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Phenolic compounds, antioxidant activity and *in vitro* inhibitory potential against key enzymes relevant for hyperglycemia and hypertension of commonly used medicinal plants, herbs and spices in Latin America

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ABSTRACT

Traditionally used medicinal plants, herbs and spices in Latin America were investigated to determine their phenolic profiles, antioxidant activity and *in vitro* inhibitory potential against key enzymes relevant for hyperglycemia and hypertension. High phenolic and antioxidant activity-containing medicinal plants and spices such as Chancapiedra (*Phyllanthus niruri* L.), Zarzaparrilla (*Smilax officinalis*), Yerba Mate (*Ilex paraguayensis* St-Hil), and Huacatay (*Tagetes minuta*) had the highest anti-hyperglycemia relevant *in vitro* α -glucosidase inhibitory activities with no effect on α -amylase. Molle (*Schinus molle*), Maca (*Lepidium meyenii* Walp), Caigua (*Cyclanthera pedata*) and ginger (*Zingiber officinale*) inhibited significantly the hypertension relevant angiotensin I-converting enzyme (ACE). All evaluated pepper (*Capsicum*) genus exhibited both anti-hyperglycemia and anti-hypertension potential. Major phenolic compounds in Matisco (*Piper angustifolium* R.), Guascas (*Galinsoga parviflora*) and Huacatay were chlorogenic acid and hydroxycinnamic acid derivatives. Therefore, specific medicinal plants, herbs and spices from Latin America have potential for hyperglycemia and hypertension prevention associated with Type 2 diabetes.

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1. Introduction

Current dietary habits, characterized by simplified and refined diets and devoid of nutritionally-rich and functionally-healthy plant foods, are leading to emergence of obesity-linked epidemics such as Type 2 diabetes, cardiovascular disease, cancer and other chronic diseases, even within poor countries (Johns and Eyzaguirre, 2006). The consequences of a high-carbohydrate, high-fat diet are further complicated and compounded among the disadvantaged communities in developing countries, where dietary changes in combination with poverty and high rates of infectious diseases and undernutrition create a double burden (Popkin, 2002; Popkin et al., 2001).

Type 2 diabetes linked to glycemic index imbalance and glucose intolerance are considered to be important cardiovascular risk factors encompassed by the term metabolic syndrome, which further typically includes central obesity, dyslipidemia, and hypertension. Major pathogenetic mechanisms of Type 2 diabetes are impaired glycemic index control, insulin secretion and insulin resistance (Leiter and Lewanczuk, 2005). Diabetes markedly affects the function of the cardiovascular system, both the microcirculation as well as in large conduit arteries supplying vital organs such as the heart,

brain and kidney. As a consequence, diabetes surpasses other conditions such as dyslipidemia and hypertension as a risk predictor for myocardial infarction, stroke, and renal failure (Luscher and Steffel, 2008).

Plants have formed the basis of traditional medicine systems that have been in existence for thousands of years. Even in modern times, plant-based systems continue to play an essential role in health care. It has been estimated by the World Health Organization that approximately 80% of the world's population from developing countries rely mainly on traditional medicines (mostly derived from plants) for their primary health care. Plant products also play an important role in the health care for the remaining 20% in developing countries, and for those in industrialized countries as well (Chivian, 2002).

Latin America offers a wide diversity of plants and unique seasonal crops mainly due to the presence of natural areas such as the Andean mountains, the Amazon rainforest and the tropical and sub-tropical forests in Central America. Several scientific reports have pointed out the therapeutic potential of certain plants and foods from this area. For example, anti-inflammatory and antioxidant properties have been found in *Uncaria tomentosa*, a vine that grows in the Amazon (Gonçalves et al., 2005) whereas “Maca” (*Lepidium meyenii*), a native tuber from the central Andes from Peru, have been linked to multi-pharmacological functions such as fertility improvement, anti-proliferative functions and capacity

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for the protection of cells against oxidative stress (Wang et al., 2007). However, many medicinal plants are still used traditionally as “folk” medicines, and more specific research related to their functional potential against the principal components of the metabolic syndrome such as Type 2 diabetes-linked hyperglycemia and related cardiovascular complications is essential. This also may help to promote the return to diversity of traditional whole food dietary patterns among population.

Based on the above rationale, the objective of this research was to investigate different traditionally used medicinal plants, herbs and spices from Latin America for their associated phenolic profiles, antioxidant activity and potential for managing early stages of Type 2 diabetes such as hyperglycemia relevant α -glucosidase and α -amylase and hypertension relevant angiotensin I-converting enzyme (ACE) using *in vitro* models.

2. Methods

2.1. Materials

Dried and packaged samples were purchased from Ecuadorian Store in Hadley, MA (USA). Fresh samples such as Molle (*Schinus molle*), Caigua (*Cyclanthera pedata*), Maca (raw) (*Lepidium meyenii* Walp), Cedron (*Aloysia triphylla*), Huacatay (*Tagetes minuta*), Paprika pepper (*Capsicum annuum*), Yellow pepper (*Capsicum baccatum*), Red pepper (*Capsicum chinense*) and Rocoto (*Capsicum pubescens*) were obtained from a local market in Arequipa (Peru) and then dehydrated at 70 °C in a hot air oven until constant weight. Table 1 summarizes some characteristics of analyzed samples. Samples were selected based on their common use as traditional medicinal plants, herbs and spices among people from the Latin American region and considering their regular form of availability at the consumer level (dried and fresh).

Table 1
Medicinal plants, herbs and spices from Latin America.

Group	No	Common name	Commercial brand	Scientific name	Family	Origin	Plant part
Medicinal Plants	1	Ayrampo	Purchased locally in Peru	<i>Opuntia soehrensii</i>	Cactaceae	Peru (Andes)	Fruit seeds
	2	Molle	Purchased locally in Peru	<i>Schinus molle</i>	Anacardiaceae	Peru (Andes)	Fruit
	3	Maca-R (Raw)	Purchased locally in Peru	<i>Lepidium meyenii</i> Walp	Brassicaceae	Peru (Andes)	Tuberous root
	4	Maca-P (pre-toasted)*	Nuestra salud	<i>Lepidium meyenii</i> Walp	Brassicaceae	Peru (Andes)	Tuberous root
	5	Caigua	Purchased locally in Peru	<i>Cyclanthera pedata</i>	Cucurbitaceae	Peru (Andes)	Fruit
	6	Zarparrilla	Nuestra salud	<i>Smilax officinalis</i>	Smilacaceae	Peru	Root
	7	Cat's claw	Nuestra salud	<i>Uncaria tomentosa</i>	Rubiaceae	Peru (Amazon)	Bark
	8	Chancapiedra	La Cholita	<i>Phyllanthus niruri</i> L.	Euphorbiaceae	Ecuador (Amazon)	Leaves
Herbal teas	9	Matico	La Cholita	<i>Piper angustifolium</i> R.	Piperaceae	Ecuador	Leaves
	10	Malva blanca	Mamá Rosa	<i>Malva silvestres</i> L.	Malvaceae	Ecuador (Andes)	Leaves
	11	Linden tea tilo	La Flor	<i>Tilia platyphyllos</i>	Malvaceae	Not especificed	Flowers
	12	Cedron	Purchased locally in Peru	<i>Aloysia triphylla</i>	Verbenaceae	Peru (Andes)	Leaves
	13	Boldo	La Cholita	<i>Peumus boldus</i>	Monimiaceae	Ecuador	Leaves
	14	Yerba Mate Organic	Silueta- Las Marias	<i>Ilex paraguayensis</i> St-Hil	Aquifoliaceae	Argentina	Leaves and young twigs
Spices	15	Ground cumin	Ile	<i>Cuminum cyminum</i>	Apiaceae	Ecuador	Seed
	16	Whole ginger	La Flor	<i>Zingiber officinale</i>	Zingiberaceae	Jamaica	Rhizome
	17	Turmeric	Cooperativa Oro Verde	<i>Curcuma longa</i> L.	Zingiberaceae	Peru (Amazon)	Rhizome
	18	Cinnamon	Ile	<i>Cinnamomum zeylanicum</i> B.	Lauraceae	Ecuador	Bark
	19	Guascas	La Fé	<i>Galinsoga parviflora</i>	Asteraceae	Colombia	Leaves
	20	Huacatay	Purchased locally in Peru	<i>Tagetes minuta</i>	Asteraceae	Peru	Leaves
Peppers	21	Chile de arbol	La Flor	<i>Capsicum annuum</i>	Solanaceae	Mexico	Fruit pulp
	22	Chile ancho	La Flor	<i>Capsicum annuum</i>	Solanaceae	Mexico	Fruit pulp
	23	Japanese chili pods	Órale	<i>Capsicum annuum</i>	Solanaceae	Mexico	Fruit pulp
	24	Paprika pepper	Purchased locally in Peru	<i>Capsicum annuum</i>	Solanaceae	Peru	Fruit pulp
	25	Yellow pepper (aji Amarillo)	Purchased locally in Peru	<i>Capsicum baccatum</i>	Solanaceae	Peru	Fruit pulp
	26	Red pepper (aji pancca)	Purchased locally in Peru	<i>Capsicum chinense</i>	Solanaceae	Peru	Fruit pulp
	27	Rocoto	Purchased locally in Peru	<i>Capsicum pubescens</i>	Solanaceae	Peru	Fruit pulp

* Information according to the package label.

Porcine pancreatic α -amylase (EC 3.2.1.1) and baker's yeast α -glucosidase (EC 3.2.1.20) were purchased from Sigma Chemical Co. (St. Louis, MO). Unless noted, all chemicals also were purchased from Sigma Chemical Co. (St. Louis, MO).

2.2. Extract preparation

A total of 5 g of powdered dried sample was added to 100 mL of distilled water and refluxed at 95 °C for 30 min and cooled. The extracts were then filtered through filter paper (Whatman No. 2) and made up to 100 mL with distilled water. The pH of the aqueous extracts were corrected to 6–8 and centrifuged at 9300g for 30 min. An aliquot of the supernatant was re-centrifuged at 3000 rpm for 10 min before each *in vitro* assay.

2.3. Total phenolics assay

The total phenolics were determined by the Folin–Ciocalteu method modified by Shetty et al. (1995). Briefly, 1 mL of the sample extract was transferred into a test tube and mixed with 1 mL of 95% ethanol and 5 mL of distilled water. To each sample 0.5 mL of 50% (vol/vol) Folin–Ciocalteu reagent was added and mixed. After 5 min, 1 mL of 5% Na₂CO₃ was added to the reaction mixture and allowed to stand for 60 min. The absorbance was read at 725 nm. The standard curve was established using various concentrations of gallic acid in 95% ethanol, and results were expressed as mg of gallic acid per gram of sample in dried weight (dw).

2.4. Antioxidant activity by 1,1-diphenyl-2-picrylhydrazyl radical (DPPH) inhibition assay

The DPPH scavenging activity was determined by an assay modified by Kwon et al. (2006). To 1.25 mL of 60 μ M DPPH in 95%

ethanol, 250 μL of each sample extract was added, and the decrease in the absorbance was monitored after 1 min at 517 nm (A517 extract). The absorbance of a control (distilled water instead of sample extract) was also recorded after 1 min at the same wavelength (A517 control). Therefore, the percentage of inhibition was calculated by:

$$\% \text{Inhibition} = \frac{A517(\text{control}) - A517(\text{extract})}{A517(\text{control})} \times 100.$$

2.5. α -Amylase inhibition assay

The α -amylase inhibitory activity was determined by an assay modified from the Worthington Enzyme Manual (Worthington Biochemical Corp., 1993a). A total of 500 μL of each sample extract and 500 μL of 0.02 M sodium phosphate buffer (pH 6.9 with 0.006 M NaCl) containing α -amylase solution (0.5 mg/mL) were incubated at 25 $^{\circ}\text{C}$ for 10 min. After preincubation, 500 μL of a 1% starch solution in 0.02 M sodium phosphate buffer (pH 6.9 with 0.006 M NaCl) was added to each tube at timed intervals. The reaction mixtures were then incubated at 25 $^{\circ}\text{C}$ for 10 min. The reaction was stopped with 1.0 mL of dinitrosalicylic acid color reagent. The test tubes were then incubated in a boiling water bath for 5 min and cooled to room temperature. The reaction mixture was then diluted after adding 15 mL of distilled water, and absorbance was measured at 540 nm. The absorbance of sample blanks (buffer instead of enzyme solution) and a control (buffer in place of sample extract) were recorded as well. The final extract absorbance (A540 extract) was obtained by subtracting its corresponding sample blank reading. The α -glucosidase inhibitory activity was calculated according to the equation below:

$$\% \text{Inhibition} = \frac{A540(\text{control}) - A540(\text{extract})}{A540(\text{control})} \times 100.$$

2.6. α -Glucosidase Inhibition Assay

A modified version of the assay described by the Worthington Enzyme Manual was followed (Worthington Biochemical Corp., 1993b; McCue et al., 2005). A volume of 50 μL of sample extract diluted with 50 μL of 0.1 M potassium phosphate buffer (pH 6.9) and 100 μL of 0.1 M potassium phosphate buffer (pH 6.9) containing α -glucosidase solution (1.0 U/mL) was incubated in 96-well plates at 25 $^{\circ}\text{C}$ for 10 min. After preincubation, 50 μL of 5 mM *p*-nitrophenyl- α -D-glucopyranoside solution in 0.1 M potassium phosphate buffer (pH 6.9) was added to each well at timed intervals. The reaction mixtures were incubated at 25 $^{\circ}\text{C}$ for 5 min. Before and after incubation, absorbance readings (A405 extract) were recorded at 405 nm by a microplate reader (Thermomax; Molecular Devices Co., Sunnyvale, CA) and compared to a control which had 50 μL of buffer solution in place of the extract (A405 control). The α -glucosidase inhibitory activity was expressed as percentage of inhibition and was calculated as follows:

$$\% \text{Inhibition} = \frac{\Delta A405(\text{control}) - \Delta A405(\text{extract})}{\Delta A405(\text{control})} \times 100.$$

2.7. Angiotensin I-converting enzyme (ACE) inhibition assay

ACE inhibition was performed by a method modified by Kwon et al. (2006). A volume of 50 μL of sample extract was incubated with 200 μL of 0.1 M NaCl-borate buffer (0.3 M NaCl, pH 8.3) containing 2 mU of ACE solution at 25 $^{\circ}\text{C}$ for 10 min. After preincubation, 100 μL of a 5.0 mM substrate (hippuryl-histidyl-leucine) solution was added to the reaction mixture. Test solutions were

incubated at 37 $^{\circ}\text{C}$ for 1 h. Sample blanks (buffer in place of enzyme and substrate), a control (distilled water instead of sample extract) and a blank (buffer instead of sample extract and enzyme) were also included. The reaction was stopped with 150 μL of 0.5 N HCl. The hippuric acid formed was detected by the High Performance Liquid Chromatography (HPLC) method. A volume of 5 μL of sample was injected using an Agilent ALS 1100 autosampler into an Agilent 1100 series HPLC (Agilent Technologies, Palo Alto, CA) equipped with a DAD 1100 diode array detector. The solvents used for the gradient were (A) 10 mM phosphoric acid (pH 2.5) and (B) 100% methanol. The methanol concentration was increased to 60% for the first 8 min and to 100% for 5 min and then decreased to 0% for the next 5 min (total run time, 18 min). The analytical column used was Agilent Zorbax SB-C₁₈, 250 \times 4.6 mm i.d., with packing material of 5 μm particle size at a flow rate of 1 mL/min at room temperature. During each run the absorbance was recorded at 228 nm and the chromatogram was integrated using the Agilent Chemstation enhanced integrator for detection of liberated hippuric acid. Pure hippuric acid was used to identify the spectra and retention time. The percentage of inhibition was calculated considering the area of the hippuric acid peak according to the equation below:

$$\% \text{Inhibition} = \frac{(\text{Area}_{\text{control}} - (\text{Area}_{\text{sample}} - \text{Area}_{\text{sample blank}}))}{(\text{Area}_{\text{control}} - \text{Area}_{\text{blank}})} \times 100$$

2.8. High performance liquid chromatography (HPLC) analysis of phenolic profiles

The sample extracts (2 mL) were filtered through a 0.2 μm filter. A volume of 5 μL of sample was injected using an Agilent ALS 1100 autosampler into an Agilent 1100 series HPLC (Agilent Technologies, Palo Alto, CA) equipped with a DAD 1100 diode array detector. The solvents used for gradient elution were (A) 10 mM phosphoric acid (pH 2.5) and (B) 100% methanol. The methanol concentration was increased to 60% for the first 8 min and to 100% over the next 7 min, then decreased to 0% for the next 3 min and was maintained for the next 7 min (total run time, 25 min). The analytical column used was Agilent Zorbax SB-C₁₈, 250 \times 4.6 mm i.d., with packing material of 5 μm particle size at a flow rate of 1 mL/min at room temperature. During each run the absorbance was recorded at 306 nm and 333 nm and the chromatogram was integrated using Agilent Chemstation enhanced integrator. Pure standards of chlorogenic acid, gallic acid, ellagic acid and quercetin in 100% methanol were used to calibrate the standard curves and retention times.

2.9. Statistical analysis

Two extractions were performed for each sample and all *in vitro* analysis were carried out 6 times ($n = 12$). In case of HPLC analysis, the experiments were performed at least in triplicates. Results were expressed as means \pm standard deviation. Data were subjected to 1-way ANOVA, means compared using Tukey's test ($p < 0.05$) and Pearson correlations were calculated according to the Statistica software package version 5.0 (StatSoft, Tulsa, OK).

3. Results and discussion

3.1. Total phenolics, antioxidant activity and HPLC phenolic profiles

Figs. 1 and 2 show the total phenolic contents of medicinal plants, herbal teas, spices and peppers related to their DPPH radical scavenging-linked-antioxidant activity. In addition, Table 2 shows the specific phenolic compounds detected by HPLC-DAD in analyzed samples.

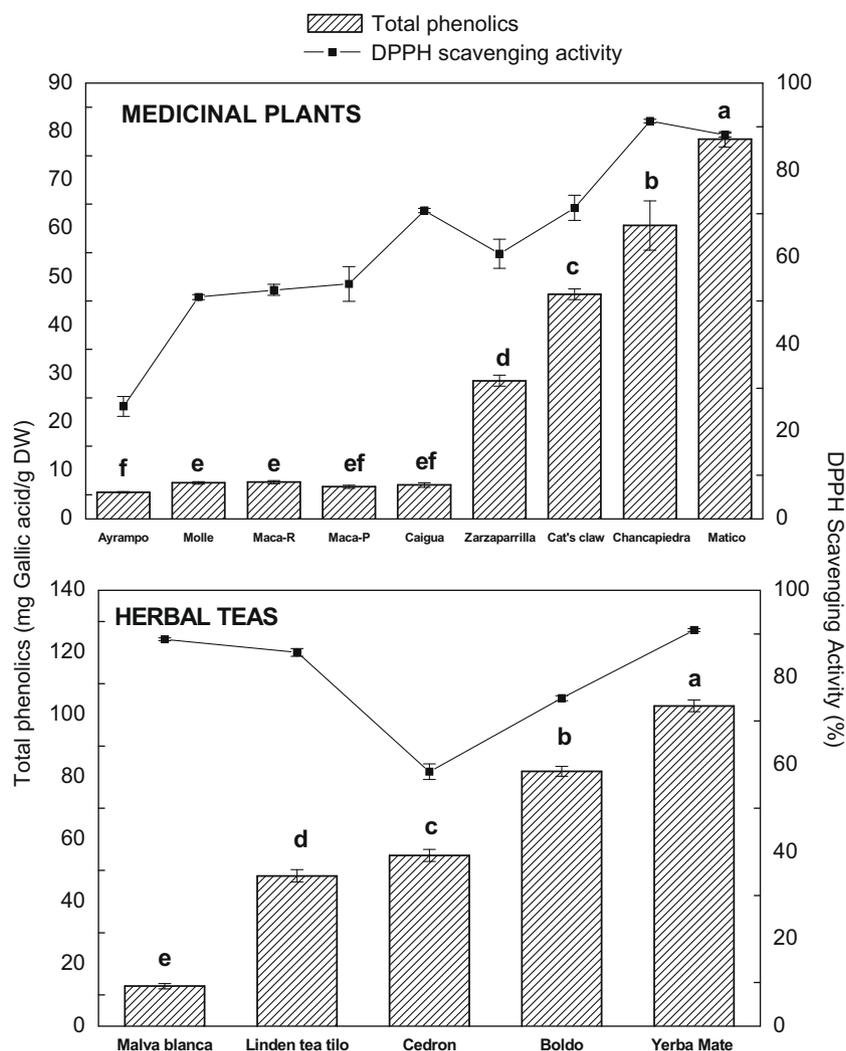


Fig. 1. Total phenolics and DPPH radical scavenging activity of medicinal plants and herbal teas. Bars with different letters are significantly different ($p < 0.05$).

3.1.1. Medicinal plants

Total phenolic contents ranged from 5.5 to 78 mg gallic acid/g dw in this group (Fig. 1). Matico (*Piper angustifolium* R.) exhibited the highest total phenolic content (78 ± 1 mg/g dw), followed by Chancapiedra (*Phyllanthus niruri* L.) (61 ± 5 mg/g dw), Cat's claw (*Uncaria tomentosa*) (46 ± 1 mg/g dw) and Zarzaparrilla (*Smilax officinalis*) (29 ± 1 mg/g dw), whereas Ayrampo (*Opuntia soehrensii*), Molle (*Schinus molle*), Maca-raw (*Lepidium meyenii* Walp) and Maca-pre-toasted showed the lowest content (from 5.5 to 7.6 mg/g dw).

The antioxidant activity based on the DPPH radical inhibition assay varied from 26% to 91% and had a significant correlation with the total phenolics ($r = 0.81$) (Table 3). Chancapiedra exhibited the highest antioxidant activity in this group (91%) followed by Matico (88%), whereas no difference in both the total phenolic content and antioxidant activity of raw and pre-toasted Maca ($p > 0.05$) was observed, indicating that thermal treatment did not have a negative effect.

According to HPLC-DAD results (Table 2), the conjugate 5-cafeoylquinic acid (chlorogenic acid) and other hydroxycinnamic acid derivatives (expressed as chlorogenic acid) were widespread not only among evaluated medicinal plants but also in the herbal teas and spices group. Matico leaves, which exhibited the highest total phenolic content, were also rich in chlorogenic acid and other hydroxycinnamic acid derivatives (24.2 ± 0.4 and 11.0 ± 0.2 mg/g

dw, respectively). In contrast, different phenolic profiles were found in Molle and Chancapiedra. Both contained ellagic acid (0.124 ± 0.002 and 1.9 ± 0.2 mg/g dw, respectively), but only Chancapiedra had gallic acid (a hydroxybenzoic acid derivative) (0.68 ± 0.03 mg/g dw).

Members of Piperaceae family have been shown to be of great interest due to the variety of biological properties displayed. Some phenolic derivatives with anti-leishmanial and anti-bacterial activities were identified as dihydrochalcones in leaves of *Piper elongatum* (Hermoso et al. 2003), whereas a new prenylated salicylic acid derivative with anti-*Helicobacter pylori* activity has been isolated from the leaves of *Piper multiplinervium* (Ruegg et al., 2006). Further, Bhattacharya et al. (2007) reported the inhibitory properties of an ethanolic extract from leaves of *Piper betel* against the photosensitization-induced damage to lipids and proteins of rat liver mitochondria, indicating that this activity was mainly correlated to its phenolic constituents such as chavibetol and 4-allylpyrocatechol. According to current results, this is the first time that chlorogenic acid and other hydroxycinnamic derivatives are reported in *Piper angustifolium* R. The high total phenolic content (highest among medicinal plants) was proportional to the antioxidant activity, and such characteristics may be linked to its high chlorogenic acid content.

Low total phenolic contents were found in Chancapiedra leaves when compared with Matico. However, the former exhibited the

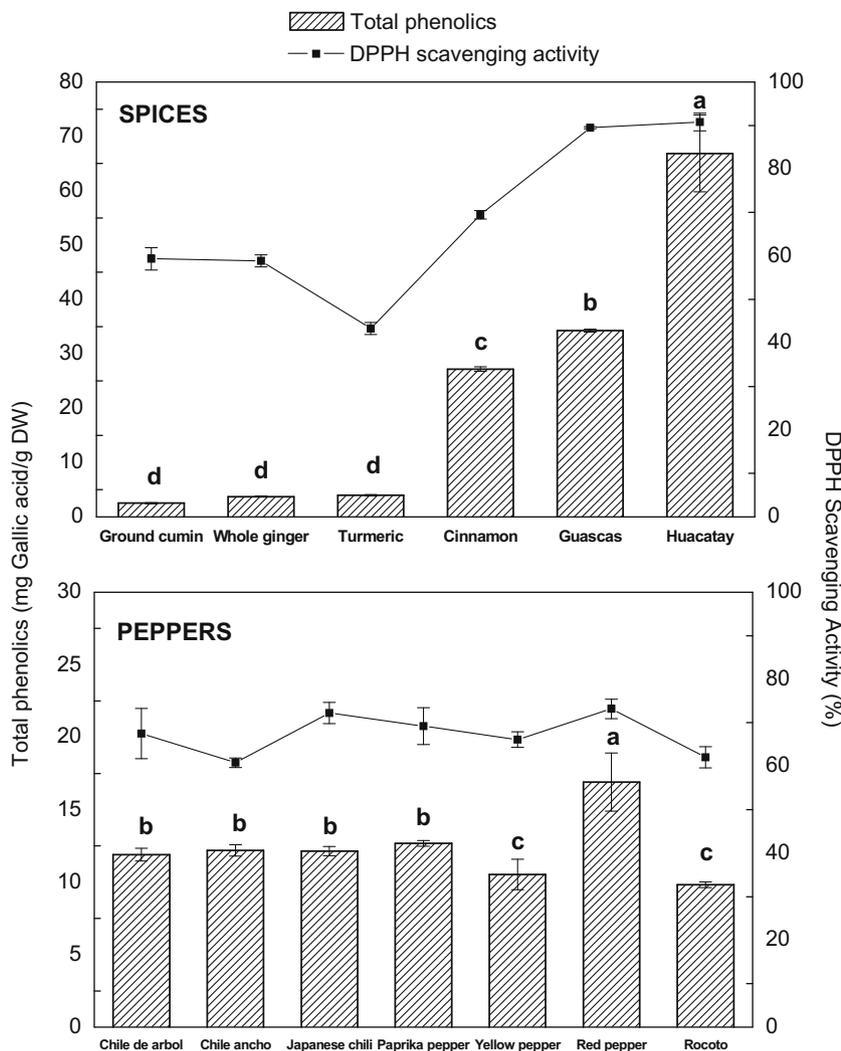


Fig. 2. Total phenolics and DPPH radical scavenging activity of spices and peppers. Bars with different letters are significantly different ($p < 0.05$).

Table 2

Phenolic compounds detected by HPLC in medicinal plants, herbal teas and spices.^a

Group	Sample	Phenolic compound (mg/g dw)					
		Protocatechuic acid	Chlorogenic acid	Hydroxycinnamic acid ^b	Gallic acid	Ellagic acid	Quercetin derivatives ^c
Medicinal plants	Ayrampo	0.18 ± 0.01	n.d	n.d	n.d	n.d	n.d
	Molle	n.d	0.19 ± 0.01	n.d	n.d	0.124 ± 0.002	0.42 ± 0.06
	Zarzaparrilla	n.d	4.64 ± 0.05	n.d	n.d	n.d	n.d
	Cat's claw	n.d	0.48 ± 0.04	n.d	n.d	n.d	n.d
	Chancapiedra	n.d	n.d	2.9 ± 0.3	0.68 ± 0.03	1.9 ± 0.2	n.d
	Matico	n.d	24.2 ± 0.4	11.0 ± 0.2	n.d	n.d	n.d
Herbal teas	Malva blanca	n.d	n.d	1.40 ± 0.06	n.d	n.d	n.d
	Yerba Mate	n.d	36.0 ± 0.2	53 ± 1	n.d	n.d	n.d
Spices	Guascas	n.d	6.1 ± 0.2	15 ± 1.6	n.d	n.d	n.d
	Huacatay	n.d	n.d	32 ± 2	n.d	n.d	10 ± 1

n.d, not detected.

^a Values are means ± SD.

^b Expressed as chlorogenic acid.

^c Expressed as quercetin aglycon.

highest antioxidant activity among evaluated medicinal plants and this may be related to the free radical scavenging properties of phenolic compounds such as gallic and ellagic acid detected only in Chancapiedra. Rice-Evans et al. (1997) highlighted the influence of the structural chemistry of polyphenols on their free radical-scavenging activities using the Trolox equivalent antioxidant activ-

ity assay (TEAC) which is also a radical quenching reaction via H atom transfer as the DPPH assay (Prior et al., 2005). In such studies, gallic acid (a 3,4,5-trihydroxy benzoic acid) showed higher antioxidant activity corresponding to the three available hydroxyl groups than chlorogenic acid (a glycoside of 3,4-dihydroxycinnamic acid). This would explain why antioxidant activity was lower in the other

Table 3

Pearson correlation coefficients for the group of medicinal plants.

	AA ^a	GLUC ^a	AMY ^a	ACE ^b
TP ^a	0.81 [*]	0.39 [*]	0.10	-0.34 [*]
AA		0.34 [*]	0.06	-0.08
GLUC			0.54 [*]	-0.44 [*]
AMY				-0.17

TP = Total phenolics; AA = Antioxidant activity; GLUC = Glucosidase inhibitory activity (2.5 mg sample); AMY = Amylase inhibitory activity (25 mg sample); ACE = Angiotensin I-converting enzyme inhibition (2.5 mg sample).

^{*} $p < 0.05$.

^a ($n = 108$).

^b ($n = 81$).

medicinal plants where chlorogenic acid was the major phenolic compound. Bagalkotkar et al. (2006) reported that *Phyllanthus niruri* L contains ellagic acid and geraniin (an ellagitannin) among other active phytochemicals such as flavonoids, alkaloids, terpenoids, lignans and saponins. The detection of gallic and ellagic acid in water extracts of Chancapiedra leaves in this research, may indicate the presence of ellagitannins and probably other gallotannin derivatives.

Water decoctions prepared from the bark of *Uncaria tomentosa* have been shown to have a potent radical scavenging activity strongly linked to the presence of proanthocyanidins and phenolic acids, mainly caffeic acid (Gonçalves et al., 2005; Pilarski et al., 2006). Similarly in this study, a significant DPPH radical inhibition (71%) was found in water extracts of Cat's claw bark, but only chlorogenic acid was detected.

Smilax officinalis (Zarzaparrilla) is known to contain steroid like compounds-saponin glycosides and some studies indicate the presence of male hormones (Singh, 2006). The potential free radical scavenging activity and its correlation to the total phenolic contents is reported here for the first time in the roots of *Smilax officinalis*.

Montoro et al. (2001) isolated six flavone glycosides in methanolic extracts from *Cyclanthera pedata* (Caigua) which showed a significant free radical scavenging activity when measured by the Trolox equivalent antioxidant assay. In the current study, fruits of *Cyclanthera pedata* exhibited high antioxidant activity as well (71%), but low total phenolic content (7.0 ± 0.5 mg/g dw), indicating that non-phenolic water soluble compounds may be involved.

3.1.2. Herbal teas

The correlation between the total phenolic content and the antioxidant activity was not significant ($p > 0.05$) in this group, and this may be explained by the fact that herbal teas Malva Blanca (*Malva silvestris* L.) and Linden tea tilo (*Tilia platyphyllos*) showed high antioxidant activity (89% and 86%, respectively) in spite of their low total phenolic levels (13 ± 1 and 48 ± 2 mg/g dw, respectively) (Table 4 and Fig. 1).

Table 4

Pearson correlation coefficients for the group of herbal teas.

	AA ^a	GLUC ^a	AMY ^a	ACE ^b
TP ^a	0.00	0.37 [*]	0.17	-0.55 [*]
AA		0.06	0.02	0.21
GLUC			0.95 [*]	-0.38 [*]
AMY				-0.23

TP = Total phenolics; AA = Antioxidant activity; GLUC = Glucosidase inhibitory activity (2.5 mg sample); AMY = Amylase inhibitory activity (25 mg sample); ACE = Angiotensin I-converting enzyme inhibition (2.5 mg sample).

^{*} $p < 0.05$.

^a ($n = 60$).

^b ($n = 51$).

Yerba Mate (*Ilex paraguayensis* St-Hil) showed the highest total phenolic content (103 ± 3 mg/g dw) linked to antioxidant activity (91%) not only among samples in this group, but also among all evaluated samples. This would be related to its high levels of chlorogenic acid and other hydroxycinnamic acid derivatives detected by HPLC-DAD (Table 2). Anesini et al. (2006) reported chlorogenic acid as the major phenolic compound in dried leaves of Yerba Mate (1.96%). However, the content of chlorogenic acid obtained in this study was higher (3.6%), and the hydroxycinnamic acid derivatives detected here likely correspond to other caffeoyl derivatives due to the similarity of their UV spectra to that shown by chlorogenic acid. Bastos et al. (2007) identified three caffeoyl derivatives such as caffeoyl glucose, caffeoylquinic acid and dicaffeoylquinic acid in aqueous and ethanolic extracts of green Yerba Mate. The same authors also found a high DPPH scavenging activity in such extracts.

Total phenolic contents in Cedron (*Aloysia triphylla*) and Boldo (*Peumus boldus*) were also proportional to their free radical scavenging-linked antioxidant activities, but no specific phenolics were detected by HPLC-DAD in water extracts from these samples. Conversely, flavonoids such as salvigenin, eupafolin, luteolin, 6-hydroxyluteolin, and other luteolin glycosides were identified in leaves of *Aloysia triphylla* (De Vincenzi et al., 1995), whereas Quezada et al. (2004) reported that catechin and boldine (an alkaloid) were the main contributors to the antioxidant activity in leaves of Boldo.

Malva Blanca had the lowest content of total phenolics (12.8 ± 0.8 mg/g dw), but exhibited a high antioxidant activity (89%) which was comparable to that showed by Yerba Mate (91%). This might be partially due to its content of hydroxycinnamic acid and other polar terpenoid derivatives probably released after the hot water extraction. It is well known that aroma properties found in certain plants are due to their content of essential oils mainly of terpenoid nature. Cutillo et al. (2006) isolated a sesquiterpene, a tetrahydroxylated acyclic diterpene and two monoterpenes from leaves of Malva Blanca (*Malva silvestris*) among other compounds such as hydroxycinnamic acid and hydroxybenzoic acid derivatives. Further, several terpenoid derivatives have shown the capacity to reduce the stable radical DPPH (Joshi et al., 2008).

3.1.3. Spices

In the spices group, the total phenolic contents and the DPPH inhibitory activities were strongly correlated ($r = 0.86$, $p < 0.05$) and varied from 2.5 to 67 mg/g dw and from 43% to 91%, respectively (Table 5 and Fig. 2). This likely indicates that phenolic compounds contributed significantly to the antioxidant activity of spices, especially in case of Huacatay (*Tagetes minuta*), Guascas (*Galinsoga parviflora*) and cinnamon.

Leaves of Huacatay had the highest total phenolic content and antioxidant activity (67 ± 7 mg/g dw and 91%, respectively). Further, this sample also exhibited high levels of hydroxycinnamic acid and quercetin derivatives (32 ± 2 and 10 ± 1 mg/g dw expressed as

Table 5

Pearson correlation coefficients for the group of spices.

	AA ^a	GLUC ^a	AMY ^a	ACE ^b
TP ^a	0.86 [*]	0.53 [*]	0.08	-0.21
AA		0.31 [*]	0.03	-0.15
GLUC			0.81 [*]	-0.32 [*]
AMY				-0.11

TP = Total phenolics; AA = Antioxidant activity; GLUC = Glucosidase inhibitory activity (2.5 mg sample); AMY = Amylase inhibitory activity (25 mg sample); ACE = Angiotensin I-converting enzyme inhibition (2.5 mg sample).

^{*} $p < 0.05$.

^a ($n = 72$).

^b ($n = 63$).

Table 6
Pearson correlation coefficients for the group of peppers.

	AA ^a	GLUC ^a	AMY ^a	ACE ^b
TP ^a	0.51 [*]	0.12	0.12	0.61 [*]
AA		0.20	0.46 [*]	0.11
GLUC			0.70 [*]	0.15
AMY				0.46 [*]

TP = Total phenolics; AA = Antioxidant activity; GLUC = Glucosidase inhibitory activity (2.5 mg sample); AMY = Amylase inhibitory activity (25 mg sample); ACE = Angiotensin I-converting enzyme inhibition (2.5 mg sample).

^{*} $p < 0.05$.

^a ($n = 83$).

^b ($n = 21$).

chlorogenic acid and quercetin aglycone, respectively) (Table 2). In general, quercetin derivatives such as quercetagenin and other quercetin glycosides are characteristic of several *Tagetes* genus (Parejo et al., 2005). However, the presence of hydroxycinnamic acid derivatives in Huacatay leaves is reported for the first time in this study. It is thus likely that these phenolic compounds were responsible for the high antioxidant activity observed in Huacatay. Moreover, no reports were found regarding the phenolic content in Guascas. The detection of chlorogenic acid and other hydroxycin-

amic acids linked-DPPH radical inhibition of water extracts from this plant are shown for the first time in this study.

Barks of *Cinnamomum zeylanicum* B. have been shown to contain dimeric, trimeric and higher oligomeric proanthocyanidins linked bis-flavan-3-ol units among other phenolic compounds such as protocatechuic acid and quercetin derivatives (Jayaprakasha et al., 2006). Analysis in this study show that antioxidant activity is relatively high (69%) in bark of cinnamon and probably might be linked to other polymeric phenolics that were not detected by the Folin–Ciocalteu method and by HPLC-DAD analysis.

The total phenolic contents were low in seeds of ground cumin (2.5 ± 0.1 mg/g dw) and in rhizomes of Whole Ginger (*Zingiber officinale*) and Turmeric (*Curcuma longa* L.) (3.7 ± 0.1 and 3.9 ± 0.1 mg/g dw, respectively). However, they exhibited a moderate DPPH radical scavenging linked-antioxidant activity (59%, 59% and 43%, respectively) whereas no specific phenolic compounds were detected by HPLC. Members of the Zingiberaceae family such as turmeric and ginger accumulate at high levels in their rhizomes active metabolites that are derived from the phenylpropanoid pathway. In ginger, these compounds are the gingerols while in turmeric are the curcuminoids (Ramirez-Ahumada et al., 2006). The moderate antioxidant activity found in water extracts of these rhizomes might be related to these compounds. However, under the conditions of conducted

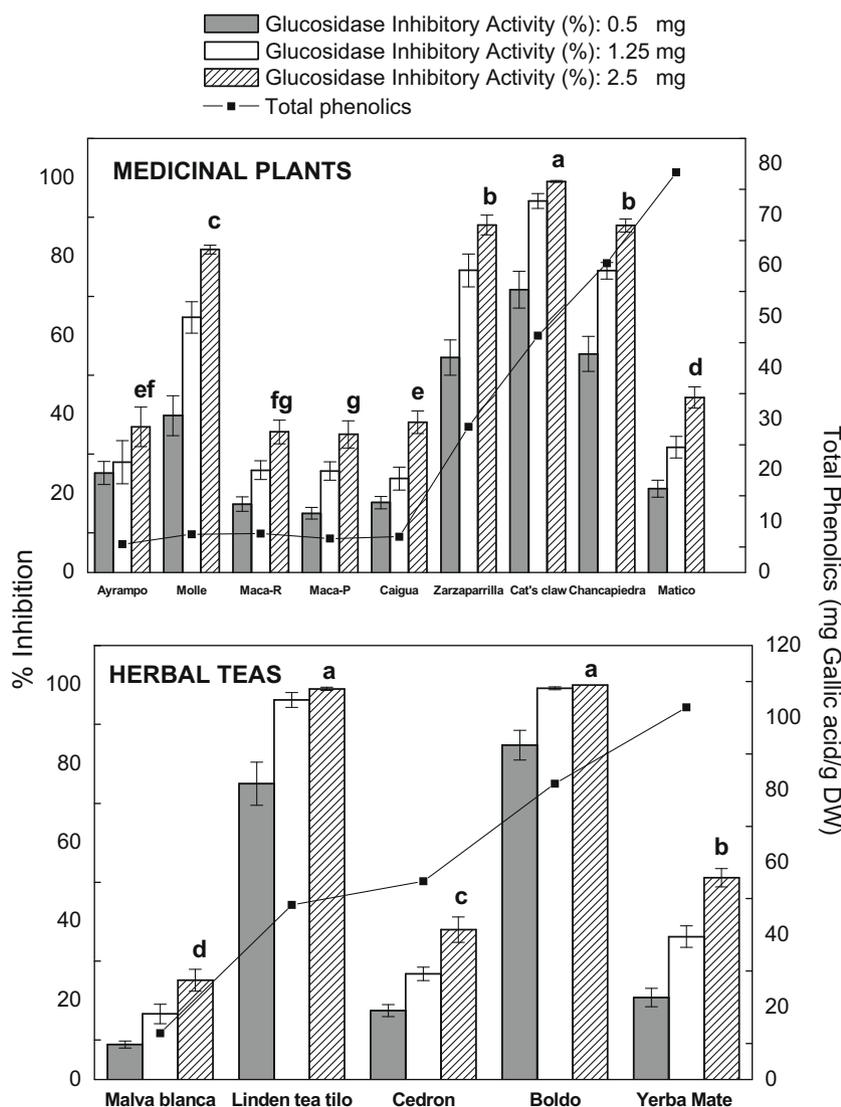


Fig. 3. Dose-dependent changes in α -glucosidase inhibitory activity of medicinal plants and herbal teas (mg of dried sample) and comparison with the total phenolic content. Bars with different letters are significantly different ($p < 0.05$).

experiments, low contents of total phenolics were obtained in both samples, which may be due to the limitation of the Folin–Ciocalteu assay for detecting methylated phenolics.

3.1.4. Peppers

Overall, peppers showed lower total phenolic contents when compared to previous sample groups (Fig. 2). Except for the red pepper (*Capsicum chinense*), which had the highest total phenolics and antioxidant activity (17 ± 2 mg/g dw and 73%, respectively), the total phenolic values were almost uniform among all evaluated peppers (from 10 to 12 mg/g dw). Interestingly, the DPPH radical scavenging-linked antioxidant activity was high in this group (from 61% to 73%) in spite of its low total phenolic contents. Additionally, the correlation between total phenolics and antioxidant activity was moderate but statistically significant ($r = 0.51$, $p < 0.05$) (Table 6). This finding may suggest that the radical scavenging ability of these samples was not only linked to their phenolic contents, but also to other non-phenolic compounds. The genus *Capsicum* is well known to possess carotenoid pigments which give peppers their characteristic color. For example, the red color of peppers is due to the presence of capsanthin, capsorubin and capsanthin 5, 6-epoxide (Sun et al., 2007). Therefore, the significant DPPH radical scavenging-linked antioxidant activities observed

among evaluated peppers were likely related to terpenoid derivatives probably solubilized after the hot water extraction. High free radical-scavenging activities have been observed in high carotenoid-pepper varieties according to previous studies (Guil-Guerrero et al., 2006).

3.2. α -Glucosidase, α -Amylase and ACE-I inhibitory activities

Type 2 diabetes is characterized by a rapid increase in blood glucose levels due to hydrolysis of starch by pancreatic α -amylase and absorption of glucose in the small intestine by α -glucosidase. This may be controlled by inhibition of these enzymes involved in the digestion of carbohydrates. The consumption of inhibitors naturally from constituents in the diet could be an effective therapy for managing postprandial hyperglycemia with minimal side effects in contrast to traditional treatments with drugs such as acarbose (Kwon et al., 2006). Furthermore, one of the main macrovascular complications of diabetes is hypertension, which is a risk factor for many cardiovascular diseases. The angiotensin I-converting enzyme (ACE) is a key enzyme involved in maintaining vascular tension. ACE converts angiotensin I to angiotensin II, a potent vasoconstrictor and stimulator of aldosterone secretion by the adrenal gland. Inhibition of ACE is considered a useful therapeutic

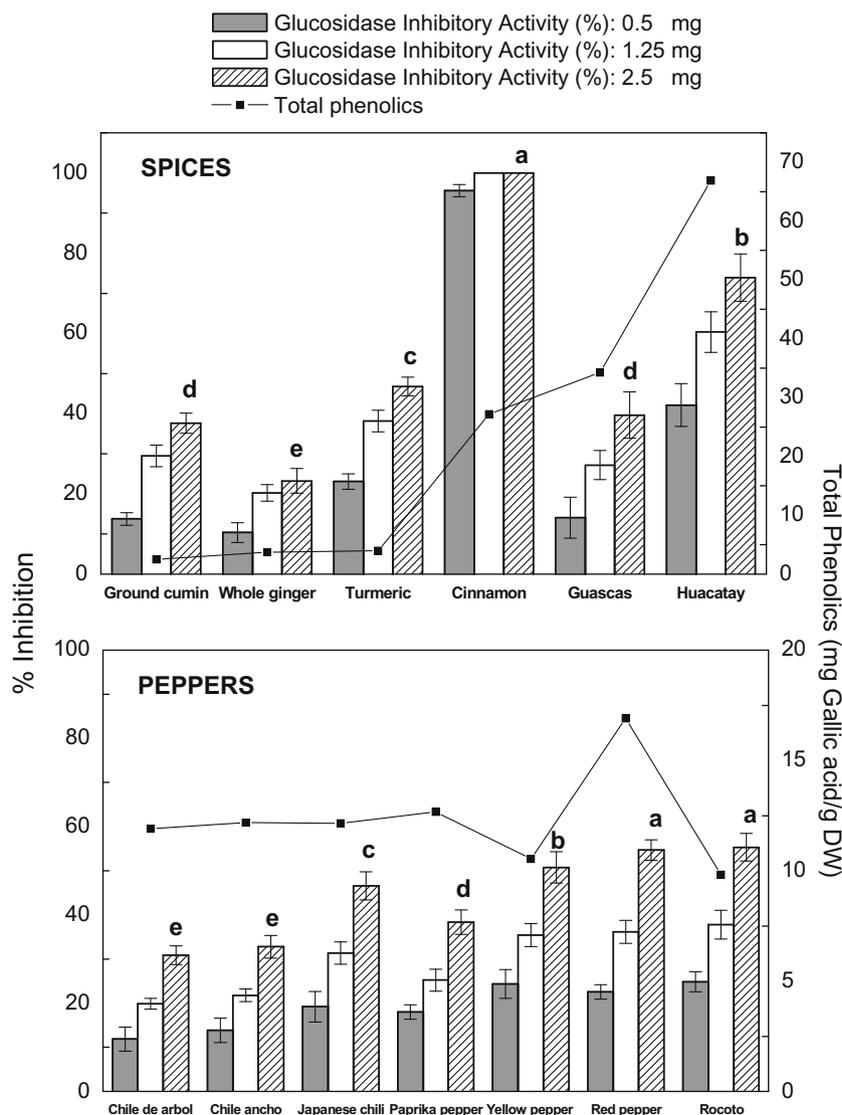


Fig. 4. Dose-dependent changes in α -glucosidase inhibitory activity of spices and peppers (mg of dried sample) and comparison with the total phenolic content. Bars with different letters are significantly different ($p < 0.05$).

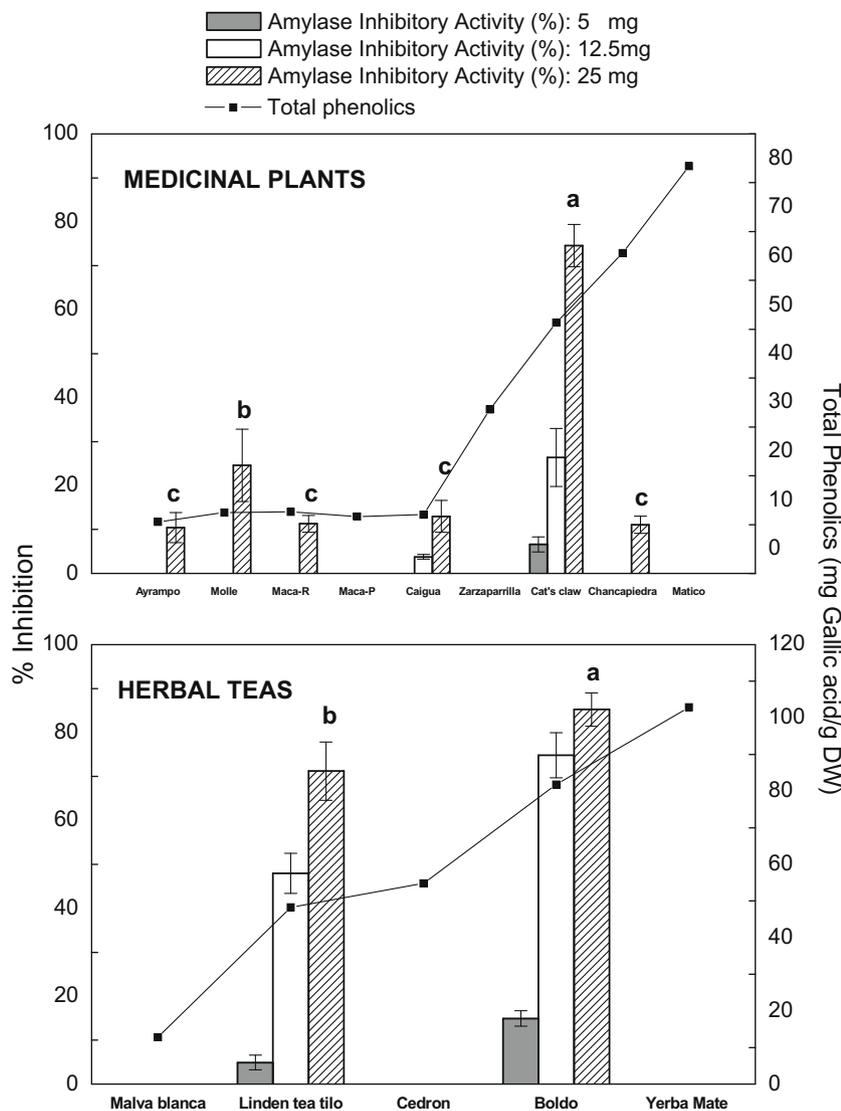


Fig. 5. Dose-dependent changes in α -amylase inhibitory activity of medicinal plants and herbal teas (mg of dried sample) and comparison with the total phenolic content. Bars with different letters are significantly different ($p < 0.05$).

approach in the treatment of high blood pressure in both diabetic and non-diabetic patients (Crook and Penumalee 2004).

The ability of sample water extracts to inhibit the yeast α -glucosidase and the porcine pancreatic α -amylase was evaluated at three different doses of dried sample (Figs. 3–6, respectively). The potential to inhibit the hypertension-related ACE was screened in all extracts and results are shown in Figs. 7 and 8. Overall, all aqueous extracts had the capacity to inhibit the yeast α -glucosidase enzyme in a dose-dependency manner. In contrast, not all extracts inhibited the α -amylase and ACE enzymes and observed trends were variable according to each sample group.

3.2.1. Medicinal plants

The α -glucosidase inhibitory activities ranged from 35% to 99% in this group (dose of 2.5 mg of dried sample) (Fig. 3). Molle (*Schinus molle*), Zarzaparrilla (*Smilax officinalis*), Cat's claw (*Uncaria tomentosa*) and Chancapiedra (*Phyllanthus niruri* L.) had the highest α -glucosidase inhibitory activities (>80%). Matico (*Piper angustifolium* R.), which showed the highest total phenolic content, inhibited moderately the α -glucosidase enzyme (44%) (Fig. 3). According to the Pearson correlation results (Table 3), the total phenolic and antioxidant activity of medicinal plants were moderately propor-

tional to the α -glucosidase inhibitory activity ($r = 0.39$ and $r = 0.34$, respectively).

Cat's claw showed the highest α -amylase inhibition (75% at 25 mg of dried sample) among samples from the medicinal plants group (Fig. 5). Conversely, lower α -amylase inhibition was observed for Ayrampo (*Opuntia soehrensii*), Molle, Maca-raw (*Lepidium meyenii* Walp), Caigua (*Cyclanthera pedata*) and Chancapiedra water extracts (from 10% to 25%). The Maca-pre-toasted extract had no inhibition against the α -amylase enzyme, indicating loss of compounds linked to α -amylase inhibition due to thermal treatment (toasting). Additionally, the total phenolic contents were not proportional to the α -amylase inhibitory activities (Tables 3–6).

Regarding the ACE inhibition potential of evaluated medicinal plants, both tuberous root extracts (Maca-raw and Maca-pretoasted) inhibited the angiotensin I-converting enzyme (ACE) in a dose dependent manner (Fig. 7). However, the thermal treated Maca (pre-toasted) had higher ACE inhibitory activity than its raw equivalent (45%, Maca-raw versus 88%, Maca-pretoasted). Although Caigua did not show interesting functional properties linked-anti-diabetes potential, its ACE inhibitory activity linked to anti-hypertension potential was the highest among all evaluated extracts (95% at 2.5 mg of dried sample). Furthermore, no

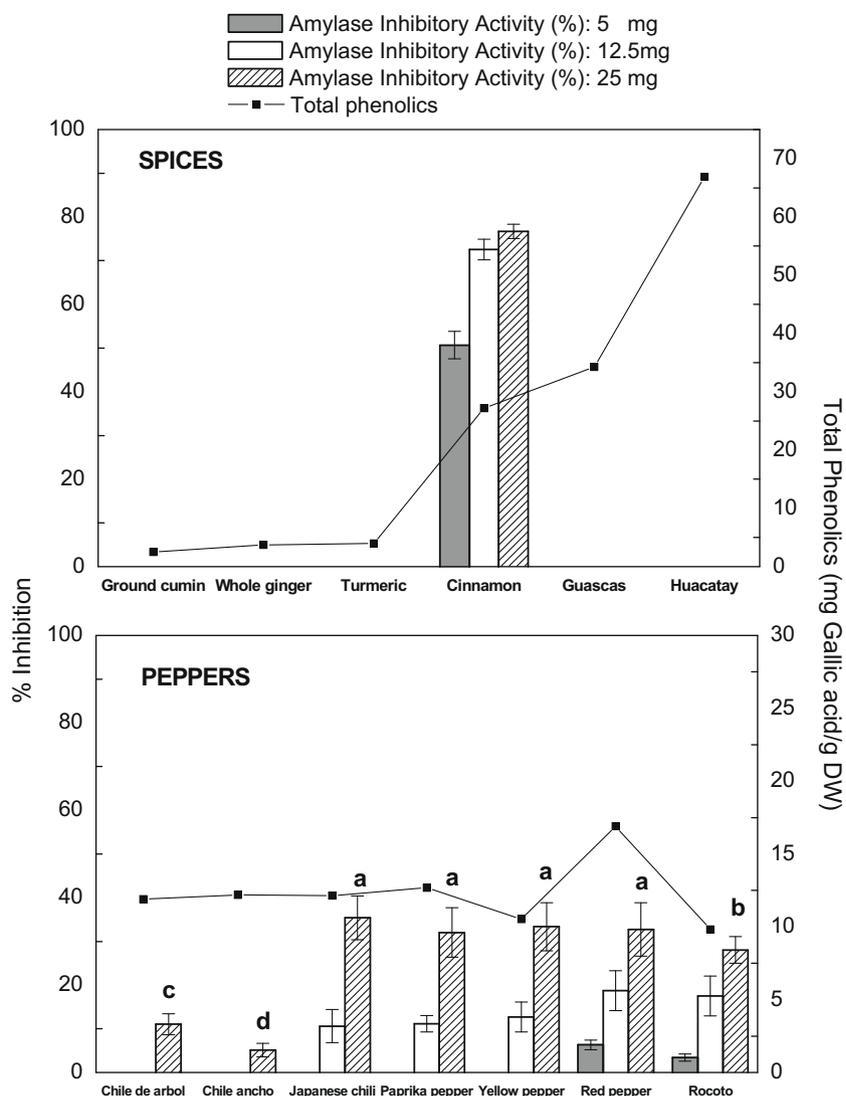


Fig. 6. Dose-dependent changes in α -amylase inhibitory activity of spices and peppers (mg of dried sample) and comparison with the total phenolic content. Bars with different letters are significantly different ($p < 0.05$).

correlation between the ACE inhibitory activity and the total phenolic contents was observed in this group (Table 3).

In general, high phenolic-linked medicinal plants such as Chancapiedra and Zarzaparrilla showed high α -glucosidase inhibitory activity with low inhibition of α -amylase. Such profiles have interesting functionality for potentially controlling glucose absorption and likely not generating side effects linked to high α -amylase inhibitory activity (Martin and Montgomery, 1996). Cat's claw had the highest α -glucosidase and α -amylase inhibition. Thus, Cat's claw may be an interesting option for Type 2 diabetes-linked hyperglycemia management as well. However, care should be taken to avoid the potential side effects of undigested starch, especially if it is consumed with starch foods.

Fruits of Molle had the lowest total phenolic content and anti-oxidant activity. However, a significant inhibition of the α -glucosidase enzyme and low inhibitory activity against porcine pancreatic α -amylase were observed in this sample. The potential for Type 2 diabetes management of Molle might be related to its phenolic profile, which was unique among medicinal plants and included chlorogenic acid, ellagic acid and quercetin derivatives. Similarly, a recent study indicated that a polyphenolic extract of black cumin containing a mixture of phenolic/flavonoid compounds such as gallic acid, protocatechuic acid, caffeic acid, ellagic acid, ferulic acid,

quercetin and kaempferol showed significant inhibition of intestinal glucosidase activity *in vitro* and also reduced postprandial hyperglycemia in rats (Ani and Naidu, 2008).

Both Maca and Caigua exhibited moderate α -glucosidase inhibitory activities, low α -amylase inhibition and low total phenolic contents. However they strongly inhibited the ACE *in vitro*, which indicates their high anti-hypertension potential. These results suggest that the high ACE inhibition in these samples is likely due to non-phenolic compounds which probably are peptides with biological functions or physiological effects. Nutritionally, Maca is abundant in protein (8.87–11.6% in dehydrated powdered Maca root; Wang et al., 2007) and probably the toasting process resulted in partial hydrolysis of its protein fraction leading to a release of small peptides. ACE inhibitory peptides can be enzymatically released from precursor proteins *in vitro* and *in vivo*, respectively during food processing and gastrointestinal digestion (De Leo et al., 2009). This may explain the higher ACE inhibitory activity found in Maca (pre-toasted sample) in comparison to its raw equivalent.

Although fruits of Caigua are not rich in protein, other phytochemicals such as triterpenoid saponins (De Tommasi et al., 1999) and serine proteinase inhibitors (Kowalska et al., 2006) also present in Caigua may be linked to its relevant ACE inhibitory

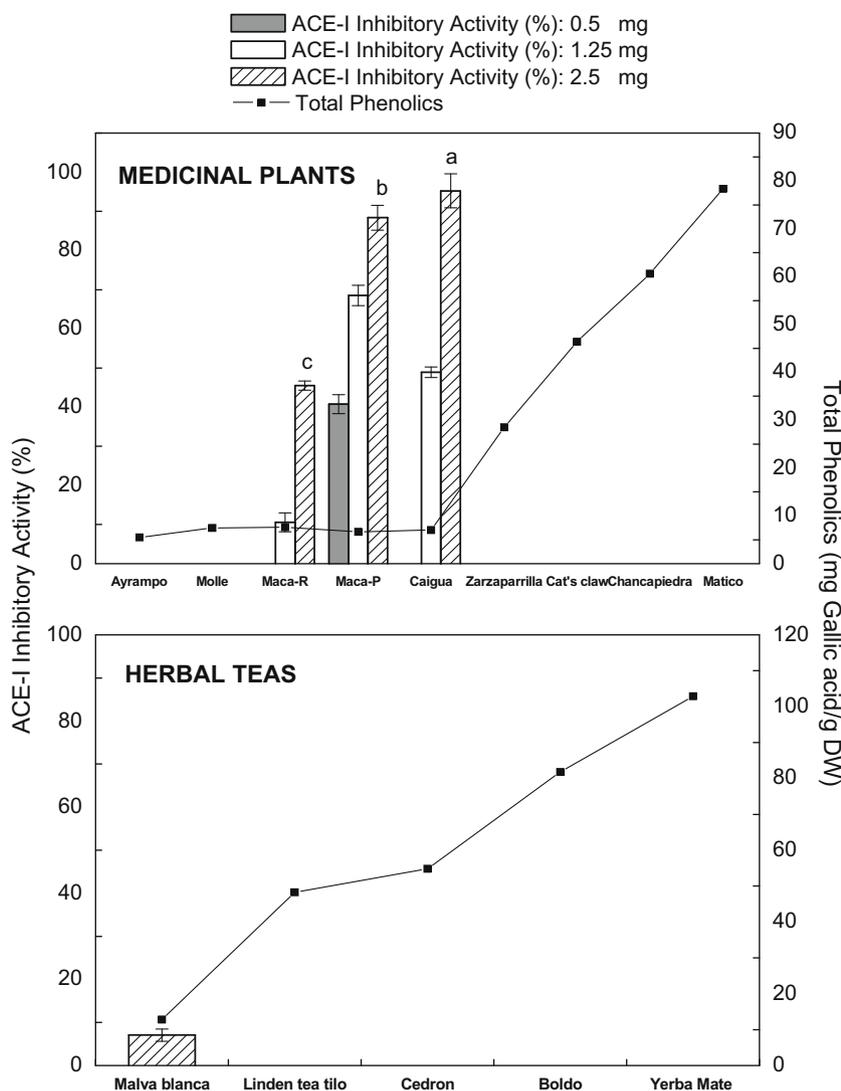


Fig. 7. Dose-dependent changes in ACE-I inhibitory activity (%) of medicinal plants and herbal teas (mg of dried sample) and comparison with the total phenolic content. Bars with different letters are significantly different ($p < 0.05$).

activity. A previous study demonstrated the strong inhibition of ACE-I activity *in vitro* in cultured human endothelial cells from umbilical veins by an aqueous extract of *Panax ginseng* rich in ginsenosides or triterpene saponins (Persson et al., 2006). However, this functional property as others could be better explained by a synergistic effect of several substances.

Maca is commonly used as a food for its nutritional value and ethno-medicinal properties linked to fertility and vitality (Wang et al., 2007), whereas Caigua is known for its hypocholesterolemic, hypoglycemic and anti-inflammatory effects (Macchia et al., 2009). However, no previous study supporting the potential of these Andean crops as anti-hypertensive has been published to date.

3.2.2. Herbal teas

The α -glucosidase inhibitory activities ranged from 38% to almost 100% (at 2.5 mg of dried sample) among evaluated herbal teas (Fig. 3). Both Linden tea tilo (*Tilia platyphyllos*) and Boldo (*Peumus boldus*) extracts exhibited the highest inhibition against α -glucosidase (~100% at 2.5 mg of dried sample) and their inhibitory activity was high even at lower doses (75% and 85%, respectively at 0.5 mg of dried sample). The correlation between the α -glucosidase inhibitory activity with the total phenolic contents was mod-

erate ($r = 0.37$), whereas no correlation was observed with the DPPH radical scavenging-linked antioxidant activity (Table 4).

In case of α -amylase inhibition potential, only Linden tea tilo and Boldo extracts inhibited the porcine pancreatic α -amylase and this activity was significant at the highest evaluated dose (71% and 85%, respectively at 25 mg of dried sample) (Fig. 5). In addition, herbal teas did not show *in vitro* ACE inhibition linked to potential anti-hypertensive benefits whereas no correlation between the total phenolic contents and ACE inhibitory activities was observed (Fig. 7 and Table 4, respectively).

Yerba Mate (*Ilex paraguayensis* St-Hil) which had the highest total phenolic contents and antioxidant activity, showed moderate α -glucosidase inhibitory activity and did not have effect on α -amylase and ACE. Such combination would be helpful to manage glucose uptake and the glucose-induced increased levels of mitochondrial ROS (reactive oxygen species) linked to hyperglycemia (Brownlee, 2005). Conversely, Linden tea Tilo and Boldo strongly inhibited both α -glucosidase and α -amylase enzymes. A proper combination of dietary and traditional medicine strategy containing combination of these herbal teas could be considered as an overall comprehensive approach to avoid lower abdominal side effects arising from excessive inhibition of pancreatic α -amylase.

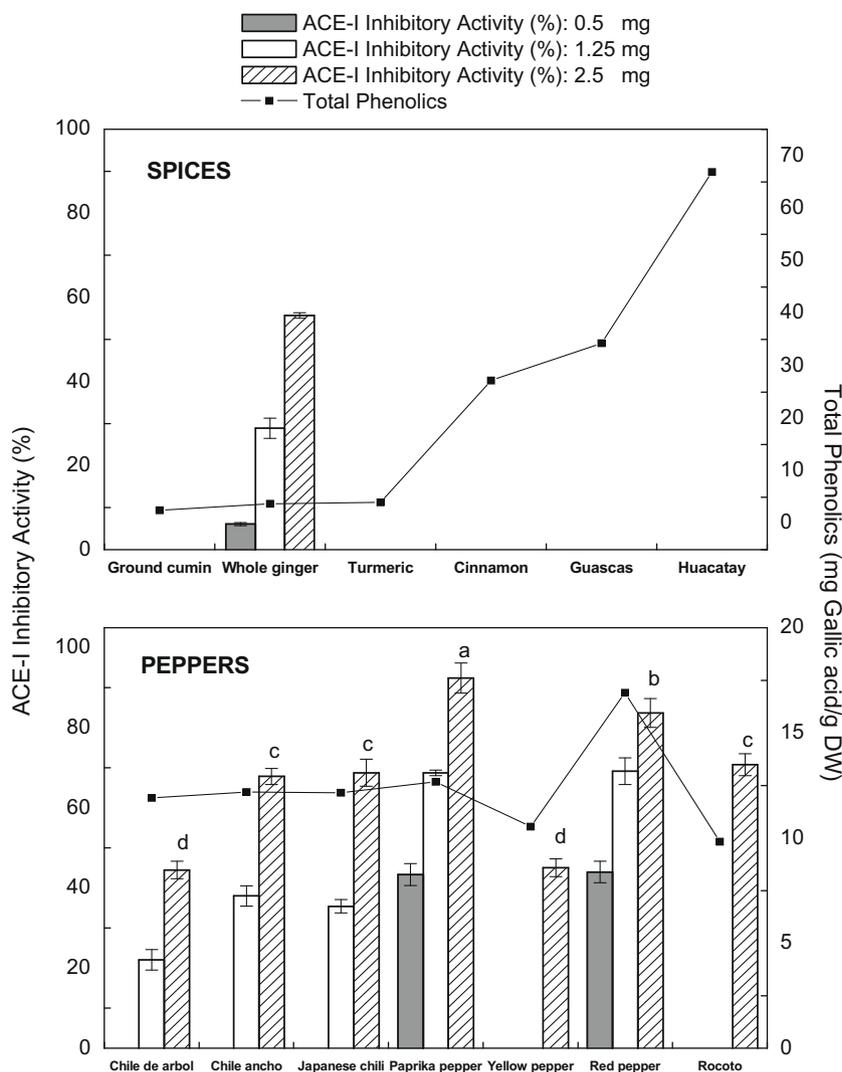


Fig. 8. Dose-dependent changes in ACE-I inhibitory activity (%) of spices and peppers (mg of dried sample) and comparison with the total phenolic content. Bars with different letters are significantly different ($p < 0.05$).

3.2.3. Spices

In the spices group, the α -glucosidase inhibition varied from 23% to 100% (at 2.5 mg of dried sample) (Fig. 4). Cinnamon and Huacatay (*Tagetes minuta*) had the highest inhibitory activity among samples in this group (100% and 74%, respectively). Moreover, the α -glucosidase inhibitory activity of the cinnamon extract was still higher at the lowest dose (95% at 0.5 mg of dried sample). Both the total phenolic contents and antioxidant activity were proportional to the α -glucosidase inhibitory activity (Table 5).

Spices such as ground cumin, whole ginger, turmeric, Guascas (*Galinsoga parviflora*) and Huacatay were not relevant regarding their potential for inhibiting the α -amylase (Fig. 6). Only the cinnamon extract showed a high α -amylase inhibitory activity (77% at 25 mg of dried sample) even at lower doses (72% and 51% at 12.5 and 5 mg of dried sample, respectively). Similarly, the ACE inhibitory activity was not significant among evaluated spices, and only the whole ginger showed a moderate ACE inhibition (56% at 2.5 mg of dried sample) (Fig. 8). Further, neither the total phenolic contents nor the antioxidant activity had correlation with the ACE inhibitory activities in this group (Table 5).

Overall, all spices were relevant for potential Type 2 diabetes management due to their moderate to high α -glucosidase inhibitory activities combined with no inhibition of porcine pancreatic α -amylase *in vitro*. In addition, Huacatay and Guascas, which

showed the highest total phenolic contents and DPPH radical inhibitory activities, also exhibited an interesting potential for prevention of postprandial hyperglycemia linked to Type 2 diabetes and could potentially reduce microvascular complications linked to oxidative dysfunction. Previous studies have reported anti-bacterial and anti-inflammatory activities of Huacatay and Guascas, respectively (Senatore et al., 2004; Matu and Staden, 2003). The potential of these spices for Type 2 diabetes-linked hyperglycemia management is reported here for the first time.

Cinnamon exhibited high α -glucosidase and α -amylase inhibitory activities, which indicates potential for side effects from undigested starch. The presence of procyanidin oligomers of the catechins and/or epicatechins from cinnamon have been related with the insulin-enhancing properties *in vitro* in adipocytes suggesting that cinnamon may mimic insulin effects and thus improve glucose utilization (Anderson et al., 2004). This current study indicates that cinnamon may also have potential for management of pre-diabetes-related glycemic control.

Although the Type 2 diabetes linked α -amylase and α -glucosidase inhibitory activities were not high in whole ginger; this spice exhibited moderate hypertension relevant ACE inhibitory activity. In a previous report, an Asian sample of ginger was also found to possess strong ACE inhibitory activity; however, a significant anti-amylase activity was observed as well (McCue et al., 2005).

Such differences may indicate the importance of influence of sample origin on Type 2 diabetes linked-functional properties. The same authors speculate that protein–phenolic and/or phenolic–phenolic synergies may be involved in the food extract enzyme-inhibition mechanism (McCue et al. 2005).

3.2.4. Peppers

In general, the α -glucosidase inhibition was moderate (from 31% to 55% at 2.5 mg of dried sample) among the different evaluated peppers (Fig. 4). The highest inhibition corresponded to the red pepper (*Capsicum chinense*) and Rocoto (*Capsicum pubescens*) extracts (55%) whereas no correlation between the total phenolics or DPPH radical scavenging-linked antioxidant activity and the enzyme inhibitory activity was observed (Table 6).

All peppers had the ability to inhibit the α -amylase enzyme (Fig. 6). The Mexican pepper “Japanese chili pods” and all Peruvian peppers showed a moderate α -amylase inhibitory activity (from 28% to 35% at 25 mg of dried sample). In contrast, the other Mexican peppers “Chile de arbol” and “Chile ancho” exhibited the lowest inhibition (11% and 5%, respectively). Interestingly, only peppers as group showed a significant correlation between the α -amylase inhibitory activity and the DPPH radical scavenging-linked-antioxidant activity ($r = 0.46$, $p < 0.05$) (Table 6).

ACE inhibitory activities of pepper samples ranged from 45% to 92% (at 2.5 mg of dried sample) and showed a good dose dependent response (Fig. 8). Peruvian samples such as Paprika (*Capsicum annum*) and red pepper had the highest ACE inhibition (92% and 84%, respectively) among all pepper samples, whereas Rocoto and yellow pepper (*Capsicum baccatum*) only exhibited ACE inhibition at the highest evaluated dose (71% and 41%, respectively at 2.5 mg of dried sample). The ACE inhibitory activities had a significant correlation with the total phenolic contents ($r = 0.61$, $p < 0.05$) but not with the antioxidant activity (Table 6).

According to results presented above, peppers had a unique profile regarding its functionality for potential Type 2 diabetes and hypertension management. Overall, all peppers had moderate to high α -glucosidase inhibitory activities, mild α -amylase inhibition and strong ACE inhibitory activities. Further, peppers exhibited high free radical scavenging-linked antioxidant activities and a significant correlation between their total phenolic contents and the ACE inhibitory activities was found. Based on these results, Peruvian and Mexican peppers evaluated in this study would have the potential to manage hyperglycemia-induced hypertension and oxidation-linked vascular complications. Similarly, Kwon et al. (2007) reported that nearly all types of peppers evaluated in their study had the potential to inhibit ACE, which indicates anti-hypertension activity. Nevertheless, the ACE inhibitory activities of the water extracts did not correlate well with the total soluble phenolic contents. In addition, other bioactive compounds such as carotenoid pigments, tocopherols and capsaicinoids (Gnayfeed et al., 2001) also contained in peppers may play a role on their health relevant functionality probably in a synergistic manner.

4. Conclusions

This study using *in vitro* analysis provides insights about the potential to inhibit key enzymes relevant to Type 2 diabetes associated hyperglycemia and hypertension of traditionally used medicinal plants, herbs and spices from Latin America in relation to their phenolic contents and DPPH radical scavenging-linked-antioxidant activity. High phenolic and antioxidant activity-linked medicinal plants (Chancapiedra, *Phyllanthus niruri* L. and Zarzaparrilla, *Smilax officinalis*), herbal teas (Yerba Mate, *Ilex paraguayensis* St-Hil) and spices (Huacatay, *Tagetes minuta* and Guascas, *Galinsoga parviflora*) have the potential for α -glucosidase inhibition with no

inhibition against porcine pancreatic α -amylase *in vitro*. In contrast, Cat's claw (*Uncaria tomentosa*), cinnamon (*Cinnamomum zeylanicum* B.), Linden tea Tilo (*Tilia platyphyllos*) and Boldo (*Peumus boldus*) inhibited strongly both the α -glucosidase and α -amylase enzymes. Medicinal plants such as Molle (*Schinus molle*), Maca (*Lepidium meyenii* Walp), Caigua (*Cyclanthera pedata*) and the spice ginger (*Zingiber officinale*) exhibited low total phenolic contents but had relevant ACE inhibitory activities indicating potential anti-hypertension activity likely related to non-phenolic compounds. All evaluated peppers showed good inhibitory profiles on carbohydrate-modulating enzymes and high ACE inhibitory activities correlated to its total phenolic contents. This finding indicates the potential of peppers for both Type 2 diabetes-linked hyperglycemia and hypertension management.

Based on results from this study, a good combination of these Latin American medicinal plants, herbs and spices associated with proper plant-based diets may lead to effective dietary strategies for controlling early stages of postprandial hyperglycemia and associated hypertension. In addition, this study provides the biochemical rationale for further animal and clinical studies.

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