Enzyme inhibitory and radical scavenging effects of some antidiabetic plants of Turkey

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**Abstract**

Objective(s): Ethnopharmacological field surveys demonstrated that many plants, such as *Gentiana olivieri*, *Helichrysum graveolens*, *Helichrysum plicatum*ssp*.* *plicatum*, *Juniperus oxycedrus* ssp. *oxycedrus*, *Juniperus communis* var. *saxatilis*, *Viscum album* (ssp. *album*, ssp. austriacum), are used as traditional medicine for diabetes in different regions of Anatolia. The present study was designed to evaluate the in vitro antidiabetic effects of some selected plants, tested in animal models recently.

Materials and Methods: α-glucosidase and α-amylase enzyme inhibitory effects of the plant extracts were investigated and Acarbose was used as a reference drug. Additionally, radical scavenging capacities were determined using 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid) ABTS radical cation scavenging assay and total phenolic content of the extracts were evaluated using Folin-Ciocalteu method.

Results: *H. graveolens* ethanol extract exhibited the highest inhibitory activity (55.7% ± 2.2) on α-amylase enzyme. Additionally, *J. oxycedrus* hydro-alcoholic leaf extract had potent α-amylase inhibitory effect, while the hydro-alcoholic extract of *J. communis* fruit showed the highest α-glucosidase inhibitory activity (IC50: 4.4 μg/ml).

Conclusion: Results indicated that, antidiabetic effect of hydro-alcoholic extracts of *H. graveolens capitulums*, *J. communis* fruit and *J. oxycedrus* leaf might arise from inhibition of digestive enzymes.

**Introduction**

Diabetes mellitus is a growing health problem worldwide causing severe and costly complications including blindness, cardiac and kidney diseases (1). According to Shaw et al (2010), the world prevalence of diabetes among adults will increase to 7.7%, and affect 439 million adults by 2030. Between 2010 and 2030, there will be a 69% increase in number of adults with diabetes in developing countries and a 20% increase in developed countries (2).

Approaches to the control of blood glucose and prevention of hyperglycemia are central to the treatment of diabetes mellitus. Appetite suppressants, inhibitors of digestion, insulin secretagogues, insulin potentiatators, insulin mimetics, stimulants of glucose utilization, inhibitors of gluconeogenesis and glucogenolysis are used to balance blood glucose. At present, none of these therapies either alone or in combination can redraw normal blood glucose homeostasis. Additionally many limitations exist in the use of anti-diabetic drugs; medicines available for management of diabetes exert serious side effects such as hepatotoxicity, abdominal pain, flatulence, diarrhea, and hypoglycemia. Also after prolonged treatment, drug resistance is reported for these medicines (3–6). Therefore, researchers have targeted towards the discovery of drug candidates from potential sources. Traditional medicines play an important role as starting material for drug discovery. For documentation of ethnopharmacological knowledge, many comprehensive field surveys have been conducted all over the world for years and many plants used against diabetes have been recorded (7–10).

Antidiabetic activities of plants used against diabetes in Turkey as folk medicine were studied in detail by our research group. In our research on in vivo antidiabetic activity of traditional medicines from 2000, seven plant species including *Gentiana olivieri* Griseb (Gentianaceae), *Helichrysum graveolens* (Bieb.) Sweet (Asteraceae), *H. plicatum*ssp*.* *plicatum* (Asteraceae), *Juniperus oxycedrus* ssp. *oxycedrus* L. (Cupressaceae), *J. communis* var. *saxatilis* Pall. (Cupressaceae), *Viscum album* L. (ssp. *album* and ssp. *austriacum*) (Loranthaceae) were evaluated for their antidiabetic activity (11–16). Due to their promising antidiabetic effect in in vivo studies, they were selected as the subject of this study.

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The plants used in this study are well known and widely consumed as food and medicine in different regions of Anatolia. Aerial parts of *G. olivieri* are used as bitter tonic, appetizer, antidiabetic, antipyretic, stomachic, and for mental disorders. Gentians are also used in small amounts as food and beverage flavoring, in antismoking products and even as a substitute for hops in beer making. *Helichrysum* species have been used as diuretics, lithagogues, anti-asthmatics, for stomachache, and against kidney stones. The capitulums of *Helichrysum* species are used to decrease blood glucose levels and aerial parts are also marketed as herbal tea in herbal stores. Juniper berries and leaves are used for antidiabetic, diuretic, antisepsic, carminative, stomachic, antirheumatic, antifungal, and disinfectant properties in many folk medicines (13, 14). Also, berries are used as spice in European cuisine to impart a sharp, clear flavor to meat dishes, pork, cabbage, and sauerkraut dishes (18). Twigs and leaves of *V. album* (European mistletoe) are used for many therapeutic applications such as diabetes mellitus, chronic cramps, stroke, stomach problems, heart palpitations, hypertension, and breathing difficulties (15). Additionally leaves of *V. album* are used as tea for bracing and fruits are eaten fresh and pickled in Turkey (19).

The goal of the present study is to determine the inhibitory effects of the selected plants that were found to have in vivo antidiabetic activity on carbohydrate digestion enzymes such as α-amylase and α-glucosidase. Inhibition of these enzymes, involved in the digestion of carbohydrates, can significantly reduce the post-prandial increase of blood glucose. So, plants with inhibitory effects on these enzymes might be beneficial in diabetic patients. Oxidative stress, is one of the major problems observed during hyperglycemia and it contributes to severe complications in diabetes (20). Plants with both antidiabetic and antioxidant effects could be useful for people suffering from diabetes mellitus. Therefore, ABTS radical scavenging activity and total phenolic contents of the extracts were also determined.

### Materials and Methods

#### Plant materials

Plant materials were collected from different localities of Turkey and identified by researchers. Voucher specimens are preserved in the herbariums of Gazi and Ankara Universities, Faculty of Pharmacy, (Ankara), Turkey. Plant names, parts used, collection sites and herbarium numbers of the plants are given in Table 1.

#### Preparation of extracts

Aqueous and hydro-alcoholic extracts of the plants were prepared according to folkloric usage as described in the previous in vivo antidiabetic activity studies (11–16). For decoctions, 1 g of air-dried plant material was added to 100 ml of distilled water and boiled on slow heat for 30 min. Infusions were prepared by pouring 100 ml of boiling water onto 1 g of dried plant material. The extraction continued for 30 min while cooling. Hydro-alcoholic extracts were prepared by maceration of 1 g of powdered material with 100 ml of ethanol (80%) at room temperature for 8 hr. Extracts were then filtered through filter paper and condensed by a rotary evaporator. Extraction yields were calculated after freeze-drying till dryness. Extract yields and other information are given in Table 1.

#### Assay for α-amylase inhibitory activity

The α-amylase inhibition method was performed using the chromogenic method of Ali et al (21). Porcine pancreatic α-amylase (EC 3.2.1.1, type VI, Sigma) was dissolved in ice-cold distilled water (4 U/ml). As substrate solution, potato starch (0.5 %, w/v) in 20 mM phosphate buffer (pH 6.9) was used. Experiments were carried out with three replicates.

40 μl of plant extract in DMSO, 160 μl of distilled water and 400 μl of starch were mixed in an Eppendorf tube. The reaction was initiated by the

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**Table 1.** General information about plants used in the study

| Plant | Place of collection | Voucher No. | Part used | Extraction method | Extract | Yield % (w/w) |
|-------|---------------------|-------------|-----------|-------------------|---------|--------------|
| *Gentiana olivieri* Griseb. | Oğuzeli, Gaziantep | GUE 2621 | Aerial part | Decoction | HA | 38.7 |
| *Helichrysum graveolens* (Bieb.) Sweet | Ilgaz Mt, Kastamonu | GUE 2356 | Capitulum | Maceration | HA | 11.5 |
| *H. plicatum* ssp. *plicatum* DC. | Palandöken Mt, Erzurum | GUE 2355 | Capitulum | Maceration | HA | 19.3 |
| *Juniperus communis* var. *saxatilis* Pall. | Akdağmadeni, Yozgat | GUE 2617 | Fruit | Maceration | HA | 36.0 |
| *J. oxycedrus* ssp. *oxycedrus* L. | Akdağmadeni, Yozgat | GUE 2616 | Fruit | Infusion | Aq | 26.0 |
| *Viscum album* L. | Bağlum, Ankara | AEF 18953 | Aerial part | Infusion | Aq | 25.9 |
| *V. album* ssp. *austriacum* (Wiesb.) | Kızılahamam, Ankara | AEF 18939 | Aerial part | Infusion | Aq | 41.2 |

AEF: Herbarium of Faculty of Pharmacy at Ankara University, GUE: Herbarium of Faculty of Pharmacy at Gazi University, HA: Hydro-alcoholic, Aq: Aqueous
addition of 200 μl of the enzyme solution. The tubes were incubated at 37°C for 5 min. After that, 200 μl of this mixture was added into another tube containing 100 μl DNS color reagent solution (96 mM 3, 5-dinitrophenol, 1.53 M sodium potassium tartrate in 2 M NaOH) and put into a 85°C heater. After 15 min, this mixture was diluted with 900 μl distilled water and taken from the heater. Tubes were cooled on ice and the absorbance of the mixture was read at 540 nm. Acarbose was used as the positive control. The absorbance (A) due to maltose generated was calculated according to the following formula:

\[
A_{540\text{nm control or plant extract}} = A_{540\text{nm Test}} - A_{540\text{nm Blank}}
\]

The amount of maltose generated was calculated by using the maltose standard calibration curve (0 – 0.1% w/v) and the obtained net absorbance. Percent of inhibition was calculated as:

% inhibition = \(\frac{1 - (\text{mean maltose in sample/mean maltose in control})}{\text{100}}\)

**Assay for α-glucosidase inhibitory activity**

α-Glucosidase activity was performed according to the method of Lam et al (22). α-Glucosidase type IV enzyme (Sigma Co., St. Louis, USA) from *B. steartothermophilus* was dissolved in 0.5 M phosphate buffer (pH 6.5) (3 U/ml). The enzyme solution (20 μl) and test extracts (10 μl) dissolved in MeOH-H2O (1:9, v/v) were preincubated in a 96-well microtiter plate for 15 min at 37°C. After that, the substrate solution [10 μl, 20 mM p-nitrophenyl-α-d-glucopyranoside (NPG), Sigma] in the same buffer was added. The mixture was incubated for 35 min at 37°C. The increase in the absorption at 405 nm due to the hydrolysis of NPG by α-glucosidase was measured by an ELISA microtiter plate reader. Acarbose (Bayer Group, Turkey) was used as a positive control. The inhibition percentage (%) was calculated by the equation:

\[
\text{Inhibition (％)} = \left[1 - \frac{(A_{\text{sample}}/A_{\text{control}})}{\text{100}}\right]
\]

IC50 values were calculated by using Sigma Plot 12.0 software. Minimum of eight different concentrations prepared from the stock solutions of extracts were used for calculating the IC50 value. The logarithmic concentrations (10.000 – 0.1 μg/ml) were chosen.

**Assay for scavenging activity of ABTS radical cation**

ABTS radical cation (ABTS⁺) scavenging assay was achieved by using the spectrophotometric methods of Re et al (23) and Meot-Duros et al (24) with slight modifications. ABTS (7 mM) was dissolved in distilled water and the ABTS radical cation was generated by adding 2.45 mM potassium per-sulfate. The radical production was completed by mixing 10 μl of extract (PBS or Trolox). Samples were vortexed and their absorbances were tested at 734 nm by the addition of phosphate buffer (pH 7.4). The absorbance of ABTS solution was adjusted to 0.7 ± 0.02 at 734 nm. The absorbance of ABTS solution was added to 10 μl of extract (PBS or Trolox). Trolox was used as the positive control. The inhibition percentage was calculated according to the following formula:

\[
\text{Inhibition percentage} = \left[1 - \frac{(A_{\text{extract}}/A_{\text{control}})}{\text{100}}\right]
\]

**Determination of total phenol content**

The extracts (100 μl) were mixed with 0.2 ml Folin-Cioicălteu reagent, 2 ml of H2O, and 1 ml of 15 % Na2CO3, respectively. The absorbance of mixture was measured at 765 nm after 2 hr at room temperature. The mean of three readings was used and the total phenol content was expressed in mg of gallic acid equivalents (GAE)/g extracts (25). The coefficient of determination was r² = 0.9957.


Table 3. α-Glucosidase inhibitory activity of plant extracts and total phenol content (TPC)

| Material/Plant          | Part used       | Extract      | IC_{50}(mg/ml)  | TPC ± SD       |
|-------------------------|-----------------|--------------|-----------------|----------------|
| Acarbose                |                 | HA           | 0.0099          | NT             |
| Gentiana olivieri       | Aerial part     | HA           | 0.1982          | 57.4 ± 2.7     |
| Helichrysum graveolens  | Capitulum       | HA           | 0.7129          | 143.4 ± 9.4    |
| H. plicatum ssp. plicatum| Capitulum      | Aq           | 2.1979          | 92.9 ± 2.0     |
| Juniperus communis var. saxatilis | Leaf | HA           | 0.0843          | 212.1 ± 9.9    |
| J. oxycedrus ssp. oxycedrus | Leaf     | HA           | 0.0044          | 4.8 ± 2.2      |
| Viscum album ssp. album | Aerial part     | HA           | 0.7962          | 21.2 ± 2.0     |
| V. album ssp. austriacum| Aerial part     | HA           | 0.6653          | 35.8 ± 1.3     |

Total phenol content data is expressed in mg equivalent of gallic acid (GAE) to 1 g of extract.
SD: Standard deviation, NT: Not tested, -: no activity, HA: Hydro-alcoholic, Aq: Aqueous

Statistical analysis

All analyses were carried out in triplicates and the results were averaged. All values are expressed as the mean ± standard deviation (SD); linear regression analyses and IC_{50} calculations were done by using SigmaPlot 12.0 software. Microsoft Excel software was used to calculate correlation coefficients to determine the relationship between 2 variables.

Results

α-amylase inhibitory activity

α-Amylase inhibitory activities of the plant extracts were evaluated at 4 different logarithmic doses (3000, 1000, 300, 100 μg/ml) and results were given in Table 2. All extracts except H. plicatum aqueous extract, showed a dose dependent inhibitory effect on α-amylase enzyme. All the extracts exerted inhibitory activity at tested doses in varying proportions (3.5 – 55.7 % at 3000 μg/ml). H. graveolens hydro-alcoholic extract exhibited the highest inhibitory activity at 3000 μg/ml (55.7 %), while the inhibition percentage of the reference drug Acarbose was found to be 73.7 %. On the other hand, J. oxycedrus ssp. oxycedrus leaf hydroalcoholic extract possessed a continuous inhibitory effect on α-amylase enzyme between 100-3000 μg/ml (25.0–51.7%).

α-glucosidase inhibitory activity

α-Glucosidase inhibitory activities of the plant extracts were evaluated at 5 different logarithmic doses between 0.3 –10000 μg/ml; the calculated IC_{50} values are given in Table 3. All the extracts showed dose dependent inhibitory effect on α-glucosidase enzyme. J. communis var. saxatilis fruit hydro-alcoholic extract possessed the highest inhibitory effect and its IC_{50} value was found to be the lowest (IC_{50} = 0.0044 mg/ml) among all extracts. IC_{50} value of reference drug (Acarbose) was 0.0009 mg/ml. H. plicatum ssp. plicatum capitulum aqueous extract (IC_{50} = 5.0933 mg/ml) and V. album ssp. album aerial part aqueous extract (IC_{50} = 3.7411 mg/ml) exerted the lowest enzyme inhibitory activity.

ABTS radical cation scavenging activity

ABTS radical cation decolorization assay is a useful method for determining the antioxidant capacity of hydrogen donating antioxidants. ABTS^+ is a blue chromophore produced by the reaction between ABTS salt and potassium per-sulfate (26). After addition of extracts to ABTS radical cation, a strong reduction was observed and the blue color turned to white immediately in some extracts (H. plicatum capitulum hydro-alcoholic, J. communis var. saxatilis leaf hydro-alcoholic, J. oxycedrus ssp. oxycedrus leaf aqueous and hydro-alcoholic extracts) at 3000 μg/ml concentration. Trolox used as a positive control, showed ABTS radical cation scavenging activity at all tested concentrations (100–3000 μg/ml). J. oxycedrus ssp. oxycedrus fruit aqueous extract exerted the lowest radical scavenging activity (0–7.5%). The results of ABTS radical cation decolorization assay is given in Table 4.

Total phenol content

Total phenol contents of all the extracts were measured and the results were shown in Table 3. The highest total phenol content was found in J. communis var. saxatilis leaf hydro-alcoholic extract (212.1 ± 9.9 mg GAE/1 g extract) while the lowest was found in J. oxycedrus ssp. oxycedrus fruit hydro-alcoholic extract (48 ± 2.2 mg GAE/1 g extract). Results presented in Table 3 show that there is a positive correlation between total phenol contents and ABTS radical scavenging activity of plant extracts (correlation coefficient= r = 0.8875 at 3000 μg/ml). However, the extracts with potent antioxidant activity and rich in phenolics did not show high inhibition on digestion enzymes. No correlation was observed between total phenol content and α-amylase/α-glucosidase inhibitory activity (r = 0.3959 and r = 0.1669 at 3000 μg/ml respectively). Additionally correlation between radical
There was no correlation between total phenol content and α-amylase/α-glucosidase inhibitory activity of these plant extracts. Many studies were conducted on the chemical profile of the selected medicinal plants. Orhan et al (13, 14) isolated and identified many compounds that are responsible for the antidiabetic activity of J. oxycedrus ssp. oxycedrus (Joso). Through in vivo bioactivity-guided fractionation processes, shikimic acid, 4-O-β-D-glucopyranosyl ferulic acid, and oleuropeic acid-8-O-β-D-glucopyranoside were isolated from the active subfractions of Joso fruit hydro-alcoholic extracts as the active components (14). Jeong et al (2012) showed strong inhibitory effects of ferulic acid derivatives on α-amylase and α-glucosidase enzymes (32). Therefore, we propound that α-amylase inhibitory effect of Joso fruit hydro-alcoholic extract might be produced by the presence of ferulic acid and other chemical constituents. Additionally, the major antidiabetic compounds in subfractions of Joso leaves were identified as fatty acids such as palmitic, linoleic, and linolenic acid (13). Su et al (2013) investigated the inhibitory mechanisms of fatty acids on key enzymes related to type 2 diabetes. Oleic and linoleic acids were found to have potent inhibitory effects on α-glucosidase activity (33). Thus, fatty acids might contribute to the α-glucosidase enzyme inhibitory effects of other active compounds found in the Joso leaf hydro-alcoholic extract.

Leaves and fruits of J. communis var. saxatilis contain relatively high amounts of monoterpene hydrocarbons such as α-pinene, limonene and β-myrcene (34). The main monoterpene component for these parts of the plant was α-pinene. Başak and Candan (2013) found that α-pinene in Laurus nobilis essential oil inhibited α-glucosidase (35). On the other hand, J. communis var. saxatilis leaf hydroalcoholic extract showed significantly α-amylase inhibitory effect which may be due to the presence of some secondary metabolites such as lignans, coumarins, steroids, aliphatic compounds, and other terpenes in the hydroalcoholic extract (34).

Table 4. ABTS radical scavenging activities of plant extracts

| Material/Plant        | Part used  | Extract | Inh. % ± SD (μg/ml) |
|-----------------------|------------|---------|---------------------|
|                       |            |         | 3000    | 1000    | 300     | 100     |
| Trolox                | -          | HA      | >100    | 99.5 ± 0.25 | 38.9 ± 1.12 | 7.5 ± 0.72 |
| Gentiana olivieri     | Aerial part| HA      | 54.3 ± 1.20 | 20.5 ± 2.41 | 7.6 ± 1.03 | 2.6 ± 0.29 |
| Helichrysum graveolens| Capitolum | Aq      | 77.0 ± 0.7 | 36.5 ± 0.74 | 11.2 ± 0.7  | 4.3 ± 0.91 |
| H. plicatum           | Capitolum  | HA      | 88.5 ± 1.89 | 42.6 ± 1.95 | 15.0 ± 0.40 | 6.5 ± 2.53 |
| Juniperus communis var. saxatilis | Leaf | HA      | 99.5 ± 0.35 | 68.9 ± 1.03 | 24.3 ± 6.37 |- |
| V. album              | Aerial part| HA      | 42.5 ± 1.2  | 12.2 ± 0.57 |-          |         |
| J. oxycedrus ssp. oxycedrus | Leaf | HA      | 7.5 ± 0.96  |         |          |         |
| V. album ssp. album   | Aerial part| Aq      | 48.9 ± 0.55 | 19.4 ± 1.81 | 5.1 ± 0.70  | 23 ± 2.77 |
| V. album ssp. austriacum| Leaf | HA      | 97.8 ± 0.53 | 46.0 ± 0.51 | 4.7 ± 1.40  | -        |

n=5, SD: standard deviation, -: no activity, HA:Hydro-alcoholic, Aq:Aqueous

Discussion

Hyperglycemia has been a classical risk factor in the development of diabetes and its complications. Therefore, control of blood glucose levels is critical in the early treatment of diabetes mellitus. One of the important therapeutic approaches is the prevention of carbohydrate absorption after food intake, which is facilitated by inhibition of the enteric enzymes including α-glucosidase and α-amylase present in the intestinal brush border (27, 28). The inhibition of these enzymes has been a strong option in the prevention of diabetes. So, inhibitors like Acarbose, voglibose, and miglotil are widely used in type 2 diabetic patients nowadays. Moreover, studies are being carried out to find new amylase and glucosidase inhibitors from natural sources (29-31).

The aim of this study is to clarify the mechanism of action of selected plants on carbohydrate metabolism. For this purpose, the inhibitory effect of 15 extracts obtained from different parts of 7 plants on α-glucosidase and α-amylase were assessed and compared with the α-glucosidase inhibitor, Acarbose. Also, radical scavenging activity and total phenol content of the extracts were investigated.

In our previous studies, we demonstrated significant hypoglycaemic and antidiabetic activities of hydro-alcoholic extracts of H. graveolens capitulums, J. oxycedrus ssp. oxycedrus leaves and J. communis var. saxatilis fruits in normoglycaemic, glucose loaded and streptozotocin-induced diabetic rats. In the present study, these extracts which were found to have potent antidiabetic activity, have also shown high inhibitory effect on enzymes that have an important role in carbohydrate metabolism. There was no correlation between total phenol scavenging and enzyme inhibitory activities of tested plant extracts were examined. No correlation was observed between ABTS radical scavenging and α-amylase/α-glucosidase inhibitory activity (r= -0.0876 at 3000 μg/ml and r= -0.1175 respectively).
Results of α-amylase inhibitory activity assay showed that *H. graveolens* hydro-alcoholic extract has *in vitro* enzyme inhibition in a degree similar to Acarbose at 3000 μg/mL. Flavonoids, acetophenones, phloroglucinol, pyrones, triterpenoids, and sesquiterpenes are secondary metabolites of the genus *Helichrysum* (36). Additionally, Albayrack et al. (2010) reported the presence of chlorogenic acid, caffeic acid, ferulic acid, syringic acid, apigenin, apigenin-7-glucoside, and hesperidin; luteolin, naringenin, quercetin, resveratrol in the methanol extracts of *H. graveolens*, and chlorogenic acid were found to be the major phenolics in the extract (37). Narita et al. (2008) reported the strong inhibitory effect of chlorogenic acid and its derivatives on porcine pancreas α-amylase (38). It is considered that high phenolic content (143.4 mg GAE/1 g extract) of hydro-alcoholic extract of *H. graveolens* capitulums might support the enzyme inhibitory effect of other constituents like chlorogenic acid and its derivatives.

### H. plicatum capitulum hydro-alcoholic, *J. communis* var. *saxatilis* leaf hydro-alcoholic, and *J. oxycedrus* ssp. *oxycedrus* leaf aqueous and hydro-alcoholic extracts have shown strong ABTS radical cation scavenging activity. Antioxidant effects of these plants might cooperate with their antidiabetic activity and these plants might be a better choice for complementary remedies for type 2 diabetic patients.

**Conclusion**

This is the first study on the *in vitro* antidiabetic activities of these seven plants: *G. olivieri*, *H. graveolens*, *H. plicatum* ssp. *plicatum*, *J. oxycedrus* ssp. *oxycedrus*, *J. communis* var. *saxatilis*, and *V. album* (ssp. *album* and ssp. *austriacum*). These seven plants with previously reported in vivo antidiabetic effect were tested for enzyme inhibitory and radical scavenging activities. Among these, *H. graveolens* hydro-alcoholic extract; *J. communis* leaf hydro-alcoholic extract and *J. oxycedrus* leaf and fruit hydro-alcoholic extracts were found to have inhibitory effect on α-amylase. On the other hand, hydroalcoholic extracts of *J. communis* (leaf, fruit) *J. oxycedrus* (leaf) had potent inhibitory activity on α-glucosidase. In conclusion, the findings of this investigation indicate that these plants might be ameliorate hyperglycemia in type 2 diabetics by their inhibitory effect on α-glucosidase and α-amylase. It is concluded that further studies are needed to explain the mechanism of actions of the other extracts and their active constituents.

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