may alter with time factor, which was corroborate with the results obtained in phytochemical investigations of fresh and old Guggulu.[26]

Administration of hyperlipidaemic diet led to marked increase in body weight and showed significant increase in liver weight in comparison with control group, which was corroborate with the previous study.[27] Both drugs significantly reversed the relative weight of liver in comparison to cholesterol-control group.

Administration of cholesterol and hyperlipidaemic diet leads to significant elevation of serum total cholesterol, triglycerides, VLDL-cholesterol and LDL-cholesterol with concomitant decrease in HDL-cholesterol in rats in comparison to normal control rats. This establishes the efficacy of the experimental protocol to induce hyperlipidaemic condition which indicated that dietary cholesterol obviously disturbed hepatic lipid metabolism. Lipid metabolism to great extent depends up on the formation and turnover of lipoproteins. Almost all lipids in the plasma are transported in the form of complexes with proteins; these proteins are termed as lipoproteins.[28] Both test drugs non-significantly lower the cholesterol level, triglyceride, VLDL and LDL-cholesterol levels in rats. The reversal effect was more pronounced in fresh *Guggulu*-treated animals than old *Guggulu*-treated animals in comparison with control group.

HDL plays very important role in preventing the artherogenesis by taking away the cholesterol from the arterial wall and by inhibiting the oxidation of atherogenic lipoproteins.[29] The elevated HDL-cholesterol in both the drug-treated groups can have good therapeutic application, because the elevation of HDL-cholesterol level will be quite useful in patients with hypercholesterolaemic conditions. It may indicate the role of *Guggulu* in restoring cholesterol induced adverse changes in the lipid metabolism.

SGOT is a mitochondrial enzyme present in large quantities in heart, liver, skeletal muscle and kidney. SGPT is a cytosolic enzyme, also present in liver; the proportion in the liver is greater than in the heart and skeletal muscle. Serum alkaline phosphatase is found in most of the tissues. However, the osteoblasts in the bone, bile canaliculi in liver, epithelia cells in the intestine, proximal tubules of the kidney, placenta and lactating mammary glands are the richest sources. Serum aminotransferase and alkaline phosphatase are elevated in most liver disorders. Highest elevations are found in conditions causing extensive hepatic necrosis such as severe acute viral hepatitis, toxic hepatitis or prolonged circulatory collapse.[30] Cholesterol-fed rats exhibited non-significant increase in SGPT, SGOT and

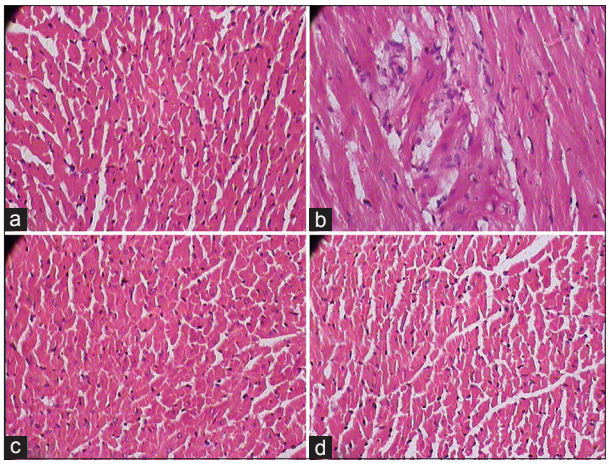

Figure 1: Photomicrographs of representative section of heart. Fatty degenerative changes and inflammatory cells in cholesterol-control group (b) in comparison with normal control group (a). Fresh *Guggulu* (c) and old *Guggulu* (d) treated rat showed almost normal cytoarchitecture (1 × 400 magnification)

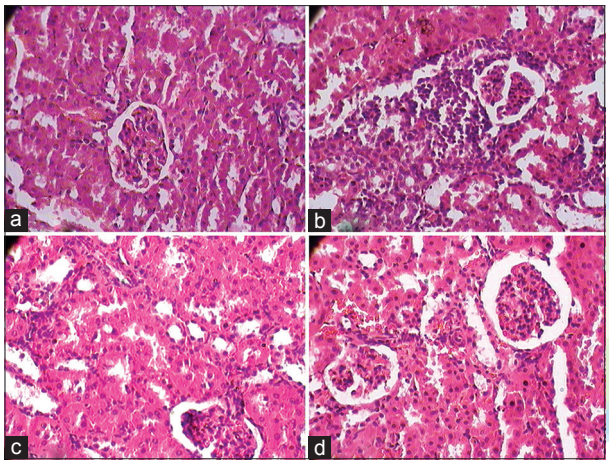

Figure 2: Photomicrographs of representative section of kidney. Fatty degenerative changes, oedema and cell infiltration in cholesterol-control group (b) in comparison to normal control group (a). Fresh *Guggulu* (c) and old *Guggulu* (d) treated rat showed mild fatty changes and oedema in comparison with cholesterol group (1 × 400 magnification)

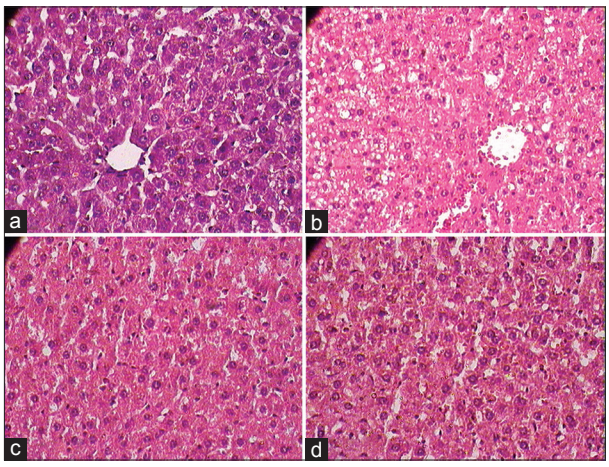

Figure 3: Photomicrographs of representative section of Liver. Accumulation of fat globules and fatty hepatic degenerative changes in cholesterol-control group (b) in comparison with normal control group (a). Fresh *Guggulu* (c) and old *Guggulu* (d) treated rat showed mild fatty changes in comparison with cholesterol group (1 × 400 magnification)

significant increase in alkaline phosphatase level suggests the liver, heart and kidney damage in rats. Fresh *Guggulu* showed non-significant reversal in SGOT, SGPT and alkaline phosphatase level while old *Guggulu* did not affect the above parameters in comparison with cholesterol- control group.

The Z-Guggulsterone and E-Guggulsterone are the active components and non-ketonic part of *Guggulu*, which appeared to be responsible for lowering blood lipids and hypolipidaemic activity. Some researchers isolated the Z- and E- isomers of Guggulsterone and it is related Guggulsterols like Guggulsterol-I to Guggulsterol-VI from the extract of *Guggulu* resin. These compounds have hypolipidaemic properties.[25]

The phytochemical studies also revealed that quantity of Guggulsterone and its isomers Z-Guggulsterone and E-Guggulsterone are more in fresh *Guggulu* in comparison to old *Guggulu* stored for one year.[26] Hence in present study, lipid lowering properties of *Guggulu* may be attributed to Guggulsterones -E and -Z. Based on previous works, four mechanisms have been proposed to explain their activity. First, it might interfere with formation of lipoproteins by inhibiting biosynthesis of cholesterol in the liver.[31] Second, may have been shown to enhance the uptake of LDLs by the liver through stimulation of LDL receptor–binding activity in the membranes of hepatic cells.[32] Third, may increase faecal excretion of bile acids and cholesterol, substantially decreasing the rate of absorption of fat and cholesterol in the intestine.[31] Finally, it may directly stimulate the thyroid gland.[33]

CONCLUSION

From the present study, it is concluded that fresh and old *Guggulu* showed anti-hyperlipidaemic activity in cholesterol-fed albino rats. Fresh *Guggulu* produced pronounced effects than one-year old *Guggulu* in lowering cholesterol and related parameters which may be due to higher concentration of Z-Guggulsterone and E-Guggulsterone in fresh *Guggulu*.

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REFERENCES

1. In: Sainani GS, editor. API Textbook of Medicine. 6th ed. Mumbai: Association of Physicians of India; 1999. p. 191.
2. In: Alwan A, editor. Global Status Report on Non-Communicable

Diseases 2010. Genewa: World Health Organization; reprinted:2011.
3. Rout OP, Acharya R, Mishra SK. Oleogum resin *Guggulu*: A review of the medicinal evidence for its therapeutic properties. Int J Res Ayurveda Pharm 2012;3:15-21.
4. In: Acharya YT editor. Sushruta Samhita of Sushruta, Sutra sthana 15/32. Nibandha smgraha Commentary by Dalhanacharya. Varanasi: Chaukhambha Surbharti Prakashan; reprint 2003. p. 73.
5. Satyavati GV. Effect of an indigenous drug on disorders of lipid metabolism with special reference to atherosclerosis and obesity (Medoroga). M.D. Ayu Thesis (Doctarate of Ayurvedic Medicine). Varanasi: Banaras Hindu University; 1966.
6. Agarwal RC, Singh SP, Saran PK. Clinical trial of guggulipid-A new hypolipedemic agent of plant origin in primary Hyperlipidaemia. Indian J Med Res 1986;84:626.
7. Nityanand S, Shrivastav JS, Asthana OP. Clinical trials with gugulipid- A new hyperlipidaemic agent. J Assoc Phys India 1989;37:323.
8. In: Mishra B, Vaisya R, editors. Bhavaprakasha of Shri Bhavamishra, Purva khanda, Karpuradi Varga/42. Vidhyodini Hindi Commentary, Vol. 1. 9th ed. Varanasi: Chaukhambha Sanskita Bhavana; 2002. p. 205.
9. In: Shastri R, editor. Bhaishajya Ratnavali of Shri Govinda Das. Paribhasha Prakarana, 4/14. Vidhyodini hindi Commentary. 20th ed. Varanasi: Chaukhambha Prakashana; 2010. p. 49.
10. In: Mishra B, editor. Bhavaprakasha of Shri Bhavamishra, Uttara khanda, Vatarakta Chikitsa/187, Vidhyodini hindi Commentary, Vol. 2. 7th ed. Varanasi: Chokhambha Sanskita Bhavana; 2010. p. 316.
11. In: Vidhyasagar P, editor. Sarngadhara Samhita of Sarngadharacarya, Prathama Khanda, 1/44. 6th ed. Varanasi: Chaukhamba Surbharati Prakashana; 2005. p. 11.
12. Ayurvedic Formulary of India, part-1, volume II. 2nd ed. *Guggulu*. New Delhi: Dept. of ISM and H, Ministry of Health and Family Welfare, Govt. of India; 2003. p. 58.
13. The Ayurvedic Pharmacopoeia of India, part-1, volume I. 1st ed. New Delhi: Dept. of ISM and H, Ministry of Health and Family Welfare, Govt. of India; 1999. p. 56-57.
14. Paget GE, Barnes JM. Evaluation of drug activities. In: Laurence DR, Bacharach AL, editors. Pharmacometrics, vol. 1. 1st ed. London: Academic Press; 1964. p. 50.
15. Nadkarni M. Clinico experimental study of hyperlipidaemia and its management by mustadighanavati. MDAyu dissertation. Jamnagar: Institute of Post Graduate Teaching and Research in Ayurveda, Gujarat Ayurved University; 2009.
16. Roeschlau P, Bernt E, Gruber WA. Enzymatic determination of total cholesterol in serum. Clin Biochem 1974;12:226-8.
17. Nauk M, Wiebe D, Warnick G. Measurement of high-density-lipoprotein cholesterol. In: Rifai N, Warnick GR, Dominiczak M, editors. Handbook of Lipoprotein Testing. 2nd ed. Washington DC: AACC Press; 2000. p. 221-44.
18. Fossati P, Prencipe L. Serum triglycerides determined colorimetrically with an enzyme that produces hydrogen peroxide. Clin Chem 1982;28:2077-80.
19. In: Tietz NW, editor. Clinical Guide to Laboratory Tests. 3rd ed. Philadelphia: WB Saunders; 1995. p. 76.
20. In: Burtis CA, Ashwood ER, Burns DE, editors. Tietz Textbook of Clinical Chemisry. 3rd ed. Philadelphia: WB Saunders; 1999. p. 652.
21. Wilkinson JH, Boutwell JH, Winsten S. Evaluation of a new system for kinetic measurement of serum alkaline phosphatase. Clin Chem 1969;15:487-95.
22. Raghramulu N, Nair MK, Kalyansundaram S. A Manual of Laboratory technique. Hydrabad: National Institute of Nutrition, Jamai Osmania; 1983. p. 92.
23. Roberts WC. Preventing and arresting coronary atherosclerosis. Am Heart J 1995;130:580-600.
24. Scandinavian simvastatin survival study group. Randomised trial of cholesterol lowering in 4444 patients with coronary heart disease: The Scandinavian simvastatin survival study (4S). Lancet 1994;344:1383-9.
25. Jasuja ND, Choudhary M, Sharama P, Sharma N, Joshi SC. A review on bioactive compounds and medicinal uses of *Commiphora mukul*. J Plant Sci 2012;7:113-37.
26. Vyas KY. Evaluation of fresh *(naveena)* and old *(purana) Guggulu* w.s.r. to their anti hyperlipidaemic (*medohara*) effect. MD Ayu dissertation. Jamnagar: Institute of Post Graduate Teaching and Research in Ayurveda, Gujarat Ayurved University; 2013.
27. Wang Y, Zhang B, Xue Y, Li Z, Wang J, Xue C, *et al*. The mechanism of dietary cholesterol effects on lipids metabolism in rats. Lipids Health Dis 2010;9:4.
28. Talwar GP. Textbook of Biochemistry and Human Biology. 1st ed. New Delhi: Prentice Hall of India Pvt Ltd; 1980. p. 349-53.
29. Barter P. The role of HDL-cholesterol in preventing atherosclerotic disease. Eur Heart J Suppl 2005;7(Suppl F):F4-8.
30. Satyanarayan U. Essential of Biochemistry. 2nd revised ed. Kolkata: Books and Allied Ltd; 2002.
31. Gupta A, Kapoor NK, Nityanand S. Mechanism of hypolipidemic action of standardized extract. Indian J Pharmacol 1982;14.
32. Singh V, Kaul S, Chander R, Kapoor NK. Simultaneous low density lipoprotein receptor activity in liver membrane of guggulsterone treated rats. Pharmacol Res 1990;22:37-44.
33. Tripathi YB, Malhotra OP, Tripathi SN. Thyroid-stimulating action of Z-guggulsterone obtained from *Commiphora mukul*. Planta Med 1984;50:78-80.

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