Hindawi
Journal of Food Quality
Volume 2023, Article ID 6658241, 7 pages
https://doi.org/10.1155/2023/6658241

Research Article

Moricandia sinaica (Boiss.): A Potent Source of Hypoglycaemic and Antidiabetic Remedy

Riaz Ullah,[1] **Abdelaaty A. Shahat**,[1] **Ahmed A. Hammad**,[2] **Ali S. Alqahtani**,[1] **Fahd A. Nasr**,[1] **Mohammed S. Alharbi**,[1] **Mohammed R. Alhuzani**,[3] **and Akash Tariq**[4]

[1]*Department of Pharmacognosy, College of Pharmacy, King Saud University, Riyadh 11451, Saudi Arabia*
[2]*Department of Internal Medicine, Faculty of Medicine, Fayoum University, Fayoum 63514, Egypt*
[3]*Department of Pharmaceutics, College of Pharmacy, King Saud University, Riyadh, Saudi Arabia*
[4]*State Key Laboratory of Desert and Oasis Ecology, Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi 830011, China*

Correspondence should be addressed to Riaz Ullah; rullah@ksu.edu.sa and Abdelaaty A. Shahat; ashahat@ksu.edu.sa

Received 28 May 2023; Revised 23 November 2023; Accepted 7 December 2023; Published 15 December 2023

Academic Editor: Timothy Omara

Here, we evaluated the antidiabetic and hypoglycaemic activities of *Moricandia sinaica*, a species of the Brassicaceae family, for the first time. The hypoglycaemic and antidiabetic activities of the *M. sinaica* shoot's methanol extract (MOR-1), butanol fraction (MOR-2), and aqueous fraction (MOR-3) were examined against streptozotocin-induced diabetes model in albino Swiss mice. The mice were divided into eight groups (each group consisted of 6 mice). MOR-1 (100 and 200 mg/kg), MOR-2 (100 and 200 mg/kg), and MOR-3 (100 and 200 mg/kg) were administered to groups III, IV, V, VI, VII, and VIII, respectively, for 15 days (daily). The blood samples were haematologically and biochemically assessed at 0 days, 7 days, and 15 days. Mice in group I were kept untreated as control while group II was treated with glibenclamide as standard. Antidiabetic effects increased with MOR-1 and MOR-2 doses in a dose-dependent manner. MOR-2 treatment (200 mg/kg) yielded the best results (29.56% and 40.07% after 7 and 15 days, respectively) compared to the results obtained at zero days. MOR-2 (200 mg/kg) showed the greatest decline in glucose levels (27.67% and 41.13% after 7 and 15 days, respectively). The results concluded that *M. sinaica* exhibited potential hypoglycaemic activity.

1. Introduction

Diabetes mellitus (DM) is a hyperglycaemic condition that develops when pancreatic beta cells fail to synthesise enough insulin and the body is unable to use the synthesised insulin or a combination of these two conditions [1–3]. Diabetes causes numerous major complications including cardiovascular diseases, renal disorders, cerebrovascular diseases, immune system problems, and inflammation. According to epidemiological studies, sex, age, and ethnicity are among the major factors that contribute to the development of DM and its complications [4]. Most government agencies and public health organisations are unaware of the present effects of this disease and its consequences, despite the fact that DM is one of the major health crises of the twenty-first century. In rich countries, it is suggested that 90% to 95% of those who have been diagnosed with diabetes typically have type II diabetes and 5% to 10% have type I diabetes. The relative prevalence of type I and type II diabetes in developing and underdeveloped nations has not been thoroughly documented [5]. Diabetes type II is evolving as one of the new clinical issues especially in children [6]. However, the precise cause of DM remains unclear. According to previous studies, the disease is influenced by genes, environmental factors, and other pathological diseases such as autoimmune destruction of pancreatic beta cells, resulting in insulin shortage and other abnormalities that result in resistance to insulin action [2, 3, 5].

Plants are globally used for both therapeutic and preventive purposes. Numerous plants have potential roles in the treatment of diabetes [7, 8]. Medicinal herbs are also

readily available and affordable to treat diabetes [9, 10]. Plant extracts also display potential hypoglycaemic effects in diabetes-induced animals [11]. In addition, several secondary plant metabolites have been formulated and used to treat DM [11]. Moreover, the benefits of plant extracts as antidiabetic agents in alloxan-induced and streptozotocin-induced diabetic animal models have been demonstrated [11]. Hence, isolating, purifying, and characterising novel compounds that can control blood glucose levels and activate the damaged β cells to resecrete insulin are of utmost importance to treat this chronic disease.

The plant *M. sinaica* investigated in the current study belongs to the family Brassicaceae and the genus *Moricandia*. The family Brassicaceae contains numerous food and oil seed crops as well as numerous significant decorative plants and noxious weeds and is commercially significant [12]. Few studies on *Moricandia* species such as *M. nitens* [12] and *M. arvensis* [13] have shown their antidiabetic activities. Our previous *in vivo* study demonstrated that large doses of *M. sinaica* exhibited remarkable cardiac and nephroprotective effects as well as analgesic, anti-inflammatory, and antipyretic effects [14, 15].

In continuation with a previous study, keeping in mind the medicinal importance of *M. sinaica* (grown in Saudi Arabia), the aim of the current study was to report the antidiabetic properties of *M. sinaica* in streptozotocin-induced diabetic mice.

2. Materials and Methods

2.1. Plant Material. The aerial parts of *M. sinaica* (Boiss.) (Wadi Hafar-Al Batin, Saudi Arabia) were collected in April 2017 and taxonomic identification was performed by a plant taxonomist at the herbarium unit of the College of Pharmacy of King Saud University in Riyadh, Saudi Arabia, where a voucher specimen was deposited under the code number SY284.

2.2. Plant Extraction. The aerial parts of *M. sinaica* were cleaned with distilled water and dried in the shade at room temperature for two months. To prepare the methanolic extract, 830 g of dried powdered shoot were macerated with 80% (v/v) aqueous methanol (MeOH) yielding 141.8 g of a methanolic extract. A portion of the extract was concentrated to dryness by using a rotary evaporator (bath temperature 45°C) yielding MOR-1, 36 g. The remaining extract was concentrated, placed in 120 mL of distilled water, sonicated for 30 mins, and defatted with hexane before extraction with butanol. The butanol and aqueous fractions, designated MOR-2 (51 g) and MOR-3 (63 g), respectively, were concentrated until dry.

2.3. Animals. Swiss albino male mice (20–25 g, of similar age) were procured from the Experimental Animal Care Centre at the National Research Centre in Cairo, Egypt, and kept under regulated circumstances (22–25°C, 55% humidity, and a 12–12 h light-dark cycle). Different *M. sinaica* extracts were administered to the mice, and the mice had unrestricted access to water. The mice were exposed to the test environment for one week before usage. This study was approved by the Ethical Committee for Animal Experimentation (approval no. 20-035, National Research Centre, Egypt). The study adhered to the National Institutes of Health's Guide for the Care and Use of Laboratory Animals [16].

2.4. Antidiabetic Activity (Induction of Streptozotocin-Induced Diabetes). Streptozotocin (STZ) in 0.1 M of cold citrate buffer (pH = 4.5) was administered intraperitoneally to induce diabetes. Diabetes was confirmed by measuring fasting blood glucose levels [17]. Eight groups of six mice each were formed from the total of 48 mice. Diabetic mice in group I (taken as the control group) and group II received the standard drug glibenclamide at a dose of 5 mg/kg/day as standard. The groups III, IV, V, VI, VII, and VIII were treated with MOR-1 (100 mg/kg), MOR-1 (200 mg/kg), MOR-2 (100 mg/kg), MOR-2 (200 mg/kg), MOR-3 (100 mg/kg), and MOR-3 (200 mg/kg), respectively. All the extract treatment was for 15 days daily. Finally, blood samples were drawn for haematological and biochemical markers on days 7 and 15. In animals that had fasted overnight, blood glucose levels by using a Reflotron Plus analyzer (Roche, Germany) and body weights were measured weekly. Blood collection did not require anesthesia [18].

2.5. Evaluation of Hypoglycaemia. Two groups of animals were used for each extract. Animals received doses of 100 and 200 mg/kg as stated. The experiment was conducted in accordance with a previously outlined process [19]. In brief, we set up eight groups of animals ($n = 6$) for the hypoglycaemia investigation. One group received the standard hypoglycaemic medication Daonil® (glibenclamide) at a dose of 1 mg/kg of body weight, while the other groups received extracts or fractions under investigation. Animals were administered the extracts, fractions, and medications orally after a 24-hour fast. Blood samples were taken before administering the medication (zero time). Blood samples were taken again after 7 days and 15 days. The Reflotron Plus analyzer (Roche, Germany) instrument was used to measure the level of glucose in blood.

2.6. Glucose Tolerance Test in Normal Mice. All animals were fasted prior to the trial. Group I received 1 mL of normal saline as control, group II received glibenclamide (1 mg/kg), and the remaining six groups received a separate extract at 100 or 200 mg/kg body weight. The animals were administered a load of glucose (3 g/kg p.o.) [20] before blood samples were taken at intervals of 30, 60, 90, and 120 mins after medication administration. Serum glucose levels were immediately measured using a Roche Reflotron (Germany) glucose measurement kit to compare the hypoglycaemic effects of the investigated extracts/fractions with those of the control and standard groups.

2.7. Biochemical Parameters. The animals were also treated for seven days at a dose of 400 mg/kg body weight. After administering 1 mg/kg of alloxan, the levels of triglycerides (TG), cholesterol, high-density lipoprotein cholesterol

Table 1: Antidiabetic study of plant extracts-induced streptozotocin in mice for two-week treatments.

Treatments	Dose (mg/kg)	Glucose level (mg/dl)				
		0 days	7 days		15 days	
		Mean ± S.E	Mean ± S.E	% change	Mean ± S.E	% change
Control (STZ)	60	310.83 ± 8.29	312.50 ± 7.87		291.83 ± 6.15	
Glibenclamide	5	315.66 ± 8.04	153.50 ± 4.99***	51.37↓	142.33 ± 5.22***	54.91↓
MOR-1	100	307.50 ± 9.67	304.16 ± 5.49		292.16 ± 6.86	4.98↓
MOR-1	200	312.16 ± 7.74	301.50 ± 6.70	3.41↓	284.00 ± 6.27*	9.02↓
MOR-2	100	338.16 ± 11.30	286.66 ± 6.25**	15.22	260.83 ± 6.62***	22.86
MOR-2	200	331.50 ± 10.76	233.50 ± 9.60***	29.56↓	198.66 ± 5.05***	40.07↓
MOR-3	100	302.33 ± 5.71	307.33 ± 9.43		319.33 ± 17.88**	5.62↑
MOR-3	200	310.33 ± 11.54	339.83 ± 9.37	9.37↑	342.00 ± 6.48*	10.20↑

All values represent mean ± SEM. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; ANOVA, followed by Dunnett's multiple comparison test. 7 days and 15 days compared with 0 days.

Table 2: Hypoglycaemic study of plant extracts in mice treated for two weeks.

Treatments	Dose (mg/kg)	Glucose level (mg/dl)				
		0 days	7 days		15 days	
		Mean ± S.E	Mean ± S.E	% change	Mean ± S.E	% change
Normal		108.93 ± 3.30	112.66 ± 3.71	3.42↑	110.61 ± 4.93	
Glibenclamide	5	116.66 ± 2.60	64.65 ± 2.00***	44.58↑	53.16 ± 2.01***	54.52↓
MOR-1	100	107.05 ± 6.55	112.66 ± 3.54	5.24↑	104.31 ± 2.16	2.55
MOR-1	200	115.83 ± 3.81	98.11 ± 3.47**	15.29↓	95.80 ± 4.55**	17.29↓
MOR-2	100	117.00 ± 3.10	83.35 ± 2.63***	28.76↓	75.48 ± 3.10***	35.48↓
MOR-2	200	118.83 ± 3.73	89.95 ± 4.44***	27.67↓	69.95 ± 1.52***	41.13↓
MOR-3	100	113.16 ± 3.19	127.16 ± 4.81*	12.37↑	137.00 ± 4.78**	21.06↑
MOR-3	200	104.48 ± 3.94	134.83 ± 3.84***	29.04↑	143.50 ± 3.28***	37.42↑

All values represent mean ± SEM. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; ANOVA, followed by Dunnett's multiple comparison test. 7 days and 15 days compared with 0 days.

(HDL-C), very low-density lipoprotein (VLDL-C), and low-density lipoprotein cholesterol (LDL-C) were measured after 72 h using the Reflotron diagnostic kit (Roche, Germany).

2.8. Statistic Evaluation. Data were statistically evaluated using a one-way analysis of variance (ANOVA) and Student's *t*-test, followed by Dunnett's multiple comparison test. The data were presented as mean standard deviation (SD). The thresholds for statistical significance were set at 0.05, 0.01, or 0.001.

3. Results

3.1. Antidiabetic Activity. The glucose-lowering behaviour was assessed as follows: normal mice were used to test the effects of the *M. sinaica* extracts at doses of 100 and 200 mg/kg body weight on fasting blood sugar levels. The results are summarised in Table 1. When compared to a conventional medicine, MOR-2 at 200 mg/kg of body weight lowered levels of glucose by as much as 29.56% (7 days) and 40.07% (15 days). The second-highest decrease was discovered following the treatment with 100 mg/kg of body weight of the MOR-2 fraction, which were 15.22% (7 days) and 22.86 (15 days).

3.2. Hypoglycaemic Activity. Normal mice were used to test the effects of *M. sinaica* extracts at doses of 100 and 200 mg/kg body weight on fasting blood sugar levels. Table 2 presents the results of the study. When compared with a conventional medicine, MOR-2 at 200 mg/kg of body weight lowered the levels of glucose by as much as 27.67% (7 days) and 41.13% (15 days). As shown in Table 2, a steady decline in blood glucose levels was observed, and as the dose of each fraction increased from 100 to 200 mg/kg body weight, the hypoglycaemic activity also increased. The second-highest decrease was discovered following treatment with 100 mg/kg of body weight of the MOR-2 fraction, which were 28.76% (7 days) and 35.48% (15 days).

3.3. Glucose Tolerance. After 30, 60, 90, and 120 mins, the blood glucose levels of mice administered with 100 and 200 mg/kg body weight of all the studied fractions were examined. When the extracts were administered, the glucose levels first increased between 30 and 60 mins and then decreased between 90 and 120 mins. As shown in Table 3, when mice were administered with 200 mg/kg body weight, MOR-2 was found to be the best extract.

3.4. Biochemistry Profile. Table 4 lists the additional parameters that were measured, including cholesterol, triglycerides, HDL, LDL, and VLDL. The profiles of lipids with the studied fraction at both dose levels exhibited a considerable alteration. After receiving a dose of 200 mg/kg of MOR-2, a very large change in HDL (47%) was discovered.

Table 3: Glucose tolerance in normal mice treated with extracts.

Treatments	Dose (mg/kg)	0 hours	30 minutes		60 minutes		90 minutes		120 minutes	
		Mean ± S.E	Mean ± S.E	% change	Mean ± S.E	% change	Mean ± S.E	% change	Mean ± S.E	% change
Normal		110.66 ± 1.83	246.16 ± 9.79***	122.44↑	300.00 ± 4.70***	171.08↑	260.83 ± 4.49***	135.69↑	214.33 ± 9.63***	93.67↑
Glibenclamide	5	113.00 ± 3.22	195.83 ± 4.77***	73↑	174.50 ± 5.54***	54.42↑	151.50 ± 2.62***	34.07↑	136.33 ± 2.33***	20.64↑
MOR-1	100	113.66 ± 3.57	243.16 ± 25.08***	113.93↑	293.50 ± 9.10***	158.21↑	277.66 ± 9.72***	141.64↑	224.50 ± 11.38***	97.50↑
MOR-1	200	124.50 ± 15.12	292.66 ± 6.60***	135.07↑	328.83 ± 3.93***	164.12↑	340.00 ± 5.96***	173.09↑	150.16 ± 4.94***	181.25↑
MOR-2	100	108.00 ± 3.78	254.83 ± 9.18***	145.21↑	207.66 ± 6.17***	92.28↑	194.83 ± 6.63***	80.40↑	163.66 ± 7.99***	51.54↑
MOR-2	200	114.16 ± 3.20	223.50 ± 8.84***	95.76↑	199.3 ± 5.88***	74.59↑	163.66 ± 3.44***	43.35↑	152.00 ± 3.55***	33.13↑
MOR-3	100	104.96 ± 2.92	286.66 ± 10.47***	173.10↑	320.50 ± 3.79***	205.33↑	298.33 ± 22.99***	173.09↑	306.00 ± 5.56***	191.52↑
MOR-3	200	109.83 ± 3.05	295.33 ± 8.79***	168.89↑	333.83 ± 5.71***	203.94↑	330.33 ± 4.17***	200.75↑	327.50 ± 5.14***	198.17↑

All values represent mean ± SEM. *** $p < 0.001$; ANOVA, followed by Dunnett's multiple comparison test. 30 m, 60 m, 90 m, and 120 m compared with 0 hour.

Table 4: Effect of extract on metabolism and serum lipoproteins of normal and diabetic mice.

Treatments	Dose (mg/kg)	Cholesterol (mg/dl)		Triglycerides (mg/dl)		HDL-C (mg/dl)		VLDL-C (mg/dl)		LDL-C (mg/dl)	
		Mean ± S.E	% change	Mean ± S.E	% change	Mean ± S.E	% change	Mean ± S.E	% change	Mean ± S.E	% change
Normal		121.66 ± 3.08		89.65 ± 2.44		51.30 ± 2.38		17.93 ± 0.48		52.43 ± 3.49	
Diabetic (STZ)		248.00 ± 5.24***	104↑	196.50 ± 4.75***	119↑	26.03 ± 1.20***	49↓	39.30 ± 0.95***	119↑	182.66 ± 5.44***	248↑
Glibenclamide	5	137.16 ± 2.93	45↓	108.93 ± 2.91***	45↓	42.15 ± 1.24***	62↑	21.78 ± 0.58***	45↓	73.23 ± 3.21***	60↓
MOR-1	100	225.50 ± 5.70	9↓	198.33 ± 2.96		25.98 ± 0.99		39.66 ± 0.59		159.85 ± 6.56*	12↓
MOR-1	200	208.16 ± 3.91***	16.↓	179.16 ± 5.95*	9↓	27.50 ± 1.02	6↑	35.83 ± 1.19*	9↓	144.83 ± 3.56***	21↓
MOR-2	100	189.00 ± 4.15***	24↓	155.66 ± 4.05***	21↓	29.98 ± 1.05*	15↑	31.13 ± 0.81***	21↓	127.88 ± 4.58***	30↓
MOR-2	200	158.83 ± 3.43***	36↓	134.00 ± 2.12***	32↓	38.30 ± 1.81***	47↑	26.80 ± 0.42***	32↓	93.73 ± 3.32***	49↓
MOR-3	100	245.16 ± 7.14		219.83 ± 7.04*	12↑	27.73 ± 0.73	7↑	43.96 ± 1.40*	12↑	173.45 ± 6.46	5↓
MOR-3	200	256.16 ± 3.69	3↑	218.00 ± 5.65*	11↑	30.63 ± 0.54**	18↑	43.60 ± 1.13*	11↑	181.93 ± 2.99	

All values represent mean ± SEM. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; ANOVA, followed by Dunnett's multiple comparison test. Treated groups compared with the diabetic group.

The highest LDL (49%) was produced by fraction MOR-2 at a dose level of 200 mg/kg, followed by MOR-2 (30%) at a dose level of 100 mg/kg. The greatest results for VLDL were likewise seen in the same fractions (32 and 21%) at 200 and 100 mg/kg body weight, respectively. Cholesterol and triglyceride levels significantly changed as a result of the two MOR-2 fractions.

4. Discussion

DM is one of the worst health problems of the twenty-first century. Diabetes is a primary factor with several major consequences, including heart disease, stroke, kidney problems, inflammatory bowel disease, immune system problems, and obesity [4]. In this study, the hypoglycaemic and antidiabetic effects of various *M. sinaica* extracts were investigated. Among the three tested extracts (MOR-1, MOR-2, and MOR-3), the MOR-2 group resulted in a significant decrease in blood glucose levels in mice at both doses of 100 and 200 mg/kg body weight, which was comparable to that of glibenclamide (standard drug). In the glucose tolerance test, the active butanol extract considerably lowered glucose levels after 60, 90, and 120 mins, which was comparable to that of glibenclamide. In terms of the biochemical parameters, butanol extract showed the greatest increase (47%) in HDL-C levels when compared with other extracts/fractions examined. It also significantly altered the levels of cholesterol, triglycerides, VLDL-C, and LDL-C, suggesting that it was the most effective extract. The considerable decrease in blood glucose levels in both normal and diabetes-induced experimental animals and the glucose tolerance test, particularly by butanol extract, ranging from 22 to 41% was a sign of hypoglycaemic activity of the *M. sinaica*. According to previous studies of Davis [21], a 25% decrease in blood glucose levels is deemed to have a significant hypoglycaemic effect. To date, the precise cause of DM remains unknown. According to scientists, the disease appears to be influenced by genes, environmental factors, and other pathological diseases, such as autoimmune destruction of pancreatic beta cells, resulting in insulin shortage and other abnormalities that result in resistance to insulin action [2, 3, 5]. Natural products such as plant extracts and their bioactive compounds may be used for the treatment and/or prevention of type II diabetes. This is related to their effects on the pancreatic β cell activity, increase in the inhibitory action against insulinase enzyme, and increase in insulin sensitivity/insulin-like activity [22]. We have previously reported 24 phytoconstituents such as malic acid, gluconapin, P-coumaric acid, tryptophan, kaempferol-3-o-β-glucosyl-7-o-α-rhamnoside, quercetin-3-o-β-glucosyl-7-o-α-rhamnoside, kaempferol-3-o-β-(2$''$-o-galactosyl)-rutinoside, sinapic acid 3-o-glucoside, caffeic acid derivative, isorhamnetin 7-o-dicaffeoyl-3-o-rutinoside, and gluconapin. [14]. The antidiabetic potential may be due to the presence of these phenols and flavonoid derivatives. Since a study reported that usually flavonoids and phenolic compounds found in medicinal plants and foods were the principal constituents responsible for various antidiabetic activities [23], these findings agreed and created a link with our current results. Phytochemical therapies can be developed into novel pharmacological treatments. So, the butanol extract of *Moricandia sinaica* (Boiss.) (aerial parts) could be subjected to other purifications and toxicological and biological investigations to support existing antidiabetic therapies.

5. Conclusion

Moricandia sinaica (Boiss) has several therapeutic applications. In this study, we confirmed that the butanol extract (MOR-2) exhibited potential hypoglycaemic activity, whereas MOR-1 and MOR-3 possessed the hypoglycaemic potential. Hence, further studies are recommended to isolate the bioactive constituents from butanol, methanol, and aqueous extracts.

Data Availability

The data used to support the findings of the study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

All authors contributed equally to this study.

Acknowledgments

The authors wish to thank the Researchers Supporting Project (no. RSPD2023R1057), at King Saud University, Riyadh, Saudi Arabia, for the financial support.

References

[1] A. Sadiq, U. Rashid, S. Ahmad et al., "Treating hyperglycemia from *Eryngium caeruleum* M. Bieb: *in-vitro*α-g, antioxidant, *in-vivo* antidiabetic and molecular docking-based approaches," *Frontiers in Chemistry*, vol. 8, Article ID 558641, 2020.

[2] N. Rachdaoui, "Insulin: the friend and the foe in the development of type 2 diabetes mellitus," *International Journal of Molecular Sciences*, vol. 21, no. 5, p. 1770, 2020.

[3] K. Khalil and A. Zrieki`, "Factors associated with glycemic control among Syrian patients with type 2 diabetes mellitus," *Research Journal of Pharmacy and Technology*, vol. 15, no. 4, pp. 1701–1708, 2022.

[4] D. Soumya and B. Srilatha, "Late stage complications of diabetes and insulin resistance," *Journal of Diabetes and Metabolism*, vol. 2, no. 09, Article ID 1000167, 2011.

[5] J. J. Joseph, P. Deedwania, T. Acharya et al., "Comprehensive management of cardiovascular risk factors for adults with type 2 diabetes: a scientific statement from the American Heart Association," *Circulation*, vol. 145, no. 9, pp. e722–e759, 2022.

[6] T. Reinehr, "Type 2 diabetes mellitus in children and adolescents," *World Journal of Diabetes*, vol. 4, no. 6, pp. 270–281, 2013.

[7] G. Arumugam, P. Manjula, and N. Paari, "A review: anti diabetic medicinal plants used for diabetes mellitus," *Journal of Acute Disease*, vol. 2, no. 3, pp. 196–200, 2013.

[8] H. Z. Lina, M. M. Samy, A. E. B. Samir, A. M. Fatma, M. T. Kawther, and A. S. Abdelaaty, "Hypoglycemic and

antioxidant effects of Hibiscus rosa-sinensis L. leaves extract on liver and kidney damage in streptozotocin induced diabetic rats," *African Journal of Pharmacy and Pharmacology*, vol. 11, no. 13, pp. 161–169, 2017.

[9] M. T. Yakubu, T. O. Sunmonu, F. B. Lewu, A. O. Ashafa, F. J. Olorunniji, and M. Eddouks, "Medicinal plants used in the management of diabetes mellitus 2015," *Evidence-based Complementary and Alternative Medicine*, vol. 2015, Article ID 467196, 2 pages, 2015.

[10] C. G. Yedjou, J. Grigsby, A. Mbemi et al., "The management of diabetes mellitus using medicinal plants and vitamins," *International Journal of Molecular Sciences*, vol. 24, no. 10, p. 9085, 2023.

[11] J. Karthikeyan, V. Kavitha, T. Abirami, and G. Bavani, "Medicinal plants and diabetes mellitus: a review," *Journal of Pharmacognosy and Phytochemistry*, vol. 6, no. 4, pp. 1270–1279, 2017.

[12] M. M. Khalil, N. Soliman, H. I. Abdel-Moaty, E. Ismael, and D. Y. Sabry, "Anti-Helicobacter pylori, anti-diabetic and cytotoxicity activity of biosynthesized gold nanoparticles using Moricandia nitens water extract," *Egyptian Journal of Chemistry*, vol. 61, no. 4, pp. 691–703, 2018.

[13] M. Marrelli, F. Morrone, M. P. Argentieri, L. Gambacorta, F. Conforti, and P. Avato, "Phytochemical and biological profile of Moricandia arvensis (L.) DC.: an inhibitor of pancreatic lipase," *Molecules*, vol. 23, no. 11, p. 2829, 2018.

[14] S. El-Mekkawy, A. A. Shahat, A. S. Alqahtani et al., "A Polyphenols-rich extract from Moricandia sinaica Boiss. exhibits analgesic, anti-inflammatory and antipyretic activities in vivo," *Molecules*, vol. 25, no. 21, p. 5049, 2020.

[15] A. A. Shahat, H. D. Hassanein, R. Ullah et al., "Renoprotective and cardioprotective potential of Moricandia sinaica (boiss.) against carbon tetrachloride-induced toxicity in rats," *Evidence-based Complementary and Alternative Medicine*, vol. 2022, Article ID 8545695, 12 pages, 2022.

[16] R. S. Sikes and W. L. Gannon, "Guidelines of the American Society of Mammalogists for the use of wild mammals in research," *Journal of Mammalogy*, vol. 92, no. 1, pp. 235–253, 2011.

[17] K. Srinivasan, B. Viswanad, L. Asrat, C. Kaul, and P. Ramarao, "Combination of high-fat diet-fed and low-dose streptozotocin-treated rat: a model for type 2 diabetes and pharmacological screening," *Pharmacological Research*, vol. 52, no. 4, pp. 313–320, 2005.

[18] S. Parasuraman, R. Raveendran, and R. Kesavan, "Blood sample collection in small laboratory animals," *Journal of Pharmacology and Pharmacotherapeutics*, vol. 1, no. 2, pp. 87–93, 2010.

[19] K. El Tahir, *A Guide to Drug Discovery: Directions for Pharmacological Screening for New Synthetic and Natural Compounds Leading to Discovery of New Medicines*, El Tahir Publication, Riyadh, Saudi Arabia, 2007.

[20] H. Pareek, S. Sharma, B. S. Khajja, K. Jain, and G. Jain, "Evaluation of hypoglycemic and anti-hyperglycemic potential of Tridax procumbens (Linn.)," *BMC Complementary and Alternative Medicine*, vol. 9, no. 1, pp. 48–57, 2009.

[21] S. N. Davis, "Insulin, oral hypoglycemic agents and the pharmacology of the endocrine pancreas," in *Goodman and Gilmans the Pharmacological Basis of Therapeutics*, L. L. Brunton, Ed., pp. 1613–1645, McGraw-Hill, New York, NY, USA, 2006.

[22] M. Bnouham, A. Ziyyat, H. Mekhfi, A. Tahri, and A. Legssyer, "Medicinal plants with potential antidiabetic activity-A review of ten years of herbal medicine research (1990-2000)," *International Journal of Diabetes and Metabolism*, vol. 14, pp. 1–25, 2006.

[23] R. Praparatana, P. Maliyam, L. R. Barrows, and P. Puttarak, "Flavonoids and phenols, the potential anti-diabetic compounds from Bauhinia strychnifolia craib. Stem," *Molecules*, vol. 27, no. 8, p. 2393, 2022.