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In vitro α-Glucosidase Inhibitory Potential and Antioxidant Activity of Selected Lamiaceae Species Inhabited in Korean Penninsula

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Abstract In the current study, inhibitory activity of 8 selected Korean edible plants of Lamiaceae family against α-glucosidases, prepared from rat small intestine acetone powder was evaluated. Total flavonoids and oxygen radical absorbance capacity (ORAC) were also investigated. Methyl alcohol extracts of *Scutellaria indica* (SI) had the highest α-glucosidase inhibitory activity relevant for potentially managing hyperglycemia, followed by *Clinopodium gracile* (CG) and *Thymus quinquecostatus* (TQ). These 3 species also showed significant antioxidant activity in ORAC system. The α-glucosidase inhibitory activity of the extracts was compared to selected phenolics. Among the standard phenolics tested quercetin which was major flavonoid in the extracts had the highest α-glucosidase inhibitory activity. CG, TQ, and SI which had high quercetin content and ORAC values also exhibited significant sucrase inhibitory activity. Results suggested that selected 3 Korean Lamiaceae species have the potential development of effective dietary strategy for postprandial hyperglycemia and oxidative stress-linked diabetes complications.

Keywords: antioxidant, non-insulin dependent diabetes mellitus, Lamiaceae, glucosidase inhibitor, oxygen radical absorbance capacity

Introduction

Non-insulin dependent diabetes mellitus (NIDDM, type 2 diabetes) is a common disorder of glucose and fat metabolism that affects 171 million people worldwide, generating immense health care costs (1). These disorders are strongly associated with diets high in calories and linked to changes in dietary pattern towards high calorie sweetened foods with maltose and sucrose. The entrocytes of small intestine can only absorb monosaccharides such as glucose and fructose from our diet (2). Therefore, the dietary disaccharides need to be broken down to monosaccharides before they can be absorbed. The intestinal absorption of dietary carbohydrates such as maltose and sucrose is carried out by a group of α-glucosidases which include intestinal maltase and sucrase. Inhibition of these enzymes can significantly decrease the postprandial increase of blood glucose level after a mixed carbohydrate diet and can be a key strategy in the control of diabetes mellitus. Furthermore postprandial hyperglycemia, a condition characterized by an abnormal increase of blood glucose level, has been linked to the onset of NIDDM and triggers the generation of free radicals and oxidation-related damage in the retina, renal glomerulus, and peripheral nerves (3,4). Therefore it is important to manage both blood glucose level and cellular redox status for managing these diabetic microvascular (i.e., retinal, renal, possibly neuropathic), macrovascular (i.e., coronary, peripheral vascular), and neuropathic (i.e., autonomic, peripheral) complications.

Lamiaceae mint family (Labiatae family) includes sage, rosemary, and lavenders and has long been used for a large range of purposes including medicine, nutrition, flavorings, beverages, dyeing, repellents, and the treatment of common aliments as traditional medicine in the Mediterranean region (5). Recent research has now indicated that phenolic phytochemicals from these herbs have high antioxidant activity and α-glucosidase inhibitory activity (6-9). Further it has shown that these phenolic phytochemicals posses specific therapeutic properties and may be responsible for their beneficial effect on human health (10). Phenolic phytochemicals from Lamiaceae family are now implicated to have potential for management of many chronic oxidation-linked diseases such as diabetes and cardiovascular disease (CVD) (11). Recently it has been shown that phenolics from the Lamiaceae family of herbs such as rosmarinic acid from *Origanum vulgare* have anti-α-glucosidases (12) and antioxidant (13) activity. Therefore, inhibition of maltase and sucrase a group of α-glucosidases using natural inhibitors from food-grade plant sources offer an attractive strategy to control of post-prandial hyperglycemia for NIDDM management via inhibition of disaccharide breakdown and intestinal glucose absorption.

The purpose of this study was to (i) evaluate a variety of culinary and medicinal plants of Lamiaceae family that were growing in Korean penninsula with respect to their total flavonoid content and antioxidant activity to find new potential sources of natural antioxidants; (ii) evaluate the relationship between flavonoid content, antioxidant activity, and α-glucosidases inhibitory activity (anti-diabetic potential); and (iii) identify and quantify major flavonoid profile in selected herbs by high performance liquid chromatography (HPLC).

Materials and Methods

Materials Korean Lamiaceae extracts (SI, *Scutellaria*

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indica; TQ, *Thymus quinquecostatus*; LS, *Leonurus sibiricus*; CG, *Clinopodium gracile* var. *multicaule*; AD, *Ajuga decumbens*; PV, *Prunella vulgaris* var. *lilacina*; PF, *Perilla frutescens* var. *japonica*; IE, *Isodon excisus*) were purchased from Korean Plant Extract Bank (KRIBB, Daejeon, Korea). α-Amylase (EC 3.2.1.1) and rat intestinal acetone powders were purchased from Sigma-Aldrich (St. Louis, MO, USA). Unless noted, all chemicals were purchased from Sigma-Aldrich.

Sample extraction A total of 2 g of dried herb powder were stirred in 100 mL of 50% concentration of methyl alcohol at 50°C for 4 hr and cooled. The extract was then filtered through a Whatman # 2 filter, centrifuged at 10,000 ×g for 10 min, vacuum-evaporated at 45°C, and kept at −20°C until analysis.

Total flavonoid assay Total flavonoid was measured by using the method of Moreno *et al.* (14). A volume of 0.1 mL of sample extract solution was added 0.9 mL of 80% ethanol. Half mL of mixture solution was mixed with 0.1 mL of 10% aluminum nitrate, 0.1 mL of 1 M potassium acetate, and 4.3 mL of 80% ethanol, and allowed to stand for 40 min at room temperature. The absorbance was read at 415 nm using spectrophotometer (UV-160A; Shimadzu Inc., Kyoto, Japan). Standard curve was established using various concentrations of quercetin. Absorbance values were converted to total flavonoids which were expressed as mg quercetin equivalent/g sample extract.

Oxygen radical absorbance capacity (ORAC) assay The ORAC assay was carried out using a Tecan GENios multi-functional plate reader (GENios; Tecan Trading AG, Salzburg, Austria) with fluorescent filters (excitation wavelength: 485 nm, emission filter: 535 nm). In the final assay mixture, fluorescein (40 nM) was used as a target of free radical attack with either 2,2'-azobis (2-amidinopropane) dihydrochloride (AAPH, 20 mM) as a peroxyl radical generator in peroxyl radical scavenging capacity ($ORAC_{ROO\cdot}$) assay (15,16). Trolox (1 μM) was used as a control standard and prepared fresh on a daily basis. The analyzer was programmed to record the fluorescence of fluorescein every 2 min after AAPH was added. All fluorescence measurements were expressed relative to the initial reading. Final results were calculated based on the difference in the area under the fluorescence decay curve between the blank and each sample. All data were expressed as μM of Trolox equivalents (TE). One ORAC unit is equivalent to the net protection area provided by 1 μM of Trolox.

α-Amylase inhibition assay Porcine pancreatic α-amylase inhibition referred to the method of Kwon *et al.* (17). A total of 200 μL of sample solution and 500 μL of 0.02 M sodium phosphate buffer (pH 6.9 with 0.006 M sodium chloride) containing α-amylase solution (0.5 mg/mL) were incubated at 25°C for 10 min. After pre-incubation, 500 μL of a 1% starch solution in 0.02 M sodium phosphate buffer was added. The reaction mixture was then incubated at 25°C for 10 min. The reaction was stopped with 1.0 mL of dinitrosalicylic acid (DNS), color reagent. The reaction mixture was then incubated in a boiling water bath for 5 min and cooled to room temperature. The reaction mixture was then diluted after adding 10 mL of water, and absorbance was measured at 540 nm with enzyme-linked immunosorbent assay (ELISA) microplate reader (SUNRISE; Tecan Trading AG, Saltzburg, Austria).

$$\text{Inhibition (\%)} = \left(\left[\frac{\Delta A_{540}^{\text{Control}} - \Delta A_{540}^{\text{Extract}}}{[\Delta A_{540}^{\text{Control}}]} \right] \right) \times 100$$

α-Glucosidase inhibition assay Rat intestinal α-glucosidase assay referred to the method of Kwon *et al.* (17) with slight modification. A total of 1 g of rat-intestinal acetone powder was suspended in 3 mL of 0.9% saline, and the suspension was sonicated 12 times for 30 sec at 4°C. After centrifugation (10,000×g, 30 min, 4°C), the resulting supernatant was used for the assay (18). Sample solution (50 μL) and 0.1 M phosphate buffer (pH 6.9, 100 μL) containing α-glucosidase solution (1.0 U/mL) was incubated at 25°C for 10 min. After pre-incubation, 5 mM *p*-nitrophenyl-α-D-glucopyranoside solution (50 μL) in 0.1 M phosphate buffer (pH 6.9) was added to each well at timed intervals. The reaction mixtures were incubated at 25°C for 5 min. Before and after incubation, absorbance was read at 405 nm and compared to a control which had 50 μL of buffer solution in place of the extract by microplate reader (SUNRISE; Tecan Trading AG). The α-glucosidase inhibitory activity was expressed as inhibition % and was calculated as follows:

$$\text{Inhibition (\%)} = \left(\left[\frac{\Delta A_{405}^{\text{Control}} - \Delta A_{405}^{\text{Extract}}}{[\Delta A_{405}^{\text{Control}}]} \right] \right) \times 100$$

Maltase and sucrase inhibition assay Rat-intestinal acetone powder (1.0 g) was suspended in 3 mL of 0.9% saline, and the suspension was sonicated 12 times for 30 sec at 4°C. After centrifugation (10,000×g, 30 min, 4°C), the resulting supernatant was used for the assay. Maltase and sucrase inhibitory activity were assayed by modifying a method developed by Dahlqvist (19). The inhibitory activity was determined by incubating a solution of an enzyme (50 μL), 0.1 M phosphate buffer (pH 7.0, 100 μL) containing 0.4 mg/mL sucrose or maltose, or 1% soluble starch, and a solution (50 μL) with various concentrations of sample solution at 37°C for 30 min. The reaction mixture was heated in a boiling water bath to stop the reaction for 10 min, and then the amount of liberated glucose was measured by the glucose oxidase method (20). The inhibitory activity was calculated from the formula as follows. Inhibition (%)=(C-T)/C×100, where C is the enzyme activity without inhibitor and T is the enzyme activity with inhibitor.

HPLC analysis of quercetin A volume of 2 mL of sample extracts were filtered through a 0.2-μm syringe filter. The quercetin in the extract were analyzed using HPLC (21), (Tosoh 8010 Series; Tosoh Corporation, Tokyo, Japan) equipped with a diode-array UV-vis detector (UV 8010; Tosoh Corp., Tokyo, Japan) at 363 nm, and TSKgel-ODS 80 (15 cm×7.6 mm) column (TSK ODS 80;

Tosoh Corp.). The mobile phase used a water-acetonitrile mixture containing 0.05% phosphoric acid, where the flow rate and sample injection volume were fixed at 1.0 mL/min and 20 μL, respectively. The solvents used for gradient elution were (A) water-acetonitrile (95:5, v/v) and (B) water-acetonitrile (50:50, v/v). The solvent (B) was increased to 30% for the first 20 min and to 80% over the next 20 min, then decreased to 10% for the next 5 min and was maintained for the next 10 min (total run time, 55 min). As reference ingredient, pure standard of quercetin (purchased from Sigma-Aldrich) in 100% methanol was used to calibrate the standard curve and retention times.

Statistical analysis All data are presented as mean± standard deviation (SD). Statistical analyses were carried out using statistical package SPSS (Statistical Package for Social Science; SPSS Inc., Chicago, IL, USA) program and significance of each group was verified with the analysis of one-way anaysis of variance (ANOVA) followed by the Duncan's test of $p<0.05$.

Results and Discussion

Total flavonoids and HPLC analysis of extract The total flavonoid content in extracts was analyzed by the method of Moreno *et al* (14). Methyl alcohol extract of CG had 42.85 mg/g-extract weight (EW) of flavonoids which was the highest among all the extracts tested (Fig. 1). The TQ and SI extracts had 41.37 and 31.60 mg/g-EW of total flavonoids, respectively (Fig. 1). The major flavonoid, quercetin was identified in the extracts using HPLC (Table 1). CG had high concentrations of quercetin (1.10 mg/g-EW). TQ was also high in quercetin content (1.09) compared to 0.71 mg/g-EW in SI extracts (Table 1). This quercetin content of the sample extract generally was proportional to total flavonoids content (Table 1 and Fig 1).

Antioxidant activity by ORAC system The ORAC assay developed by Cao *et al.* (16) has been proved to be a widely accepted method for evaluating antioxidant capacity of various foods and biological samples (22,23). ORAC assay system has been used successfully to determine the reaction capacity with peroxyl radical, one of harmful and reactive oxygen species in biological system. Antioxidant activity of sample extracts was investigated for their peroxyl radical scavenging capacity using ORAC assay system, where AAPH was used as a generator of peroxyl radicals. Figure 2 demonstrates that the scavenging activity of sample extract on peroxyl radicals generated from AAPH was found to be dose-dependent between 1 and 10 μg/mL. The bars in Fig. 2 represents the $ORAC_{ROO\cdot}$ activity of 1 μM of the tested sample equivalent to 1 μM Trolox, a water-soluble α-tocopherol analogue. The ORAC values for the sample extracts ranged from 0.8 to 12.6 μM TE. The sample extracts (10 μg/mL) with the highest ORAC values were CG (12.6), TQ (12.5), and SI (12.4 TE). These ORAC values of the sample extract was proportional to total flavonoids content (Fig 1 and 2; The Pearson's correlation coefficient of sample extracts between ORAC values and total flavonoids content was 0.8033).

A major flavonoid identified in the extracts using HPLC

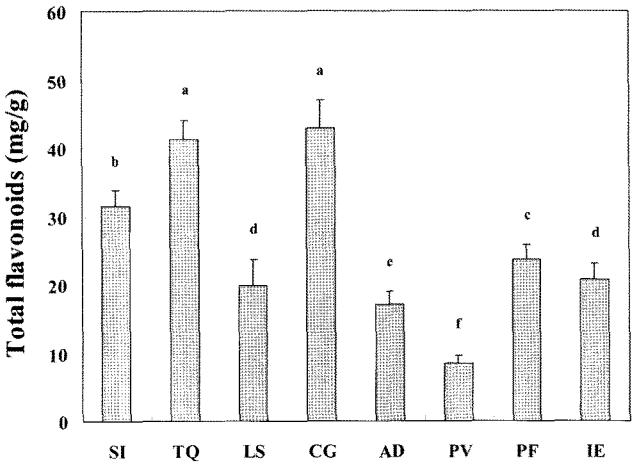

Fig. 1. Total flavonoid content in methyl alcohol extracts of 8 selected Korean edible plants of Lamiaceae family. SI, *Scutellaria indica*; TQ, *Thymus quinquecostatus*; LS, *Leonurus sibiricus*; CG, *Clinopodium gracile* var. *multicaule*; AD, *Ajuga decumbens*; PV, *Prunella vulgaris* var. *lilacina*; PF, *Perilla frutescens* var. *japonica*; IE, *Isodon excisus*. [a-f]Values are the mean ±SD of total flavonoid content of 3 replicated samples. Bar with different letters indicate statistically significance of differences among groups at $p<0.05$ by Duncan's test.

Table 1. Quercetin content (mg/g-extract weight) analyzed by HPLC in methyl alcohol extracts of Korean edible plants of Lamiaceae family

Lamiaceae family[1)]	Quercetin (mg/g-extract weight)
SI	0.71±0.02
TQ	1.09±0.04
LS	ND[2)]
CG	1.10±0.01
AD	ND
PV	ND
PF	ND
IE	ND

[1)]SI, *Scutellaria indica*; TQ, *Thymus quinquecostatus*; LS, *Leonurus sibiricus*; CG, *Clinopodium gracile* var. *multicaule*; AD, *Ajuga decumbens*; PV, *Prunella vulgaris* var. *lilacina*; PF, *Perilla frutescens* var. *japonica*; IE, *Isodon excisus*.
[2)]Not detected.

was quercetin (Table 1). The most widespread and diverse phenolics are the flavonoids which have the same C15 (C6-C3-C6) skeleton and possess antioxidant capacity toward a variety of easily oxidizable compounds (24). In herbs, the main flavonoid constituents are flavonol aglycones such as quercetin and myricetin (25). Generally, flavonoids containing multiple hydroxyl groups have higher antioxidant activities against peroxyl radicals than do phenolic acids (24). The reduction capacity of CG, TQ, and SI extracts appear to increase with increasing the concentration from 1 to 10 μg/mL (Fig. 2). These results suggest that the peroxyl radical scavenging capacity of Korean Lamiaceae extracts could be attributed to the fact that its reducing ability reduces peroxyl radicals by donating electrons or hydrogens to make them into relatively stable compounds. Recent studies have reported that the water extract of Lamiaceae species such as rosemary, lemon balm, oregano showed a

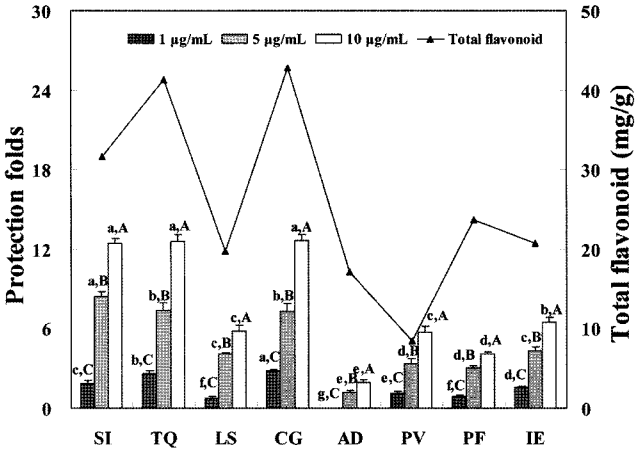

Fig. 2. Peroxyl radical scavenging activity (Trolox equivalent, μM) of 8 selected Korean edible plants using ORAC *in vitro* system. Lamiaceae family: SI, *Scutellaria indica*; TQ, *Thymus quinquecostatus*; LS, *Leonurus sibiricus*; CG, *Clinopodium gracile* var. *multicaule*; AD, *Ajuga decumbens*; PV, *Prunella vulgaris* var. *lilacina*; PF, *Perilla frutescens* var. *japonica*; IE, *Isodon excisus*. ORAC value is calculated by dividing the area under the sample curve by the area under the Trolox curve, with both areas being corrected by subtracting the area under the blank curve. One ORAC unit is assigned as the net area of protection provided by Trolox at a final concentration of 1 μM. The area under the curve for the sample is compared to the area under the curve for Trolox, and the anti-oxidative value is expressed in μM TE/L. The results represent mean±SD of values obtained from 3 measurements. Different corresponding letters indicate significant differences at $p<0.05$ by Duncan's test. First letter is among different samples and second one is among different concentrations within same sample extracts. The Pearson's correlation coefficient between ORAC values and total flavonoids content is 0.8034.

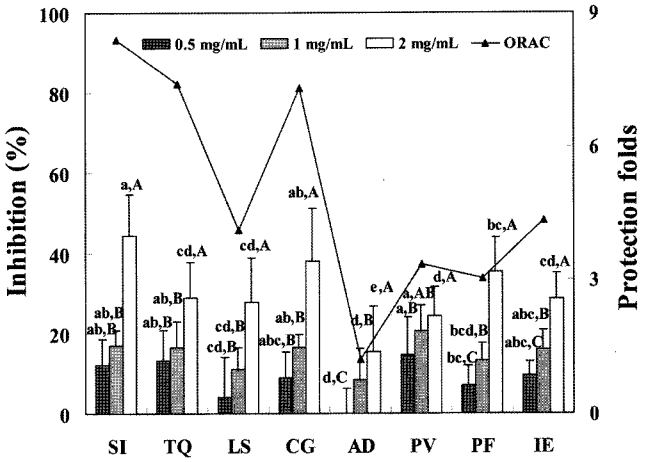

Fig. 3. Dose dependent changes in rat intestinal α-glucosidase inhibitory activity of Korean edible plants of Lamiaceae family. The results represent mean±SD of values obtained from 3 measurements. Different corresponding letters indicate significant differences at $p<0.05$ by Duncan's test. First letter is among different samples and second one is among different concentrations within same sample extracts. The Pearson's correlation coefficient between α-glucosidase inhibitory activity and ORAC values is 0.7784.

dose-dependent free radical scavenging activity of 1,1-diphenyl-2-picryl hydrazyl (DPPH) radical (12). Therefore, higher antioxidant activity of the methyl alcohol extracts in this assay suggests a possible biological functionality in preventing the oxidative degradation of membrane lipids relevant for complications of NIDDM via oxidative stress-linked cell damages.

α-Amylase/α-glucosidase inhibition The α-glucosidase inhibitors, which interfere with enzymatic action in the brush-border of the small intestine, could slow the liberation of D-glucose from oligosaccharides and disaccharides, resulting in delaying glucose absorption and decreasing postprandial plasma glucose levels (26). Recent research with clonal herbal extracts reported an association between antioxidant activity and α-glucosidase inhibition activity (12). Previous research with clonal herbal extracts reported a microbial (baker's yeast) α-glucosidase inhibitory activiy with water extract and 12% ethanol extracts (12). Water extracts of *Origanum vulgare* (93.7) had the highest α-glucosidase inhibitory activity followed by *Mentha piperata* (85.9) and *Melissa officinalis* (83.9%). All the extracts showed a comparable inhibition of the α-glucosidase but did not have any inhibitory activity against porcine pancreatic α-amylase which reflected potential for reduced side-effects (12). Therefore, we evaluated the inhibitory activity of 8 selected Korean edible plants of Lamiaceae family against α-amylase from porcine pancreas and α-glucosidase prepared from rat small intestine acetone powder. The methyl alcohol extract of SI had the highest α-glucosidases inhibitory activity (44.4) followed by CG (38.1), TQ (29.0), and PF (35.3%) also showed significant α-glucosidase inhibitory activity (Fig. 3). These α-glucosidase inhibitory activities of the sample extracts were proportional to ORAC values (Fig. 2 and 3; The Pearson's correlation coefficient of sample extracts between α-glucosidase inhibitory activity and ORAC values was 0.7784).

In order to estimate the correlation between standard phenolic content and α-glucosidase inhibitory of activity of the sample extracts, the α-glucosidase inhibitory activity of the extracts was also compared to selected specific phenolics (Fig. 4). Pure quercetin on a constant weight basis had the highest α-glucosidase inhibitory activity (83.8) followed by protocatechuic acid (20.3), hydrobenzoic acid (19.9), and rosmarinic acid (13.4%). The α-glucosidase inhibitory of activity of the sample extracts generally was not proportional to quercetin content which individually showed high α-glucosidase inhibitory activity (Fig. 3 and 4). This may be due to the composition and profile of unidentified individual phenolics in the extracts. All the extracts showed a comparable inhibition of the α-glucosidase but did not have any inhibitory activity against porcine pancreatic α-amylase (data not shown), indicating that this result was similar to that of oregano, lemon balm, and rosmary which has been known to natural α-glucosidase inhibitor with less side-effect due to excessive inhibition of α-amylase (17). Our previous experiment using yeast α-glucosidase assay indicated that flavonol such as quercetin had significantly high inhibitory activity (12). It have been reported that most of yeast α-glucosidase inhibitors did not show inhibitory activity against mammalian α-glucosidase due to the difference of molecular recognition in the binding

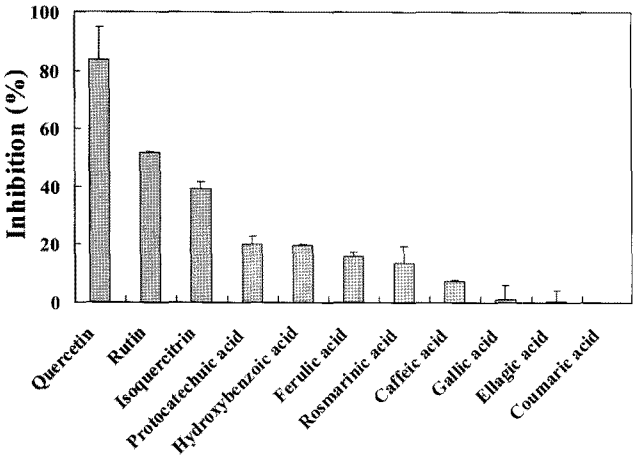

Fig. 4. α-Glucosidase inhibitory activity of standard phenolics at constant concentration (1.0 mM). The results represent mean±SD of values obtained from 3 measurements.

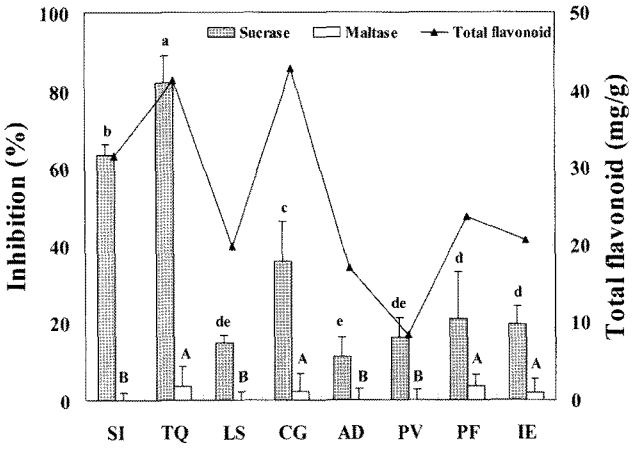

Fig. 5. Dose dependent (1.67 mg/50 μL) changes in rat intestinal sucrase and maltase inhibitory activity of Korean edible plants of Lamiaceae family. Results represent mean±SD. of values obtained from 3 measurements. Different corresponding letters indicate significant differences at $p<0.05$ by Duncan's test. $^{a\text{-}e,\ A\text{-}B}$Values are mean±SD of sucrase and maltase inhibitory activities of 3 replicated samples, respectively. The Pearson's correlation coefficient between sucrase inhibitory activity and total flavonoids content is 0.7636.

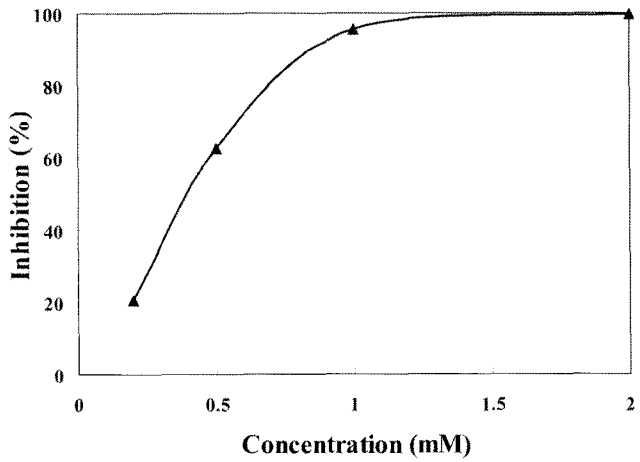

Fig. 6. Dose dependent changes in the sucrase inhibitory activities of quercetin.

site of enzymes (27), and that 5,6,7-trihydroxyflavanone structure of flavonol was crucial for exerting activity (27). Therefore, correlation of the α-glucosidase inhibitory activities of the standard phenolics samples may suggest the phenolic profile of each samples may be important factor in contributing to the α-glucosidase inhibitory activity. Many tested phenolics showed a comparable inhibition of the α-glucosidase activity. These results suggest that phenolic compounds may play a role in the inhibition of α-glucosidase activity of several herb extracts of Korean Lamiaceae family. This α-glucosidase inhibitory activity correlated to total flavonoid content, antioxidant activity and content of individual phenolics in the extract.

Sucrase and maltase inhibition The intestinal absorption of dietary carbohydrates such as maltose and sucrose is carried out by a group of α-glucosidases which include intestinal maltase and sucrase. Inhibition of these enzymes can significantly decrease the postprandial increase of blood glucose level after a mixed high calorie carbohydrate diet and can be a key strategy in the control of diabetes mellitus. Results of screening for sucrase and maltase inhibitory activities of sample extracts are shown in Fig. 5. The sucrase inhibitory activities ranged from 11.4 to 82.1%, with the highest value in TQ (82.1), followed by SI (63.4) and CG (35.9%). All the extracts showed a comparable inhibition of the sucrase but did not have significant inhibitory activity against maltase. Among all the extracts, the TQ which had high quercetin content also had the most potent sucrase inhibitory activity (Table 1 and Fig. 5). This was followed by SI which also contained high quercetin content. The sucrase inhibitory activity of the sample extracts correlated with quercetin content which individually showed high α-glucosidase inhibitory activity (Table 1, Fig. 4, and 5; The Pearson's correlation coefficient of sample extracts between sucrase inhibitory activity and quercetin content was 0.8337). Furthermore, this sucrase inhibitory activity of the sample extracts was proportional to total flavonoids content (Fig. 1 and 5; The Pearson's correlation coefficient of sample extracts between sucrase inhibitory activity and total flavonoids content was 0.7636). The ORAC values of sample extracts were also correlated with sucrase inhibitory activity (Fig. 2 and 5; The Pearson's correlation coefficient of sample extracts between sucrase inhibitory activity and ORAC values was 0.8382).

To evaluate the potency of active ingredient in Korean Lamiaceae extracts the dose dependency and IC_{50} of the quercetin, major active ingredient in sample extracts on the sucrase inhibitory activity was measured using different amount of quercetin (mM) (Fig. 6). Quercetin had strong sucrase inhibitory activity (IC_{50}, 0.41 mM, approximately). This suggested that the content of quercetin in Korean Lamiaceae was critical for high sucrase inhibitory activity and could be used for parameter of anti-hyperglycemia capacity.

As seen in Fig. 1, 2, and 5, data trends for flavonoids content, antioxidant activity, and sucrase inhibitory activity

in sample extracts have important implications for the development and new design of Korean Lamiaceae-based functional foods. This has clear potential for managing blood glucose level and oxidative stress-linked diabetes complications using the specific enrichment of flavonoids profile in plant foods. It is suggested that selected Korean Lamiacea species with high quercetin content may be used for the development of pharmaceutical food to control the blood glucose level of diabetic patients by inhibiting sucrase in intestinal tract.

Hyperglycemia-induced microvascular complications are likely from oxidative dysfunction from mitochondrial reactive oxygen species (ROS). Insights from this study indicate that selected edible Lamiaceae species inhabited in Korean penninsula have sucrase inhibitory activity and high flavonoids content with high free radical scavenging-linked antioxidant activity and therefore have the potential to contribute to the reduction of hyperglycemia-induced microvascular complications. The above benefits (anti-hyperglycemia and antioxidant activity) taken together indicate the potential of traditional Korean edible plants to reduce the hyperglycemia and associated macro and microvascular complications and support the evidence that diets rich in fruits and vegetables are associated with lower incidences of oxidation-linked diseases such as diabetes (28-30). Based on these results the sucrase inhibitory activity and antioxidant activity in select Korean Lamiaceae species (CG, TQ, and SI) would be helpful to manage glucose uptake and the glucose-induced increased levels of mitochondrial ROS linked to hyperglycemia.

Acknowledgments

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