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Anti-hyperglycemic activity of drumstick leaves (*Moringa oleifera*)

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Abstract
Moringa oleifera (MO), also known as Drumstick, belongs to the family Moringaceae. It possesses pharmacological properties such as antioxidant, antibacterial, anticancer, antiulcer, and wound healing activities. Experiments conducted on rats have indicated that aqueous and methanol extracts of MO has decrease serum glucose, low-density lipoprotein, and total cholesterol levels in the body, while simultaneously increasing serum insulin and high-density lipoprotein levels. MO leaf powder is known to reduce blood sugar levels by increasing insulin sensitivity and body weight in diabetes-induced rats. These studies have demonstrated that the phytochemicals present in MO have potent therapeutic effects on diabetes mellitus.

Keywords: Antioxidant, blood glucose, insulin, high-density lipoprotein, antihyperglycemic

Introduction
According to the estimation of World Health Organization, 80% of the world's population relies mostly on traditional medicine, which uses plant extracts or their chemically active by-products. In countries like India and the rest of the world, medicinal plants are therefore far more important economically [1]. Drumstick is such a precious plant which is widely cultivated member of the sub-Himalayan regions of India, Pakistan, Bangladesh, and Afghanistan. It belongs to the family Moringaceae, which contains nearly thirteen different species of moringa. It has been a regular ingredient in traditional foods in India for around 5000 years [2]. Immature seed pods of M.O are consumed in certain regions, while the leaves are commonly utilized as a staple food due to their rich nutritional value [3]. The plant's leaves are extremely nutrient- rich and abundant in amino acids, vitamins, minerals, and natural antioxidants. The plant is short, easy to cultivate, grows quickly, and does not shed its leaves in the dry season [4]. This is well- known in African folk medicine and was referenced 5000 years ago in Charaka Samhita. According to the Bureau of Plant Industry, moringa is an excellent provider of nutritious components. Traditional human societies around the world use a variety of plant items as part of their ancient medical systems to treat various diseases [5].

Morphology of M.O
M.O is a small, fast-growing, evergreen or deciduous tree that usually grows up to 10 or 12 m in height. It has spreading, open crown of drooping, fragile branches. Leaves are bipinnate or more tripinnate up to 45 cm long, leaflets are 1.2 to 2 cm long and 0.6 to 1.0 cm wide, leaflets are finely hairy, green and almost hairless on the upper surface. Twigs are finely hairy and green, later becomes brown. Flowers are yellowish white with fragrant and bisexual. Pendulous fruits are dark green in color, typically 20 to 50 cm long and 2 to 2.5 cm broad, with nine longitudinal ridges. They have a linear shape and are three-sided pods [1].

Habitat of M.O
M.O is indigenous to Himalayan foothills of South Asia from northern Pakistan to northern West Bengal State. It grows at elevations from sea level to 1400 m. M.O has become familiar in other parts of India, Nepal, Afghanistan, Bangladesh, Srilanka [6].

Phytochemistry of M.O
Moringa is rich in compounds containing sugar, rhamnose and it is rich in unique groups of compounds called glucocinolates and isothiocyante. It is also rich in vitamins and minerals and more commonly recognised phytochemicals are carotenoids [7].

Table 1: Phytochemistry of M.O [7]

SI. No.	Group	Phytoconstituents
1	Flavonoids	Kaempferol, Quercetin, Apigenin, Myricetin, Rutin, Rhamnetin
2	Glucosinolate	4-o (a-L-rhamnopyranosyloxy)-benzyl glucosinolate, 4- [(a-L-rhamnopyranosyloxy) benzyl] isothiocyanate.
3	Glycoside	Niazirin, niazimicin, Pterygospermin, niaziridin
4	Phenolic acid	Gallic acid, Ellagic acid, Ferulic acid, Caffic acid
5	Alkaloids	Marumoside A and Marumoside B

Traditional uses of M.O

M.O is often referred to as the "Mother of Medicine" due to its encompassing nutritional and medicinal attributes [8]. Its versatile capabilities include wound healing, stress reduction, immunity enhancement, as well as the regulation of blood glucose levels and blood pressure. Virtually every component of this plant boasts beneficial properties that contribute to the alleviation of various conditions such as anemia, asthma, headache, joint pain, fever, and diarrhea. The leaves of the Moringa are effective in treating eye and ear infections, while its flowers contribute to the reduction of cholesterol levels.

Nutritional composition of M.O

Table 2: Nutritional composition of M.O fresh leaves [9]

Nutrients	Amount/100 g
Energy (kcal)	92
Carbohydrate (g)	12.5
Protein (g)	6.7
Fat (g)	1.7
Fibre (g)	0.9
Calcium (mg)	440
Copper (mg)	0.07
Vitamin C (mg)	220
Vitamin E (mg)	448

Anti-diabetic activity of M.O

Human studies

Alessandro Leone *et al*. studied the anti-hyperglycemic activity of M.O Leaf powder on Humans; they took 20 pre-diabetic patients for their study and treated them with M.O leaf powder once with a meal for 2 days. As a result, decrease in fasting blood glucose and post-prandial glucose was observed [10].

Kumari *et al*., studied Antidiabetic Activity of M.O leaf on Humans with type-2 diabetes were treated with tablets made with leaf powder of M.O (8 mg/day) for 40 days. Due to the prolong treatment, the postprandial blood glucose levels and fasting blood glucose level were found to be reduced upto 26% and 28% respectively [11].

Table 3: Anti-diabetic activity of M.O leaves

SI. No.	Model	Treatment	Result	Reference
1.	Humans (58-62 yrs.) (♂,♀) n = 20 Prediabetic	LP 20 g/day Once with meal 2 days	↓FBG ↓PPG	[10]
2.	Type-2 diabetic patients 40 n	LF Tablet 8 g/day 40 days	↓FBG 28% ↓PPG 26%	[11]

[LP- Leaf powder, FBG- Fasting blood glucose, PPG – Postprandial glucose]

Animal studies

Rajnish Gupta *et al.*, studied the anti-hyperglycemic activity of M.O leaves on Albino Wister rats. Diabetes was induced by streptozotocin (50 mg/kg) intraperitoneal and treated them with methanolic extract of M.O leaf (300 mg/ kg b.w) orally for 21 days. As observed after 21 days, there was reduced level of serum glucose and increase in insulin levels [12].

Jaiswal *et al*., studied the anti-hyperglycemic activity of M.O leaves on Albino Wister rats. Diabetes was induced by STZ (55 mg/kg) intraperitoneal and treated them with aqueous extract of M.O leaf (200 mg/kg b.w) orally for 21 days. They observed the reduction in blood glucose levels, increase in glucose uptake level, Hb, total protein, and insulin [13].

Adeolu Alex *et al.*, studied the anti-hyperglycemic activity of M.O leaves on Albino rats. Diabetes was induced by STZ (70 mg/kg), intraperitoneal and treated them with aqueous extract of M.O leaf (100 mg/kg b.w) twice a day for 21 days. As the result, increase in insulin level, body weight and decrease in blood glucose was observed [14].

Table 4: Anti-hyperglycemic activity of M.O leaves

SI. No.	Model	Treatment	Result	Reference
1	Albino Wister rats (♂, ♀) n = 7 STZ (50 mg/kg) i.p	ME 300 mg/kg b.w Oral 21 days	↓Serum glucose ↑ Serum insulin ↑Serum albumin ↑Serum protein	[12]
2	Albino Wister rats (♂) (n = 6) STZ (55 mg/kg) i.p	AqE 300 mg/kg b.w Oral 21 days	↓BG ↑tissue utilization of glucose ↑Hb and total protein. ↑Insulin ↑ BW	[13]
3	Albino rats (♂) (n = 7) STZ (70mg/kg) I.p,	Aq. E 100 mg/kg b.w Oral 21 days	↑Insulin level ↓BG ↑BW	[14]

(STZ- Streptozotocin, AqE- Aqueous extract, LP- Leaf powder, BG-Blood glucose, BW-Body weight, Hb-Haemoglobin, ME- Methanol extracts)

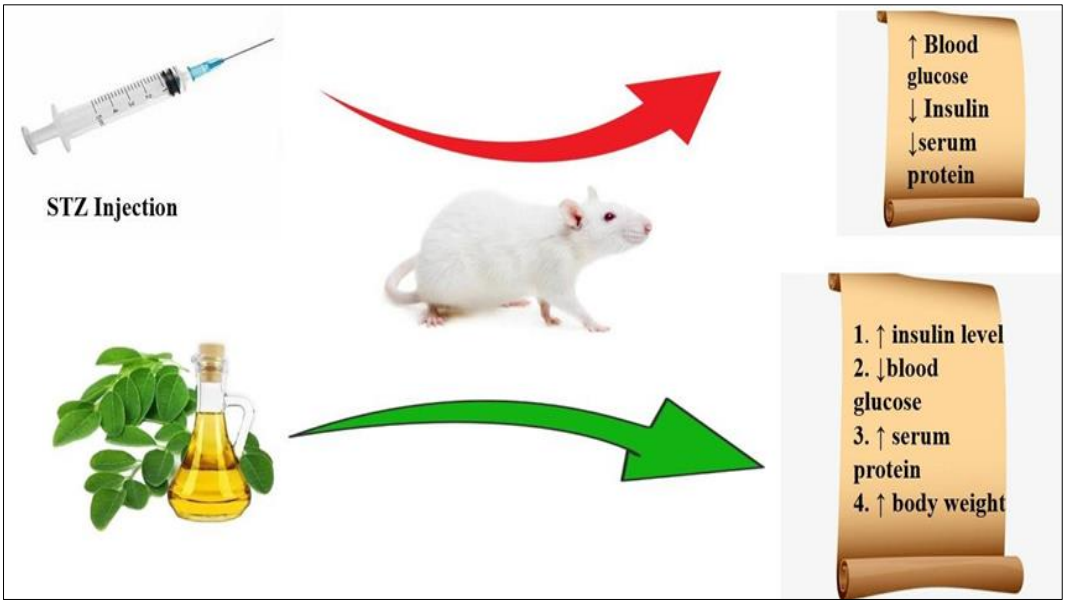

Fig 1: Schematic representation of Anti-hyperglycemic activity of M.O leaves

Conclusion

M.O leaf extracts, both methanolic and aqueous, reduced serum glucose and increased insulin levels in diabetic Albino Wister rats. They not only lowered blood glucose but also improved glucose uptake, Hb levels, total protein, and insulin levels in these rats, suggesting a comprehensive diabetes management effect. Aqueous M.O leaf extract consistently increased insulin, improved body weight, and lowered blood glucose in Albino rats when given twice daily over 21 days. In pre-diabetic patients, M.O leaf powder, consumed with meals for two days, rapidly reduced fasting and post-prandial glucose levels. Individuals with type-2 diabetes experienced sustained reductions in postprandial and fasting glucose over 40 days with M.O leaf powder tablets. In conclusion, M.O leaves showed significant anti-diabetic potential in both animal and human models with rapid and sustained effects on blood glucose and insulin levels. However, further research and clinical trials are needed for a deeper understanding and optimal human dosage determination.

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