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Research Article

Assessment of Antioxidant and Antihyperglycemic Activities of the Essential Oil of *Micromeria myrtifolia* from Jordan

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ABSTRACT

Background: *Micromeria myrtifolia*, a member of the Lamiaceae family, has been traditionally used in various cultures for its medicinal properties. This study evaluated the antihyperglycemic and antioxidant properties of the essential oil extracted from *its aerial parts*.

Methods: The essential oil was extracted by hydrodistillation using the Clevenger apparatus, and it was analyzed using Gas Chromatography-Mass Spectrometry (GC-MS) to identify its composition. The antioxidant activity was evaluated via the DPPH radical scavenging assay. The antihyperglycemic activity was evaluated in alloxan-induced diabetic Balb/c mice treated intraperitoneally with low (220 mg/kg) and high (440 mg/kg) doses of the essential oil.

Results: The GC-MS analysis identified sesquiterpenes as the major constituents, including caryophyllene (8.40%), copaene (2.13%) caryophyllene oxide (1.80%), germacrene D (1.23%), β-Bourbonene (0.82%), and humulene (0.82%). The essential oil exhibited antioxidant activity, with half maximal inhibitory concentration (IC50) value of 6.21± 0.011 mg/ml.

In vivo studies showed that both low (220 mg/kg) and high (440 mg/kg) doses of the essential oil significantly reduced blood glucose levels in diabetic mice ($p < 0.05$). The lowest reduction was observed at 6 hours post-treatment, where the percent glycemic reduction was 54.50 ± 21.4 % and 35.30 ± 42.7 % for the low-dose and high-dose treatment groups respectively.

Conclusion: The outcomes of this study suggest that the essential oil of *Micromeria myrtifolia* has both antioxidant and antihyperglycemic properties, indicating its potential as a natural therapeutic agent for managing diabetes.

Introduction

Diabetes mellitus (DM) is a serious health burden around the globe. It is a complex, chronic metabolic disorder that affects the endocrine system and is diagnosed by hyperglycemia, an abnormally high blood glucose level (1, 2). It is considered to be one of the leading causes of morbidity and mortality in the world(3, 4). By 2045, it is estimated that 693 million adults will be diagnosed with diabetes, according to the International Diabetes Federation (IDF)(1).

Diabetes is associated with numerous complications that affect both the microvascular and macrovascular systems (5). Early detection and treatment of diabetes helps to reduce the progression rate and life-threatening complications. Depending on the type of diabetes, physicians often prescribe a variety of anti-diabetic drugs to patients to manage blood sugar levels (6). Despite the large number of efficient diabetes treatments, the reality is that there is no perfect solution that works quickly and is free of side effects (6). This leads to an increase in demand for alternative and traditional medicinal systems, which use herbal plants as an important tool in diabetes treatment (6).Plants are considered to have enormous structural diversity, easy availability, affordable prices, and various biological properties (7). These reasons made research and use of plants more vital since more than 45% of all approved drugs from 1981 to 2019 were of natural origin (7, 8).

Along with the increased acceptance and consumer demand for natural products, the market for raw materials, extracts, and essential oils continues to grow (9). Numerous medicinal plants manage diabetes through various mechanisms, such as reducing glucose absorption from the intestine, preventing glucose production in the liver, enhancing glucose uptake by tissues, and stimulating insulin secretion from pancreatic β-cells (10, 11). Historically, natural sources were prominent in disease treatment and served as pivotal starting points for drug discovery (4).

Since ancient times, *Micromeria* (Zofa), which belongs to the *Lamiaceae* family, has been widely used, especially in Mediterranean countries. *M. myrtifolia* is used traditionally as an expectorant and to treat gastrointestinal disorders and gallstone problems, nervous system disorders, respiratory system disorders, including infections and pneumonia, wound and skin infections, and headaches(12-14). However, it is reported to have a lot of pharmacological effects, including cytotoxic, antirheumatic, antiseptic, and anesthetic effects(15). It is also used to fight asthma, fever, inflammatory disorders, cardiovascular problems, skin diseases, and digestive disorders(12). *Micromeria* species are widely regarded as a rich source of essential oils (13).

The major compounds reported in the essential oils derived from *M. myrtifolia* collected from several geographical regions were β-caryophyllene (BCP), caryophyllene oxide (BCPO), and alpha-copaene (α-copaene)(13, 16). Jordan possesses rich plant biodiversity, comprising approximately 2,500 species. Several native plants to Jordan have been scientifically investigated for their pharmacological effects, particularly in managing diabetes (11). The aim of this study is to evaluate the antihyperglycemic effect of the essential oil obtained from aerial parts of *M. myrtifolia* collected from Jordan. To the best of our knowledge, there is no literature data concerning the antihyperglycemic properties of *M. myrtifolia* present particularly from Jordan.

Methods

Plants Material

The dried aerial parts of *M. myrtifolia* used for the investigation were acquired from a Jordanian market in Ajloun in June 2022. These plants were originally collected during the month of June 2021 and subsequently dried. The flowers and leaves were carefully separated from the stems for individual study purposes. The identification of *M. myrtifolia* was conducted by Dr. Hatem Tayifor (Jordan Royal Botanical Garden).

Preparation of Plant Extracts

M. myrtifolia dried flowers and leaves were ground using an electric blender (Reren KR-500A). One hundred grams of ground *M. myrtifolia* was added to 1 liter of distilled water in a 2-liter round-bottom flask. The setup was then subjected to hydrodistillation using a Clevenger-type apparatus for a duration of 5-6 hours.. The collected essential oil was subsequently dried under anhydrous sodium sulfate and stored in a sealed amber glass container at 4 °C until further use.

GC-MS Analysis

GC-MS analysis was carried out following the procedure described in previous studies with slight modifications (Naik et al., 2021; Hasan et al., 2023).. The analysis utilized a Shimadzu QP2020 GC-MS system equipped with a GC-2010 Plus (Shimadzu Corporation, Kyoto, Japan), featuring a split-splitless injector and a DB5-MS fused silica column (5% phenyl, 95% polydimethylsiloxane, 30 m × 0.25 mm, 25 µm film thickness). A linear temperature program was employed to facilitate the separation of different components. The oven temperature was initially held at 50°C for 1 minute, followed by a temperature ramp of 7 °C/min until reaching 280 °C, where it was held for 10 minutes, resulting in a total run time of 44 minutes. The injector temperature was maintained at 260 °C, with a split ratio of 20:1, and an injection volume of 1 µL. Helium was used as the carrier gas, with a flow rate of 1.50 mL/min and a pressure control of 88.3 kPa.

The mass spectrometer was set with an ion source temperature of 240 °C, and an interface temperature of 250 °C, and operated at an electron ionization energy of 70 eV. The scan range was set between 35 and 500 amu, with a scan speed of 1666. A solvent cut-off was applied at 3 minutes, and data collection began at 4.5 minutes. Data were processed using Lab-Solution GC-MS software (version 4.45SP1).

DPPH Scavenging Activity

The determination of antioxidant activity was adopted from Kandi (17) with minor modifications. A stock solution of DPPH was prepared by mixing 0.025mg/mL of DPPH per 1 mL of methanol. Then, a solution consisting of 0.5 mL of essential oil was added to 1.5 mL of methanol. Serial dilutions of this solution were made by transferring 1mL of the essential oil solution into separate test tubes containing 1 mL of methanol. In another set of 6 test tubes, each containing 1.5mL of DPPH solution, 100 µL of the previously diluted solution was added. Each mixture was tightly sealed, covered with microfilm, vortexed briefly, and incubated in the dark at 37°C for 30 minutes. Following incubation, 200 µL were transferred from each test tube in triplicate to a 96-well cell plate. Ascorbic acid was used as a reference compound. The absorbance of each well was measured at 517 nm using a UV/VIS spectrophotometer (BEL PHOTONIC, Italy). The ability to scavenge the DPPH radical was calculated using the following equation (18):

DPPH radical scavenging activity (%) = [($Abs_{control}$ - Abs_{sample})]/($Abs_{control}$)]*100

where Abs control is the absorbance of DPPH radical + methanol; Abs sample is the absorbance of DPPH radical + sample extract/standard.

In Vivo Assessment of Antihyperglycemic Potential

Ethical Approval

This study was approved by the Institutional Review Board (IRB) of the Faculty of Pharmacy at Applied Science Private University (ASU) under approval number 2024-PHA-43. The research adhered strictly to the ethical guidelines set by the IRB.

Experimental Diabetes Grouping and Dosing of Animals

Forty healthy adult (6–10 weeks of age) male BALB/c mice weighing between (25–30g) were used. The mice were maintained under standard conditions. The animals were kept in suitable cages and maintained under (12 h light and 12 h dark cycle, 22–25 °C, 45–65% humidity) with *ad libitum* access to food and tap water in accordance with the in-house ethical guidelines for animal protection.

Induction of Diabetes in Mice

Diabetes was induced by a single intraperitoneal (IP) injection of alloxan monohydrate to fasted mice at a dose of 200mg/kg b.wt, followed by an oral glucose solution with a concentration of 10% for 48 hours to prevent hypoglycemia. On the day of the experiment, animals were fasted for five hours, and blood glucose levels were tested.

Experimental Procedure of Administering *M.myrtyfolia* Essential Oil on Mice

The effect of *M. myrtifolia* essential oil was studied in alloxan-induced diabetic mice. The experimental mice were divided based on their blood glucose levels into 6 groups of 6 animals each:

- **Group 1:** normal healthy control.
- **Group 2:** diabetic mice **were** given intraperitoneal 0.1 mL dimethyl sulfoxide (DMSO), the solvent used to solubilize the extract.
- **Group 3:** diabetic mice were given intraperitoneal essential oil at a dose of 220 mg/kg body weight (b.wt).
- **Group 4:** diabetic mice were given intraperitoneal essential oil at a dose of 440mg/kg b.wt.
- **Group 5:** diabetic mice were given intraperitoneal insulin standard at a dose of 1 IU/kg b.wt.
- **Group 6:** diabetic mice were given intraperitoneal Glibenclamide standard at a dose of 3mg/kg b.wt.

Blood Collection and Glucose Determination

Blood sugar levels were assessed for each animal immediately before treatment (at 0 minutes) as a baseline measurement. Subsequently, blood samples were taken at 0.5, 1, 1.5, 2, 4, and 6 hours after treatment. The blood glucose level was measured from tail tips and was determined using the glucometer (Accu-Check® Performa, Germany). The percentage change in blood glucose level from the initial glycemia was calculated using the following formula:

$$\%\text{Glycemic change} = (G_x - G_o)/G_o * 100$$

Where G_o is the initial blood glucose value at zero time after fifteen hours of fasting (mg/dL) and G_x is the blood glucose value at x minutes after tested compounds administration (mg/dL) (Yeap, et al., 2013).

Statistical Analysis

All values are presented as mean percent radical scavenging activity after calculations were done for three absorbance readings. The IC_{50} values were calculated from the linear regression analysis of the dose-response data. The biological evaluation data collected were expressed as the means ± standard error of means (SEM) for all 6 mice in each group. Statistical differences between the treated and the control groups were performed using the Statistical Package for the Social Sciences (SPSS) version 24 software. A difference in the mean values of ($p \leq 0.05$) was considered statistically significant.

Results

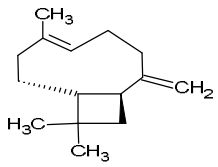
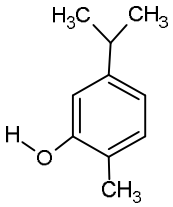
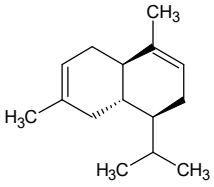
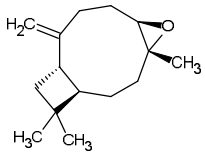
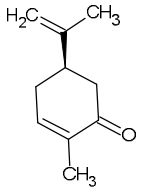
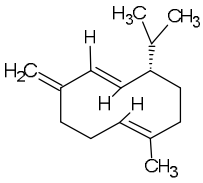
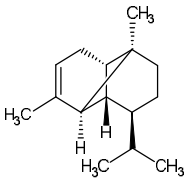
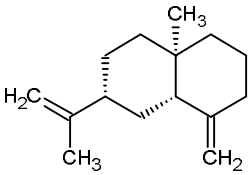
Composition of *M.myrtifolia* Essential Oil (GC-MS analysis)

The components of the essential oil obtained from *M. myrtifolia* were separated and identified by GC-MS. The quantitative composition was expressed as normalized peak area percentages (Area%), which were calculated relative to the sum of all detected peak areas. This normalization describes the relative abundance of constituents as percentage content. The main active constituents (n=13) identified in the oil are listed in Table 1 with their retention times and relative content. The structures are illustrated in Table 2. The oil was dominated by sesquiterpenes such as caryophyllene (8.36%) and caryophyllene oxide (1.77%), along with notable amounts of β-cadinene (2.76%), β-selinene (2.21%), copaene (2.13%), and carvacrol (2.08%), indicating a terpene-rich profile typical of the genus.

Table 1. Major compounds of the essential oil collected from *M. myrtifolia.*

Compounds	Percentage content	Retention time
Caryophyllene	8.36	17.747
β-cadinene	2.76	19.564
β-selinene	2.21	22.089
Copaene	2.13	16.824
Carvacrol	2.08	15.166
Palmitic acid	1.98	26.825
Caryophyllene oxide	1.77	20.246
(-)-Carvone	1.52	14.039
Germacrene D	1.23	18.913
D- Limonene	0.85	9.082
(-)β-Bourbonene	0.82	16.997
Humulene	0.82	18.433
Linalool	0.74	10.733

Table 2. Structure of Active Ingredients Present in the Essential Oil of M. myrtifolia with high percentage.

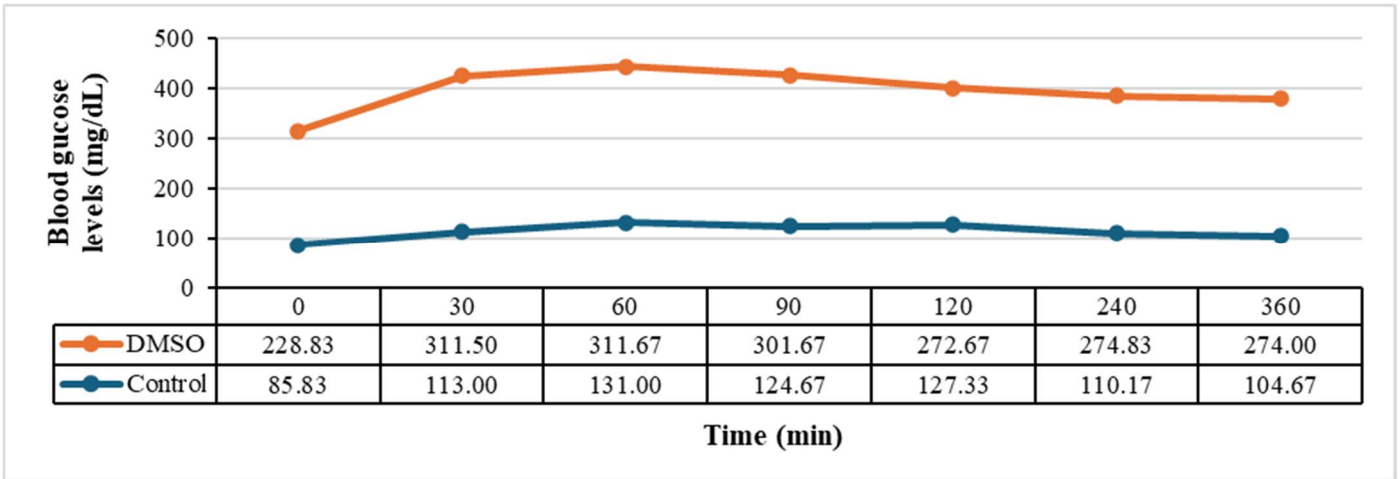
 Caryophyllene	 Carvacrol	 β-Cadinene	 Caryophyllene oxide
 (-)-Carvone	 Germacrene D	 Copaene	 β-selinene

Antioxidant Activity

The DPPH radical scavenging assay demonstrated that the essential oil of M. myrtifolia possesses considerable antioxidant potential. The calculated IC_{50} for *M.myrtifolia* was 6.21± 0.045 mg/ mL, compared to 0.057 ± 0.06 mg/mL for ascorbic acid, illustrating moderate antioxidant activity.

Antihyperglycemic Activity of *M.myrtifolia* Essential Oil on Alloxan-Induced Diabetic Mice

Mice receiving 220 mg/kg and 440 mg/kg of essential oil demonstrated a significantly pronounced antihyperglycemic effect compared to the negative diabetic control group (Group 2; $p<0.05$). Figure 1 illustrates the means of blood glucose in the healthy control group (Group1) and the diabetic negative control group (Group 2) over a 6-hour period. At the baseline (0 minutes), Group 2 shows elevated glucose levels (228.80± 48.6 mg/dL), while the Group 1 maintains normal glucose levels (85.80± 5.9 mg/dL). Blood glucose levels were observed to rise steadily in Group 2, peaking at 60 minutes (311.70 ± 69.0 mg/dL) and remaining consistently elevated throughout the experiment. In contrast, glucose levels remained relatively stable in Group 1, peaking at 60 minutes (131 ± 6.8 mg/dL) followed by a gradual decrease down to 104.67 ± 3.8 mg/dL at 360 minutes. These results confirm a successful diabetes induction and the absence of hypoglycemic activity in DMSO which was used as a vehicle for the treatments. Blood glucose reduction observed in other diabetic mice groups particularly Groups 3 and 4 (administered with a single-dose of *M. myrtifollia* essential oil at two dosage levels) indicates time-dependent reduction in blood glucose. Changes in blood glucose levels is attributed to the treatment received as shown in Table 3 and illustrated in Figure 2. Statistical analysis involved comparing glucose levels at 0 hours to those at 4 and 6 hours to assess time-dependent effects, and between treatment and control groups for 6 hours to evaluate treatment efficacy. Both the low and high doses (Group 3 and 4) of the tested compound resulted in a significant reduction in blood glucose levels when compared to the negative control group (group 2), particularly at the 6 -hour mark, with the low dose showing a more pronounced effect (127 ± 23.4 mg/dL) compared to the high dose (149 ± 46.8 mg/dL). Insulin exhibited the most rapid and significant glucose-lowering effect. The oral antihyperglycemic agent showed a significant effect at 4 hours (225± 46.5mg/dL), while the negative control (DMSO) showed minimal change, indicating no significant inherent hypoglycemic action. These results suggest that the tested compound, especially at low doses, possesses promising antihyperglycemic properties, comparable to the oral antihyperglycemic agent, glipalamide. The significance level was * $p < 0.05$ for t-paired analysis (0 hrs compared to 4 hrs), ** $p < 0.05$ for (0hr compared to 6hrs), ^ comparison between (treatment versus control) after 4 and 6 hrs.



	0	30	60	90	120	240	360
DMSO	228.83	311.50	311.67	301.67	272.67	274.83	274.00
Control	85.83	113.00	131.00	124.67	127.33	110.17	104.67

Figure 1. Mean of blood glucose levels in group1 versus group 2 at different time intervals.

Table 3. Blood glucose levels in different groups of diabetic mice over 6 hours.

Group No	Glucose level (mg/dL)						
	0	30 min	60 min	90 min	120 min	240 min	360 min
2	228.8 ± 48.6	311.5± 70.1	311.7 ± 69.0	301.7 ±65.3	272.7 ± 72.3	274.8 ± 72.0	274 ±70.3
3	279.3 ±61.7	418.5 ± 53.6	425.3 ±54.5	427.5 ±51.5	335.2 ±47.4	177 ±29.6	127± 23.4**^
4	270.7 ± 70	342.8 ± 63.9	367 ± 57.7	290 ±48.8	230.2 ±70.6	140.8 ±74.4	149± 46.8^
5	251.3 ± 63.2	153.3 ±67.1	104.7 ±39.4	78.2± 24.1^	60.7±14.8^	81.8±17.0*^	127±21.0^
6	324.5 ±63.7	375.2 ±46.6	402 ±45.0	402.3 ± 54.0	356.2 ± 50.0	225± 46.5*	238.2± 58.3

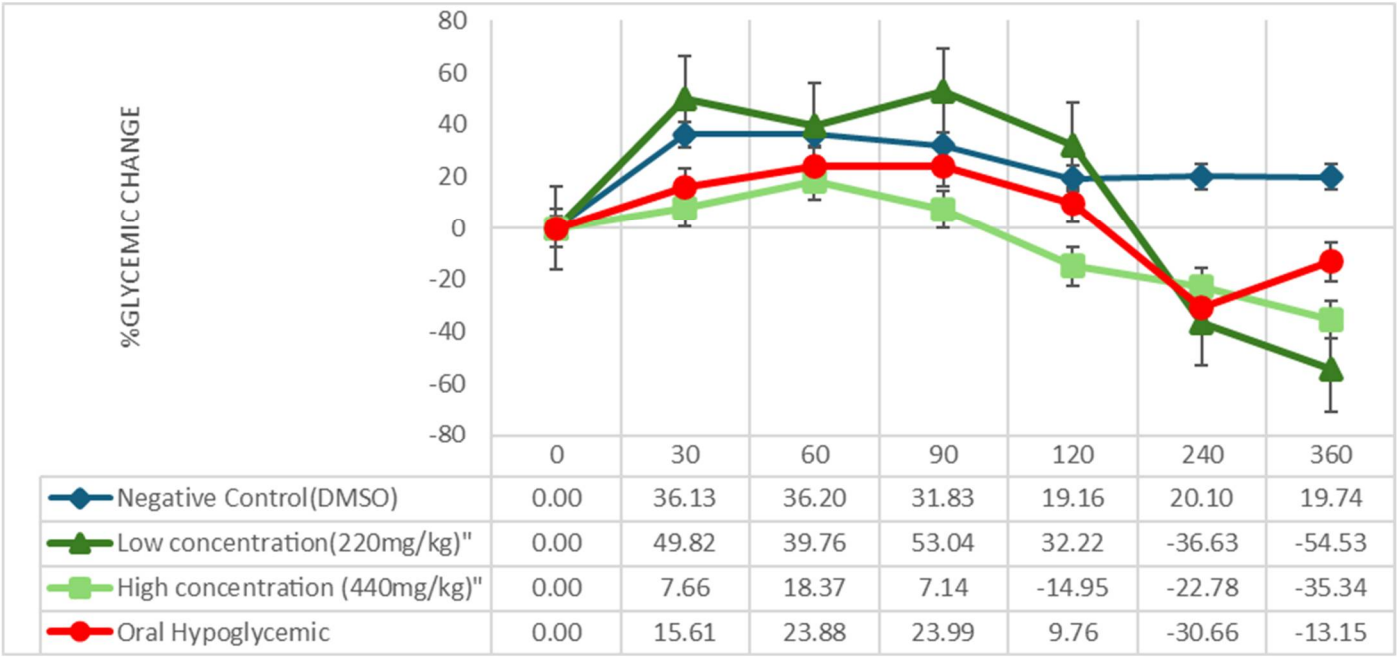


Figure 2. Mean percentage change in blood glucose levels in alloxan-induced hyperglycemic mice at different time intervals after intraperitoneal treatment.

Discussion

Traditional and herbal medicines are essential sources of healthcare for populations in developing countries. These remedies play a crucial role in the development of medicinal formulations, largely derived from herbal extracts that are traditionally prepared and rich in active compounds (19). The *Lamiaceae* family has long been recognized as a valuable source of antihyperglycemic agents. Among its notable members is *M. myrtifolia*, which is esteemed for its medicinal properties. This plant, like others in the family, is deeply integrated into the traditional practices of various communities, regions, and tribes throughout the African sub-region and beyond (20).

In diabetes, oxidative stress plays a crucial role in the onset and progression of the disease and its associated complications (5). Prolonged hyperglycemia leads to the excessive production of free radicals, which are unstable molecules and are capable of oxidizing cellular components such as proteins, nucleic acids, and lipids (21). Additionally, they could trigger harmful signaling pathways, which further promote inflammation and insulin resistance (22). This contributes significantly to β-cell dysfunction and impaired insulin action (23). In diabetic individuals, the natural antioxidant defense system is often impaired, which aggravates cellular damage and disease progression. In this context, antioxidants have emerged as promising therapeutic agents (23). By neutralizing free radicals and enhancing endogenous antioxidant defenses, antioxidants protect against lipid peroxidation, receptor oxidation, and genetic damage(24). Natural antioxidants, particularly plant-derived compounds, have shown significant therapeutic potential in diabetes management. The essential oil extracted from *M. myrtifolia* demonstrated significant inhibition of DPPH radical in a dose-dependent manner. These results are expected, because the oil of *M. myrtifolia* is rich in potential terpenoid antioxidants, such as linalool and D-limonene(25). In addition, beta-caryophyllene and caryophyllene oxide, as well as monoterpenes like D-germacrene, D-limonene and linalool are well documented for their antioxidant activity (21, 22). This result aligns with another study where the antioxidant activity of *M. myrtifolia* essential oil was tested in several ways. The oil was able to scavenge stable radicals, tested via DPPH, reaching IC_{50} values of 25.36 ± 1.6 mg/mL (13).

These agents help in lowering blood glucose levels and in diminishing oxidative stress, thereby potentially preventing or delaying the onset of diabetes-related complications(26). Mice and rats are frequently utilized in diabetic research due to their similar signaling and metabolic pathways to humans, allowing them to develop insulin resistance and hyperglycemia, which mimic the condition in humans (27). Results revealed distinct patterns in blood glucose changes over time. The group of mice given a low concentration of essential oil shows the highest peak at 60 minutes with a glycemic change of approximately 53% above baseline. This was followed by a marked decline, with glucose levels dropping to 54.53% below baseline at 360 minutes, indicating sustained hypoglycemic affect. The high concentration group also peaks at 60 minutes with a glycemic change of 35.59% above baseline, showing a lower peak compared to the low concentration group, followed by a more rapid reduction, reaching 47.98% and 44.95% below baseline at 240 and 360 minutes respectively. These findings suggests that the higher dose initiates glucose reduction earlier but with a slightly less pronounced final effect compared to the lower dose.

Significant changes ($p < 0.05$) were observed for comparisons between baseline (0 hours) and 4/6 hours, as well as between treatment groups and the control group at 6 hours ($p < 0.05$). The low-dose treatment exhibited a marked reduction at 6 hours (127 mg/dL) compared to baseline, reaching statistical significance. Moreover, both, low-dose and high-dose essential oil treatments exhibited a statistically significant reduction in blood glucose levels when compared to the control group ($p < 0.05$), highlighting their potential antihyperglycemic effects. This efficacy is further supported by comparisons with the oral antidiabetic agent, glipalamide, which showed a moderate effect, with a significant reduction observed only at 4 hours compared to baseline. Notably, the blood glucose levels in the orally treated group remained consistently higher than those observed in the groups treated with plant-derived essential oils throughout the experimental period. This further emphasizes the potential efficacy of essential oils as antihyperglycemic agents, offering promising alternatives to conventional oral medications under experimental conditions (28). The hypoglycemic activity observed in the glimepiride-treated group was due to the effect provoked by the sulfonylurea drug that can selectively block the ATP-sensitive K+ channels in the plasma membrane of the pancreatic β-cells, thereby potentiating insulin release. This suggests that streptococci intraperitoneal injection did not destroy the β-cells (29) .

Thus, the hypoglycemic activity of *M. myrtifolia* essential oil may be due to the potentiation of insulin secretion from the beta cells. Furthermore, it was noticed that the extracts had relatively the same onset of action as the standard drug glimepiride, which further supports the postulated mechanism. Insulin treatment produced the most substantial reductions, with statistically significant effects as early as 90 minutes until the end of the study, when compared to the control group, in addition to the significant reduction of blood glucose at 4 hours compared to baseline.

These results highlight the therapeutic potential of plant-derived essential oils in reducing hyperglycemia, showing effectiveness that may exceed that of conventional oral antidiabetic medications. Supporting this, a previous study on the aqueous extract of *M. graeca* aerial parts administered orally at a dose of 20mg/kg to streptozocin-induced diabetic rats, demonstrated a significant reduction in blood glucose levels at 4- and 6-hours post-treatment (p <0.01) (30). Such findings reinforce the antihyperglycemic efficacy of *Micromeria* species, suggesting that essential oils derived from *M. myrtifolia* may offer promising alternatives to standard oral therapies(31). β-caryophyllene (BCP) is one of the major active components present in *M. myrtifolia* essential oil. According to the Essential Oil Database, BCP has been shown to exert beneficial effects in diabetic rats' models by significantly enhancing insulin secretion and reducing blood glucose levels (23).

Additionally, the monoterpenoid, D-limonene, is also recognized for its potential antihyperglycemic effect (28). While linalool has been shown to regulate blood glucose levels through the inhibition of protein glycation (29). It also reduces plasma glucose levels by increasing insulin levels and promoting glucose uptake by cells, and by alleviating oxidative damage (30). In another hand, D-germecane was reported to possess antihyperglycemic in a previous study (26). It demonstrated significant inhibitory effects against α-glucosidase, and α-amylase enzymes suggesting potential therapeutic applications in managing diabetes (27).

The present study highlights the significant potential of *M. myrtifolia* essential oil as a therapeutic agent in managing diabetes and combating oxidative stress. The essential oil possesses notable antioxidant activity, as evidenced by its ability to effectively scavenge DPPH radicals, with an IC_{50} value of 32.51 µg/ml. Furthermore, the GC-MS analysis revealed a rich composition of bioactive compounds, including significant concentrations of terpenes which may play crucial roles in mediating the observed antihyperglycemic effects. In the evaluation of the essential oil from *M. myrtifolia*, both low (220 mg/kg) and high (440 mg/kg) doses resulted in significant reductions in blood glucose levels in alloxan-induced diabetic mice. This suggests that *M. myrtifolia* oil has a potential hypoglycemic effect, offering promise as a therapeutic option for managing diabetes.

Conclusion

Overall, the findings of this study highlight the relevance of traditional herbal remedies in contemporary medicine, particularly as sources of bioactive compounds with potential applications in the treatment of chronic diseases such as diabetes. The integration of natural products like *M. myrtifolia* into holistic treatment approaches could provide valuable adjuncts to current pharmacotherapy, supporting the WHO's advocacy for the role of traditional medicines in healthcare systems.

Study limitations

Acute and sub-acute toxicological study is required to establish safety profile for this dose of essential oil. Only single dose was evaluated; multiple doses are needed to define potency and optimal range. The antihyperglycemic mechanism should be elucidated with targeted mechanistic assays.

Conflict of Interests

The author are no competing interests.

Data Sharing Statement

All data, documentation, and Arduino program code used in this will be made available upon reasonable request to the corresponding author.

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"Not applicable"

References

1. Cho NH, Shaw JE, Karuranga S, Huang Y, da Rocha Fernandes JD, Ohlrogge A, et al. IDF Diabetes Atlas: Global estimates of diabetes prevalence for 2017 and projections for 2045. *Diabetes Res Clin Pract*. 2018;138:271–281. doi:10.1016/j.diabres.2018.02.023.

2. Erener S. Diabetes, infection risk and COVID-19. *Mol Metab*. 2020;39:101044. doi:10.1016/j.molmet.2020.101044.

3. Xu L, Li Y, Dai Y, Peng J. Natural products for the treatment of type 2 diabetes mellitus: Pharmacology and mechanisms. *Pharmacol Res*. 2018;130:451–465. doi:10.1016/j.phrs.2018.01.015.

4. Mechchate H, Es-Safi I, Louba A, Alqahtani AS, Nasr FA, Noman OM, et al. In vitro alpha-amylase and alpha-glucosidase inhibitory activity and in vivo antidiabetic activity of *Withania frutescens* L. foliar extract. *Molecules*. 2021;26(2):293. doi:10.3390/molecules26020293.

5. Tommerdahl KL, Shapiro AL, Nehus EJ, Bjornstad P. Early microvascular complications in type 1 and type 2 diabetes: recent developments and updates. *Pediatr Nephrol*. 2022;37:1–15. doi:10.1007/s00467-021-05050-7.

6. Gothai S, Ganesan P, Park SY, Fakurazi S, Choi DK, Arulselvan P. Natural phyto-bioactive compounds for the treatment of type 2 diabetes: inflammation as a target. *Nutrients*. 2016;8(8):461. doi:10.3390/nu8080461.

7. Sun C, Zhao C, Guven EC, Paoli P, Simal-Gandara J, Ramkumar KM, et al. Dietary polyphenols as antidiabetic agents: advances and opportunities. *Food Front*. 2020;1(1):18–44. doi:10.1002/fft2.15

8. Azab A. *Micromeria*: chemistry and medicinal activities. *Eur Chem Bull*. 2016;5(7):300–307.

9. Smith T, Majid F, Eckl V, Reynolds CM. Herbal supplement sales in US increase by record-breaking 17.3% in 2020. *HerbalGram*. 2021;131:52–65.

10. Aminifard T, Razavi BM, Hosseinzadeh H. The effects of ginseng on the metabolic syndrome: an updated review. *Food Sci Nutr*. 2021;9(9):5293–5311. doi:10.1002/fsn3.2475.

11. Shehadeh MB, Suaifan GA, Abu-Odeh AM. Plant secondary metabolites as blood glucose-lowering molecules. *Molecules*. 2021;26(14):4333. doi:10.3390/molecules26144333.

12. Brahmi F, Guendouze N, Hauchard D, Okusa P, Kamagaju L, Madani K, et al. Phenolic profile and biological activities of *Micromeria graeca* (L.) Benth. ex Rchb. *Int J Food Prop*. 2017;20(Suppl 2):2070–2083. doi:10.1080/10942912.2017.1362650.

13. Sarikurkcu C, Ceylan O, Zeljkovi S. *Micromeria myrtifolia*: essential oil composition and biological activity. *Nat Prod Commun*. 2019;14(6):1934578X19851687. doi:10.1177/1934578X19851687.

14. Zebib B, Beyrouthy ME, Safi C, Merah O. Chemical composition of the essential oil of *Satureja myrtifolia* (Boiss. & Hohen.) from Lebanon. *J Essent Oil Bear Plants*. 2015;18(1):248–254. doi:10.1080/0972060X.2014.890075.

15. Çarikçi S. The essential oil components of five *Micromeria* species grown in Anatolia. *BAÜ Fen Bil Enst Derg*. 2013;15:1–15.

16. Formisano C, Oliviero F, Rigano D, Saab AM, Senatore F. Chemical composition of essential oils and in vitro antioxidant properties of extracts and essential oils of *Calamintha origanifolia* and *Micromeria myrtifolia*. *Ind Crops Prod*. 2014;62:405–411. doi:10.1016/j.indcrop.2014.08.043.

17. Kandi S, Charles AL. Statistical comparative study between the conventional DPPH spectrophotometric and dropping DPPH analytical method. *Food Chem*. 2019;287:338–345. doi:10.1016/j.foodchem.2019.02.110.

18. Ngo DH, Ngo DN, Vo TTN, Vo TS. Mechanism of action of *Mangifera indica* leaves for antidiabetic activity. *Sci Pharm*. 2019;87(2):13. doi:10.3390/scipharm87020013

19. Abu-Reidah I, Al-Nuri M, Afifi A, Omar G, Adwan G, Warad I. GC–MS based metabolite profiling and biological activities of *Micromeria fruticosa*. *Preprints*. 2022. doi:10.20944/preprints202204.0119.v1.

20. Etsassala NG, Hussein AA, Nchu F. Potential application of some Lamiaceae species in the management of diabetes. *Plants*. 2021;10(2):279. doi:10.3390/plants10020279.

21. Saracino IM, Foschi C, Pavoni M, Spigarelli R, Valerii MC, Spisni E. Antifungal activity of natural compounds vs *Candida* spp. *Antibiotics*. 2022;11(1):73. doi:10.3390/antibiotics11010073.

22. Naowaboot J, Pannangpetch P, Kukongviriyapan V, Kukongviriyapan U, Nakmareong S, Itharat A. Mulberry leaf extract restores arterial pressure in streptozotocin-induced diabetic rats. *Nutr Res*. 2009;29(8):602–608. doi:10.1016/j.nutres.2009.06.002.

23. Gupta R, Sharma AK, Dobhal M, Sharma M, Gupta R. Antidiabetic and antioxidant potential of β-sitosterol in streptozotocin-induced hyperglycemia. *J Diabetes*. 2011;3(1):29–37. doi:10.1111/j.1753-0407.2010.00107.x.

24. Kassaee SM, Goodarzi MT, Oshaghi EA. Antioxidant, antiglycation and antihyperlipidemic effects of *Trigonella foenum* and cinnamon in type 2 diabetic rats. *Jundishapur J Nat Pharm Prod*. 2018;13(1):e38414. doi:10.5812/jjnpp.38414.

25. Shah BB, Mehta AA. In vitro evaluation of antioxidant activity of D-limonene. *Asian J Pharm Pharmacol*. 2018;4(6):883–887. doi:10.31024/ajpp.2018.4.6.25.

26. Cavaleiro C, Salgueiro L, da Cunha AP, Figueiredo A, Barroso J, Bighelli A, et al. Composition and variability of essential oils of *Juniperus navicularis*. *Biochem Syst Ecol*. 2003;31(2):193–201. doi:10.1016/S0305-1978(02)00080-7.

27. Atrooz F, Alkadhi KA, Salim S. Understanding stress: insights from rodent models. *Curr Res Neurobiol*. 2021;2:100013. doi:10.1016/j.crneur.2021.100013.

28. Bungau SG, Vesa CM, Bustea C, Purza AL, Tit DM, Brisc MC, et al. Antioxidant and hypoglycemic potential of essential oils in diabetes mellitus. *Int J Mol Sci*. 2023;24(22):16501. doi:10.3390/ijms242216501.

29. Abu-Odeh A, Shehadeh M, Suaifan GA, Karameh N, Abdel Rahman D, Kandil Y. In vitro and in vivo antidiabetic activity of *Terfezia claveryi*. *Molecules*. 2022;27(15):4843. doi:10.3390/molecules27154843.

30.Akdad M, Azzane A, Al Ouady F, Moujani A, Khallouki F, Eddouks M. Antihyperglycemic activity of *Micromeria graeca* aqueous extract in diabetic rats. *Endocr Metab Immune Disord Drug Targets*. 2021;21:887–894. doi:10.2174/1871530320666200807124940.

31.Yousef NM. Chemical composition and pharmacological screening of *Micromeria fruticosa serpyllifolia* volatile oils collected from West Bank–Palestine [thesis]. Nablus: An-Najah National University; 2018.