Plant Foods Hum Nutr (2008) 63:27–33
DOI 10.1007/s11130-007-0065-5

ORIGINAL PAPER

# Determination of *In Vitro* Antidiabetic Effects, Antioxidant Activities and Phenol Contents of Some Herbal Teas

**Aynur Büyükbalci · Sedef Nehir El**

Published online: 9 January 2008


**Abstract** In this research, some herbal teas and infusions traditionally used in the treatment of diabetes in Turkey, have been studied for their antidiabetic effects on *in vitro* glucose diffusion and phenolic contents and antioxidant activities. Ten aqueous herbal tea extracts were examined using an *in vitro* method to determine their effects on glucose movement across the gastrointestinal tract. Total phenol content of herbal teas was analyzed by Folin–Ciocalteu's procedure. Antioxidant activities of herbal teas were evaluated by the effect of extracts on DPPH radical and hydrogen peroxide scavenging. Antioxidant activity was defined as the amount of the sample to decrease the initial $DPPH^{\cdot}$ concentration by 50% as efficient concentration, $EC_{50}$. Antiradical activity [AE] was calculated as $1/EC_{50}$. Values were evaluated statistically. Results support the view that none of the herbal teas showed antidiabetic effect on glucose diffusion using *in vitro* model glucose absorption. Teas were arranged in the order of green tea > peppermint > thyme > black tea > relax tea > absinthium > shrubby blackberry > sage > roselle > olive leaves according to their total phenol contents. Among ten herbal teas, green tea had the highest hydrogen-donating capacity against to DPPH radical. Ranking of the herbal teas with respect to their DPPH radical scavenging activity were green tea > peppermint > black tea > thyme > relax tea > absinthium > roselle > olive leaves > sage > shrubby blackberry. It was determined that adding flavoring substances such as lemon, bergamot, clove and cinnamon, which are commonly used in preparation of black tea in Turkey resulted to have synergistic effect on total antioxidant activities of black and peppermint teas. The highest hydrogen peroxide inhibition value (65.50%) was obtained for green tea at a 250 μl/ml concentration. The $H_2O_2$ scavenging activity of herbal teas decreased in the order green tea > peppermint > relax tea > black tea > thyme > olive leaves > sage > absinthium > shrubby blackberry > roselle. In particular, their phenolic compounds and antioxidant activities may be useful for meal planning in type 2 diabetes. They could contribute to sustain plasma antioxidant level because antioxidants present in plants and herbs prevent the development of vascular diseases seen in type 2 diabetes.

**Keywords** Antidiabetic · Antioxidant activity · Glucose diffusion · Phenolic compounds

## Introduction

Within the increasing interest to survive a healthy life, using traditional plants is presented as an alternative medicine and most of the people use these plants for their everyday health care needs. Although some of the therapeutic properties attributed to plants have been proven to be erroneous, medicinal plant therapy is based on the empirical findings of hundreds and thousands of years [1–3]. The most practical and frequently used traditional remedy is preparing an infusion or a decoction from the valuable parts of plants and herbs such as flowers, leafs and roots. The herbal teas are being used frequently in the treatment of chronic diseases such as cancer, gastrointestinal diseases and type 2 diabetes (diabetes mellitus). Diabetes, as one of the most common global diseases, affects approximately 200 million individuals worldwide and approximately 300 million people worldwide are at risk of diabetes [2]. There are two types of diabetes: type 1 and type 2. In type 1 diabetes insulin

A. Büyükbalci · S. N. El (✉)
Food Engineering Department, Nutritional Science,
Ege University,
Izmir 35100, Turkey
e-mail: sedef.el@ege.edu.tr

deficiency originated from allergic reactions in genetically susceptible people that eventually destroy the pancreatic β-cells producing insulin. Type 1 diabetics are insulin dependent. Type 2 diabetes is the most common form of diabetes accounting for 90% of cases worldwide. Patients with type 2 diabetes are not dependent to use insulin. Obesity, age and inactivity are the common reasons in developing type 2 diabetes. In long-term acute and chronic complications can occur if blood glucose concentration is not kept in normal levels [4, 5]. Another risk for diabetes are the reduced plasma antioxidant level [6], because antioxidants present in plants and herbs prevent the development of the disease [2, 7]. It is found that the main factor to improve vascular diseases seen in type 2 diabetics is a decreased plasma antioxidant level [8]. The approach to the management of type 2 diabetes is based on weight management and life-style modification. In general, it is best to take a stepped approach starting with nonpharmacological interventions to improve diet, achieve weight reduction in obese patients and increase physical activity. If these measures are inadequate to achieve good metabolic control, oral antidiabetic medications should be added. Besides all this medical treatments people still need to use traditional remedies prepared from herbs and plants [6, 7]. Approximately 800 plants worldwide have been documented to support antidiabetic effects [3, 9, 10], however a few comprehensive studies on traditional antidiabetic plants have been carried out. The antidiabetic actions of 37 European plants were investigated by dietary administration on mice and these studies identified 11 plants with significant anti hyperglycemic activity [11]. Further studies with these plants demonstrated that the anti hyperglycemic activities were in part explained by the ability of water soluble plant compounds to inhibit or delay the absorption of glucose in intestine [2, 3, 8, 11], to increase glucose transport and metabolism in muscle and/or to stimulate insulin secretion. The latest study was carried out by Gallagher et al. [11] in which ten plants were examined on their effects on *in vitro* glucose diffusion in small intestine.

The objective of this study was to investigate the effects of herbal teas prepared from ten plants (black tea, green tea, sage, peppermint, thyme, absinthium, relax tea, shrubby blackberry, roselle, olive leaves) traditionally used in treatment of diabetes and sold as antidiabetics in Turkey. Antidiabetic effects of herbal teas on glucose diffusion across dialysis membrane into external solution were examined by a method used by Gallagher et al. [11], which is a convenient model for assessing factors affecting glucose absorption *in vitro*. The beneficial effects of herbal teas are generally attributed to the antioxidant activity of their phenolic compounds. Because of this approach the total phenolic contents and total antioxidant activities of herbal teas were examined too. Moreover, the herbal teas in Turkey are consumed commonly by adding lemon, bergamot, clove or cinnamon. For this reason the synergistic and antagonistic effects of these aromatic additives on total antioxidant activity of teas were also studied.

## Materials and Methods

### Materials

*Reagents* Glucose Assay Kit (GAGO-20) [Reagents: Glucose Oxidase/Peroxidase G-3660, *o*-Dianisidine Reagent D-2679, Glucose Standard Solution G-3285], (+)-Catechin (C-1251), Folin–Ciocalteu's Phenol Reagent (F-925), Trolox, DPPH· (1,1-diphenyl-2 picrylhydrazyl) (D-9132), hydrogen peroxide were purchased from Sigma-Aldrich Chemical Co.

*Selection of plants* Ten different plants most widely used as antidiabetic agents for type 2 diabetes during day life in Turkey were choosed. Black and green tea (*Camellia sinensis*), sage (*Salvia officinalis*), peppermint (*Mentha piperita*), thyme (*Thymus vulgaris*), absinthium (*Artemisia absinthium*), shrubby blackberry (*Rubus fructicosis*), roselle (*Hibiscus sabdariffa*), olive leaves (*Olea europaea*), cinnamon sticks and grounded cinnamon (*Cinnamomum* spp.), lemon (*Citrus limon*), clove (*Syzygium aromaticum*), bergamote (*Citrus bergamia*) and relax tea (a commercial brand containing: St. Johnswort, *Hypericum perforatum*; Melissa, *Melissa officinalis*; garden valeran, *Valeriana officinalis*; sweet fennel, *Foeniculum vulgare*; lavander, *Lavandula agustifolia*) were obtained from a local special market on herbs.

*Preparation of teas* Herbal teas were prepared by infusion or decoction methods according to recommendations on their labels (Table 1). Also some commonly used ways for these teas in Turkey were used in experimental design and summarized in Table 2. Infusion: teas were prepared with water; 100 ml deionised boiling water were added to a specific amount of tea and were incubated for 3 min without additional heating. Decoction: 100 ml cold deionised water were added to a specific amount of tea and boiled for 15 min and waited 10 min after boiling. All of the samples were filtered through Whatman No. 4 paper and then concentrated under vacuum at 55 °C to a final volume of 50 ml.

### Methods

*Effect of Herbal Teas on In Vitro Glucose Diffusion*

A method described by Gallagher et al. [11] was used to evaluate the effects of herbal teas on glucose movement *in*

**Table 1** Experimental herbal plants and methods for preparing their teas

| Herbal plant samples | | | Used part | Concentration g/100 ml | Method of use |
|---|---|---|---|---|---|
| Common name | Scientific name | Turkish name | | | |
| Black tea | *Camellia sinensis* | Siyah çay | Leaves | 3.5 | Decoction |
| Green tea | *Camellia sinensis* | Yeşil çay | Leaves | 5 | Infusion |
| Sage | *Salvia officinalis* | Adaçayı | Whole plant | 2 | Infusion |
| Peppermint | *Mentha piperita* | Nane | Whole plant | 3 | Infusion |
| Thyme | *Thymus vulgaris* | Kekik | Whole plant | 3 | Infusion |
| Absinthium | *Artemisia absinthium* | Pelin otu | Whole plant | 3 | Decoction |
| Roselle | *Hibiscus sabdariffa* | Hibisküs | Flower | 1.25 | Decoction |
| Olive leaves | *Olea europaea* | Zeytin yaprağı | Leaves | 5 | Decoction |
| Shrubby blackberry | *Rubus fructicosis* | Böğürtlen | Root | 5 | Infusion |
| Relax tea | Brand mix | Relaks çay | Leaves | 1 | Infusion |

*vitro*. This *in vitro* model used consisted of a dialysis tube (6 cm×15 mm)(Spectra/Por®, MWCO:2000) into which 6 ml of herbal tea and 2 ml of 0.15 M NaCl containing 1.65 mM D-glucose were added. The dialysis tube was sealed at each end and placed in a centrifuge tube containing 45 ml 0.15 M NaCl. The tubes were placed on an orbital shaker water bath and incubated at 37 °C for 3 h. The movement of glucose into the external solution was provided. Concentration of glucose within the dialysis tubing was measured and control tests were conducted in the absence of herbal tea. Glucose concentrations were analyzed by enzymatic method using glucose oxidase kit. All tests were carried out in triplicate and the results were presented as means ± SD.

### *Total Phenol Content*

The amount of total phenolic compounds was determined, according to the Folin–Ciocalteu colorimetric method [12, 13], using (+)-Catechin as the standard and expressing the results as catechin equivalents (CE). 1 ml, 6M HCl was added to 3 ml of liquid herbal tea samples (given in Table 1). On the other hand cinnamon and clove were weighed as 0.5 g after milling and 4.5 ml, 1.2 M HCl were added. Tubes were vortexed and incubated at 90 °C for 2 h with regular swirling. After cooling, tube volumes were made up to 10 ml with water. Each sample was passed through filter paper and 100 µL were taken into test tubes; 1,900 µL of 10 % Folin–Ciocalteu's reagent were added. The tubes were mixed and incubated at 50 °C for 20 min. Absorption at 760 nm was measured by using a Pharmacia Biotec Novaspec II spectrophotometer. All tests were done in triplicate and the results were presented as means ± SD.

### *DPPH Radical Scavenging Activity*

The total antioxidant potential of samples was determined by using the procedure described by Brand-Williams et al. [14] and Parejo et al. [15]. In this method, total antioxidant potential of samples were evaluated in terms of radical scavenging ability of tea extracts using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical assay. An appropriate dilution series at five different concentrations (0–0.2 ml sample/ml methanol) were prepared and 0.1 ml of each dilution was added to 3.9 ml of a $6.0\times10^{-5}$ M methanol solution of DPPH·, followed by vortexing. The reaction was allowed to take place in the dark at room temperature to reach a plateau. The decrease in the absorbance at 515 nm was determined by using a Pharmacia Biotec Novaspec II spectrophotometer. The concentration of remaining DPPH· in the reaction medium was calculated from the calibration curve, as follows: rem DPPH· % = $[DPPH\cdot]_{T}/[DPPH\cdot]_{T=0}$, where $[DPPH\cdot]_{T}$ was the concentration of DPPH· at the time of steady state and $[DPPH\cdot]_{T=0}$

**Table 2** Commonly preparing ways of herbal teas

| Tea samples | Amounts (g)/100 ml water | Method of use |
|---|---|---|
| Black tea with lemon | 3.5 g black tea + 5 g lemon | Decoction and diluted to half and added lemon |
| Black tea with bergamot | 3.5 g black tea + 25 µL linalool | Decoction and diluted to half and added linalool |
| Black tea with clove | 3.5 g black tea + 4 kernel | Decocted together and diluted to half |
| Black tea with cinnamon | 3.5 g black tea + 0.5 g cinnamon (stick and grounded) | Decocted together and diluted to half |
| Peppermint with lemon | 3 g peppermint + 10 g lemon | Decocted together |

**Table 3** Effect of herbal teas on the diffusion of glucose out of dialysis tube after 3 h

| Herbal tea samples | Glucose diffusion to out of dialysis membrane (%)[1,2] | Increase of movement (%)[1,3] |
|---|---|---|
| Black tea | 96.01±0.19[bd] | 30.72±3.35 |
| Green tea | 96.06±0.13[bd] | 30.78±3.44 |
| Sage | 89.55±2.33[acd] | 21.88±0.19 |
| Peppermint | 95.92±0.18[bd] | 30.59±3.35 |
| Thyme | 96.18±0.03[bd] | 30.95±3.57 |
| Absinthium | 92.11±1.26[abd] | 25.39±1.75 |
| Roselle | 93.24±0.08[abd] | 26.96±3.61 |
| Olive leaves | 93.4±0.71[abd] | 27.18±4.48 |
| Shrubby blackberry | 95.69±0.37[bd] | 30.29±3.09 |
| Relax tea | 87.23±0.06[ac] | 18.77±3.19 |
| Avocado extract | 41.75±1.01[e] | – |
| Control | 73.48±2.03[f] | 0 |

[1] Each value is the mean ± standard deviation of three replicate analyses
[2] Means with the same superscripted letter within an assay are not significantly different as determined by Bonferroni analysis [$P<0.05$]
[3] Means are not significantly different as determined by Bonferroni analysis [$P<0.05$]

was the concentration of DPPH· at zero time. These values were plotted against mg of herbal extract/mg DPPH· to show the amount of antioxidant required to scavenge the initial DPPH · concentration in the reaction mixture by 50% ($EC_{50}$) using the exponential curve. [rem DPPH·%] = $b$ [moles antioxidant/mole DPPH·] + $a$; ($y=A.e^{BX}$). Antiradical efficiency (AE) was also calculated ($AE=1/EC_{50}$). Lower $EC_{50}$ values indicate higher antioxidant efficacy. Results were expressed as standard equivalents using Trolox on the basis of $EC_{50}$ value. All tests were done in triplicate and the results were presented as means ± SD.

*Hydrogen Peroxide Scavenging Activity*

Hydrogen peroxide scavenging activity was measured by the method of Wettasinghe and Shahidi [16]. One milliliter of sample (50–250 µg/ml) was mixed with 2.4 ml of 0.1 M phosphate buffer (pH 7.4), and then 0.6 ml of a 43 mM solution of $H_2O_2$ in the same buffer were added. After 40 min the absorbance values at 230 nm (using a Pharmacia Biotec Novaspec II spectrophotometer) of the reaction mixtures were recorded against a blank solution containing phosphate buffer without $H_2O_2$ for each sample. For each concentration, a separate blank sample was used for background subtraction. The percentage inhibition activity was calculated from: $[(A_0-A_1)/A_0]\times 100$, where $A_0$ is the absorbance of the control and $A_1$ is the absorbance of the extract/standard. All tests were done in triplicate and the results were presented as means ± SD.

*Statistical Analyses*

Differences between the variants were analyzed by Bonferroni and ANOVA tests. Correlation between total phenolic compound content and $EC_{50}$ were determined using by Spearman's rho test.

## Results

### Glucose Diffusion of Herbal Teas

In the present study, aqueous tea extracts of all samples did not demonstrated significant inhibitory effects on glucose movement into external solution across dialysis membrane compared to control. In contrast, they exhibited an increasing effect on glucose movement from dialysis tube to external solution (Table 3). Gallagher et al. [11] reported that agrimony and avocado extracts were the most potent inhibitors of glucose movement in the same model system. Also we studied avocado and determined that in the presence of avocado extract (5 g/100 ml) glucose diffusion was decreased. Avocado extract decreased the overall glucose movement by 43.18% compared to control ($P<0.005$). For all samples, the overall rates of glucose movement into external solution were higher than control (Table 3).

### Total Phenol Content

The content of phenolic compounds was calculated as milligram catechin equivalent per liter of herbal infusion (mg CE/L). The amount of total phenolics in the studied herbs and teas are shown in Table 4. Total phenols in those herbal teas varied from 70 mg CE/L for leaves of olea europaea to 4,070 mg CE/L for green tea. Only four tea samples had phenolic concentration > 1,000 mg CE/L: green tea > peppermint > thyme > black tea. The highest phenol content (4,070 mg CE/L) was found in green tea infusion. Cinnamon stick and clove were analyzed as solid and total phenol content were 3.31 and 86.45 mg CE in g of sample, respectively.

### DPPH Radical Scavenging Activity

The ability of the samples to donate hydrogen was checked by using the staple free radical DPPH ·. The amount of sample needed to decrease the initial DPPH· concentration ($EC_{50}$) by 50% is a parameter widely used to measure the antioxidant activity. The lower the $EC_{50}$, the higher is the antioxidant power. Another parameter is antiradical activity or power (AE). The higher the AE, the higher is the radical activity [14]. As shown in Table 4, there were big dif-

**Table 4** The total phenolic content of the herbal tea samples and scavenging activities of samples on the DPPH radical and Trolox

| Herbal tea samples | Total phenolic content (mg CE/L tea)[1,2] | $EC_{50}$[1,2,3] | AE[4] |
|---|---|---|---|
| Black tea | 1,430±0.05[b] | 0.62±0.01[a] | 1.61 |
| Green tea | 4,070±0.38[a] | 0.40±0.05[b] | 2.50 |
| Sage | 330±0.01[c] | 4.95±0.05[c] | 2.04 |
| Peppermint | 3,750±0.30[a] | 0.58±0.01[d] | 1.72 |
| Thyme | 1,510±0.01[b] | 0.99±0.09[e] | 1.01 |
| Absinthium | 570±0.01[c] | 2.98±0.09[f] | 0.33 |
| Roselle | 170±0.00[c] | 3.93±0.01[g] | 0.25 |
| Olive leaves | 70±0.01[c] | 4.86±0.01[c] | 0.20 |
| Shrubby blackberry | 340±0.03[c] | 6.22±0.01[h] | 0.16 |
| Relax tea | 860±0.05[bc] | 1.34±0.00[e] | 0.07 |
| Trolox | – | 0.091±0.02 | 10.98 |

[1] Each value is the mean ± standard deviation of three replicate analyses
[2] Means with the same superscripted letter within an assay are not significantly different as determined by Bonferroni analysis [$p<0.05$]
[3] Efficient concentration [$EC_{50}$] [mg sample/mg $DPPH^{\cdot}$]: amount of test sample needed [measured as the concentration of stock solution added to the reaction mixture] to decrease the initial $DPPH^{\cdot}$ [60 μM] concentration by 50%
[4] Antiradical efficiency [AE] = $1/EC_{50}$

ferences among the antioxidant capacity (DPPH) of the herbal teas. The $EC_{50}$ values varied from 0.40 to 6.22. The best values were obtained for green tea, closely followed by peppermint, black tea and thyme infusions, while shrubby blackberry was the weakest of all. The significant inversely linear correlation ($r=-0.88$, $P<0.05$) was confirmed between the amount of total phenols and $EC_{50}$ values of herbal tea extracts by Spearman's rho test. In this study, we researched and determined some applications commonly used of preparing herbal teas in public. These applications are mostly to add on some flavored plant such as clove, cinnamon during infusion or decoction of herbal teas (Table 2). Antioxidant activities of black tea with lemon, bergamot, clove and cinnamon and peppermint with lemon were presented in Table 5. According to our results, using lemon, bergamot, clove and stick and grounded cinnamon in preparation of black tea increased antioxidant activity of black tea. Also there is synergetic effect of lemon on peppermint tea ($P<0.005$).

**Table 5** Antioxidant activity of herbal teas by adding lemon, bergamot, clove or cinnamon

| Herbal tea samples | $EC_{50}$[1] |
|---|---|
| Black tea with lemon | 0.54±0.30[a] |
| Black tea with bergamot | 0.48±0.20[a] |
| Black tea with clove | 0.52±0.18[a] |
| Black tea with grounded cinnamon | 0.53±0.57[a] |
| Black tea with stick cinnamon | 0.52±0.04[a] |
| Peppermint with lemon | 0.37±0.12[b] |

[1] Each value is the mean ± standard deviation of three replicate analyses
[a] Significantly different, $P<0.005$ compared to black tea ($EC_{50}$ value, 0. 62)
[b] Significantly different, $P<0.005$ compared to peppermint tea ($EC_{50}$ value, 0.58)

## Scavenging of Hydrogen Peroxide

The scavenging ability of various extracts with hydrogen peroxide is given in Table 6. It is noticed that all the samples are not capable of scavenging hydrogen peroxide in an amount-dependent. The percentage of scavenging hydrogen peroxide is determined with 250 μl/ml of the herbal teas extracts as follows: green tea > peppermint > relax tea > black

**Table 6** Scavenging activity of samples on hydrogen peroxide

| Herbal tea samples | Concentration (μg/ml) | Inhibition (%)[1,2] |
|---|---|---|
| Black tea | 50 | 21.67±4.1 |
| | 150 | 35.65±3.4 |
| | 250 | 38.50±2.9[a] |
| Green tea | 50 | 56.34±1.2 |
| | 150 | 63.41±3.2 |
| | 250 | 65.50±1.0[b] |
| Sage | 50 | – |
| | 150 | 21.34±2.3 |
| | 250 | 25.56±2.4[c] |
| Peppermint | 50 | 34.20±2.0 |
| | 150 | 56.70±4.1 |
| | 250 | 61.80±3.0[b] |
| Thyme | 50 | 13.71±5.2 |
| | 150 | 20.60±3.4 |
| | 250 | 34.30±2.1[d] |
| Absinthium | 50 | 12.40±1.4 |
| | 150 | 15.40±1.8 |
| | 250 | 23.31±1.5[c] |
| Roselle | 50 | – |
| | 150 | – |
| | 250 | 11.70±2.1[e] |
| Olive leaves | 50 | – |
| | 150 | 14.51±2.6 |
| | 250 | 25.64±1.2[c] |
| Shrubby blackberry | 50 | – |
| | 150 | – |
| | 250 | 22.18±2.6[c] |
| Relax tea | 50 | 15.50±3.2 |
| | 150 | 34.45±4.5 |
| | 250 | 39.56±3.1[a] |

[1] Each value is the mean ± standard deviation of three replicate analyses
[2] Means with the same superscripted letter within an assay are not significantly different as determined by Bonferroni analysis [$p<0.05$]

tea > thyme > olive leaves = sage > absinthium > blackberry > roselle. The concentration of hydrogen peroxide in water may vary according to the phenolic compounds. Since phenolic compounds present in the extract are good electron donors, they may accelerate the conversion of $H_2O_2$–$H_2O$ [17].

## Discussion

Gallagher et al. [11] studied the ability to inhibit glucose diffusion using same *in vitro* method. They reported that agrimony and avocado represented the most inhibitory effect on glucose diffusion [more than 60%] and mushrooms, coriander, eucalyptus, juniper, lucerne, mistletoe decreased significantly (ranged 6–48%) and elder, nettle extracts did not significantly decrease glucose diffusion. Published research suggests that there is a direct relationship between a plant's ability to inhibit glucose absorption and the viscosity of the plant's constituent soluble polysaccharides. Also some investigators suggest that concentration and molecular mass of soluble fibers are major determinants of the plant's antihyperglycemic activity [11, 18]. According to our results, herbal teas, traditionally used in the treatment of diabetes did not show any *in vitro* inhibitory effects on glucose absorption. Gallagher et al. [11] reported that the plant extracts exhibited a concentration-dependent inhibitory effect on glucose movement. We did not study different concentration of herbal teas their dose-dependent effect on glucose diffusion. Concentrations in commonly using way of herbal teas in the diet of type 2 diabetic subjects are mainly considered. However, the plant's antihyperglycemic activity depends on many factors such as pH, other nutrients, and content of meal [11]. Further studies are needed to explain representing therapeutic potential of herbal teas. Kelble [8] reviewed that current research on phytochemicals and how they may alleviate type 2 diabetes by improving activity in the body. Green, black and oolong tea were reported to play a role in lowering blood glucose, increasing insulin sensitivity, and increasing glucose synthesis in response to food intake. Some antidiabetic plants may exert their action by stimulating the function or number of β-cells and thus increasing insulin release. In some other plants, the effect is due to decreased blood glucose synthesis due to the decreased of the activity of enzymes like glucose-6-phosphatase, fructose 1,6-bisphosphatase, etc. ın still other plants, the activity is due to slow absorption of carbohydrate and inhibition of glucose transport [10]. Katalinic et al. [19] analyzed the total phenolic content and related total antioxidant capacity of 70 medicinal plants. They found that total phenol content and total antioxidant capacity differs significantly among 70 selected medicinal plant infusions. Also, significant linear correlation between phenolic concentration and FRAP (Ferric Reducing/Antioxidant Power assay) in infusions was reported. Previous studies strongly shown that there were significant linear correlations between the total phenol concentration and antioxidant activity values determined for the analyzed foods [20–23]. Our assays confirm these results.

Black tea is the most consumed hot drink in Turkey. In a study Karakaya and El [20], evaluated the food frequency questionnaire received from Turkish volunteers, and reported that 240–340 ml of tea were consumed daily. The highest total phenolic matter content supplied per person from the black tea in Turkey had been reported as 441 mg/day [20]. There are not publications on phenolic content and related antioxidant properties of medicinal or herbal plants, traditionally used in Turkey. Usually foods in the diet are studied. The usage of various methods for the calculations (catechin or quercetin equivalent) and the evaluation of antioxidant capacity and substrates or products monitored makes comparison even more difficult. Good results of antioxidant activity were also obtained for different Mentha species in another study. Mentha extracts have a great potential in food industry, not only because of its flavorings properties but for its biological and medicinal benefits. From the $IC_{50}$ values calculated, it can be deduced that methanolic and aqueous extracts of Mentha × piperita were more potent than the other Mentha species tested [24]. Atoui et al. [25] reported that a high content of total phenolic compounds was observed in green and black teas, 1,216 mg and 847 mg, respectively, while mint was the lowest of all as calculated 106 mg gallic acid equivalent per cup. Ivanova et al. [22] studied *in vitro* antioxidant activity and phenolic compounds content in extracts of 21 plants used in Bulgarian phytotherapy for various disorders. They reported that high total phenolic content was detected for peppermint comparable to green and black teas as quercetin equivalents. Similar result for the scavenging activity of green tea was reported by Atoui et al. [25]. They determined that green tea had the highest radical scavenging capacity, closely followed by black tea. Antidiabetic properties have been found in green, black and oolong tea. The primary phytochemical responsible for tea's antidiabetic effects is epigallocatechin gallate [8]. The consumption of black tea and green tea exceeds 100 ml per person in a day in Turkey. For that reason these teas can be considered the phytochemicals as antioxidant sources between selected herbal teas. Also, our results showed that the combined antioxidant activity of the black tea by adding lemon, bergamot, clove or cinnamon is greater than their individual actions. Black tea and especially green tea have been studied extensively for their antioxidant activity. Black tea has lower antioxidant activity than green tea, probably a factor of the fermentation process that reduces catechin content to 9% from green tea's 30%. Most of the boreal plant treatments of diabetes or its complications potentially con-

tributed antioxidants to the traditionally lifestyle in greater amounts than is available via commonly consumed produce and beverages that can be purchased from contemporary markets, and some to a greater degree than standard antioxidant vitamins [2].

## Conclusion

Our results support the view that some herbal medicinal plants did not inhibit glucose diffusion using *in vitro* model glucose absorption. In particular, their phenolic compounds and antioxidant activities may be useful for meal planning in type 2 diabetes. They could contribute to sustain plasma antioxidant level because antioxidants present in the plants and herbs prevent the development of vascular diseases seen in type 2 diabetes.

## References


1. Grover JK, Yadav S, Vats V (2002) Medicinal plants of India with anti-diabetic potential. J Ethnopharmacol 81:81–100
2. McCune LM, Johns T (2002) Antioxidant activity in medicinal plants associated with the symptoms of diabetes mellitus used by the Indigenous Peoples of the North American boreal forest. J Ethnopharmacol 82:197–205
3. Gurib-Fakim A, Subratty H, Narod F, Govinden-Soulange J, Mahomoodally F (2005) Biological activity from indigenous medicinal plants of Mauritius. Pure Appl Chem 77(1):41–51
4. Ziegler EE, Filer LJ (1996) Present knowledge in nutrition. ILSI Press, Washington, DC
5. Berdanier CD (2002) Handbook of nutrition and food. CRC Press, New York
6. Facchini FS, Hua NW, Reaven GM, Stoohs RA (2000) Hyperinsulinemia: the missing link among oxidative stress and age-related disease? Free Radic Biol Med 29:1302–1306
7. Thompson KH, Godin DV (1995) Micronutrients and antioxidants in the progression of diabetes. Nutr Res 15(9):1377–1410
8. Kelble A (2005) Spices and type 2 diabetes. Nutr Food Sci 35(2):81–87
9. Alarcon-Aguilara FJ, Roman-Ramos R, Perez-Gutierrez S, Aguilar Contreras A, Contreras-Weber CC, Flores-Saenz JL (1998) Study of the anti-hyperglycemic effects of plants used as antidiabetics. J Ethnopharmacol 61:101–110
10. Chhetri DR, Parajuli P, Subba GC (2005) Antidiabetic plants used by Sikkim and Darjeeling Himalayan tribes. J Ethnopharmacol 99:199–202
11. Gallagher AM, Flatt PR, Duffy G, Abdel-Wahab YHA (2003) The effects of traditional antidiabetic plants on *in vitro* glucose diffusion. Nutr Res 23:413–424
12. Singleton VL, Rossi JA (1965) Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. Am J Enol Vitic 16:144–158
13. Shahidi F, Naczk M (1995) Food phenolics sources chemistry effects applications. Technomic, Lancaster, Basel
14. Brand-Williams W, Cuvelier ME, Berset C (1995) Use of a free radical method to evaluate antioxidant activity. LWT-Food Sci Tech 28:25–30
15. Parejo I, Codina C, Kefalas P (2000) Evaluation of scavenging activity assessed by Co(II)/EDTA-induced luminal chemiluminescence and DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical assay. J Pharmacol Toxicol Methods 44(3):507–512
16. Wettasinghe M, Shahidi F (2000) Scavenging of reactive-oxygen species and DPPH free radicals by extracts of borage and evening primrose meals. Food Chem 70:17–26
17. Kumaran A, Karunakaran RJ (2007) *In vitro* antioxidant activities of methanol extracts of five *Phyllanthus* species from India. LWT-Food Sci Tech 40(2):344–352
18. Wood PJ, Beer MU, Butler G (2000) Evaluation of role of concentration and molecular weight of oat beta-glucan in determining effect of viscosity on plasma glucose and insulin following oral glucose load. Br J Nutr 84:19–23
19. Katalinic V, Milos M, Kulisic T, Jukie M (2006) Screening of medicinal plant extracts for antioxidant capacity and total phenols. Food Chem 94:550–557
20. Karakaya S, El SN (1999) Quercetin, luteolin, apigenin and kaempferol contents of some foods. Food Chem 66:289–292
21. El SN, Karakaya S (2004) Radical scavenging and iron chelating activities of some greens used as traditional dishes in Mediterranean diet. Int J Food Sci and Nutr 55:67–74
22. Ivanova D, Gerova D, Chervenkov T, Yankova T (2005) Polyphenols and antioxidant capacity of Bulgarian medicinal plants. J Ethnopharmacol 96:145–150
23. Karakaya S, El SN, Taş A (2001) Antioxidant activity of some foods containing phenolic compounds. Int J Food Sci Nutr 52:501–508
24. López V, Akerreta S, Casanova E, García-Mina JM, Cavero RY, Calvo MI (2007) *In vitro* antioxidant and anti-rhizopus activities of lamiaceae herbal extracts. Plant Foods Hum Nutr 62:151–155
25. Atoui AK, Mansouri A, Boskou G, Kefalas P (2005) Tea and herbal infusions: their antioxidant activity and phenolic profile. Food Chem 89:27–36