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Antioxidant Capacity and Phenolics Content of Apricot (*Prunus armeniaca* L.) Kernel as a Function of Genotype

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Abstract Fourteen apricot genotypes grown under similar cultural practices in Trans-Himalayan Ladakh region were studied to find out the influence of genotype on antioxidant capacity and total phenolic content (TPC) of apricot kernel. The kernels were found to be rich in TPC ranging from 92.2 to 162.1 mg gallic acid equivalent/100 g. The free radical-scavenging activity in terms of inhibitory concentration (IC_{50}) ranged from 43.8 to 123.4 mg/ml and ferric reducing antioxidant potential (FRAP) from 154.1 to 243.6 $FeSO_4.7H_2O$ μg/ml. A variation of 1–1.7 fold in total phenolic content, 1–2.8 fold in IC_{50} by 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay and 1–1.6 fold in ferric reducing antioxidant potential among the examined kernels underlines the important role played by genetic background for determining the phenolic content and antioxidant potential of apricot kernel. A positive significant correlation between TPC and FRAP (r=0.671) was found. No significant correlation was found between TPC and IC_{50}; FRAP and IC_{50}; TPC and physical properties of kernel. Principal component analysis demonstrated that genotypic effect is more pronounced towards TPC and total antioxidant capacity (TAC) content in apricot kernel while the contribution of seed and kernel physical properties are not highly significant.

Keywords Antioxidant capacity · Dry fruit · Genotypes · Ladakh · Nutrition · Seed

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Abbreviations

DPPH	2,2-diphenyl-1-picrylhydrazyl
D_g	Geometric mean diameter
FRAP	Ferric reducing antioxidant potential
GAE	Gallic acid equivalent
IC_{50}	Inhibitory concentration
L*	Color in lightness
PCA	Principal component analysis
TAC	Total antioxidant capacity
TEAC	Trolox equivalent antioxidant capacity
TPC	Total phenolic content
TPTZ	2,4,6-tri (2-pyridyl)-s-triazine
Wt	Weight in grams
Ø	Sphericity

Introduction

Natural products for food and nutritional supplements have gained increased attention in recent years. In this context, there is an increasing interest in the beneficial health effects of plant derived antioxidants. Epidemiological studies have demonstrated that there is a positive relation between intake of antioxidant rich diets and lower incidence of degenerative diseases including cancer, heart disease, inflammation, arthritis, immune system decline, brain dysfunction and cataracts [1–3]. Apart from playing an important role in the biological system, antioxidants have been used in food industry to extend the shelf-life of foods containing oxidizable lipids such as vegetable oils, animal fats, flavourings, spices, nuts, processed meat and snacks [4]. Along with other antioxidant components, polyphenols present in fruit and vegetable have been reported to play a

major role in disease prevention due to their ability to scavenge free radicals in the biological system [3]. As antioxidants, polyphenols have been reported to be able to interfere with the activities of enzymes involved in reactive oxygen species generation, scavenging free radicals, chelating transition metals and rendering them redox inactive in the Fenton reaction. These results have stimulated research to characterize different types of plants with regards to phenolic content and antioxidant potential [5].

The apricot (*Prunus armeniaca* L., Rosaceae) fruits are widely consumed in many parts of the world. The total world production of apricot is about 2.6 million tons, with Turkey (370,000 tons) as the leading country, Iran (285,000 tons) and Italy (244,000 tons) being the other main producers [6]. The fruit contain different level of phytochemicals such as vitamins, carotenoids and polyphenols, which contribute significantly to their taste, color and nutritive value [7]. The apricot seed represents about 15% of the fruit and kernel represent about 34% of the seed [8]. The kernel is a valuable by-product. Sweet kernels taste like almond and are used as its substitutes in dried form. Apricot kernels are used in the production of oils, benzaldehyde, cosmetics, active carbon, aroma and perfume [9]. Since fresh apricot fruits are good source of antioxidants [5, 10] such as chlorogenic acid, neochlorogenic acid, caffeic acid, *p*-coumaric acid, ferulic acid, β-carotene and γ-carotene [7], it is expected that the kernels are rich in these compounds. It has been previously reported that seed has much higher antioxidant activity and phenolic content than the flesh of the fruit [11].

TPC and TAC depends on the specific plant genotype and interactions of cultivation conditions [5]. Although the importance of genotype in determining TAC in fruits has been demonstrated [5, 10, 12, 13], the effect of genotype on TAC of kernel has not been deeply investigated. The present investigation was therefore carried out to evaluate the importance of genotype on TPC and TAC of kernel of fourteen apricot cultivars grown under similar cultural practices. An attempt was also made to relate weight, geometric mean diameter, sphericity and color of seed and kernel with that of TPC and TAC. The present investigation represents to our knowledge the first study addressing the importance of genotype on phenolic content and antioxidant capacity of kernel of apricot cultivars grown under similar cultural practices.

Materials and Methods

Plant Material

Seeds of 14 apricot cultivars harvested at commercial maturity stage in 2009 harvest season were used. Safeda, Afghani and Charmagz are introduced cultivars while the rest are native cultivars of cold desert Ladakh region commonly used as source of fresh fruit. The cultivars are maintained in field gene bank (latitude 34° 08.2′N, longitude 77°34.3′E, altitude 3340 m) established in 2000 at Defence Institute of High Altitude Research. All cultivars were grafted on 'Chuli' wild apricot rootstock. The orchard contains 12 rows, eight trees per row. Trees were trained to the modified central leader system and planted at a spacing of 4 m×4 m. All trees had the same age and standard cultural practices were performed. The soil texture of the orchard was silty loam with pH 6.8±0.3. Organic carbon and organic matter content was 0.7±0.3% and 1.2±0.5%, respectively. The selection of the cultivars was based on their importance in the region and differences in physical characteristics of fruit, seed and kernel. Halman and Raktsey Karpo are the most important cultivars predominantly grown under orchard system while the rest are grown on limited scale in the region.

Physical Properties of Apricot Pit and Kernel

The length (L), width (W), thickness (T) and weight (Wt) were measured in 40 randomly selected apricot seed and kernel of each cultivar. Seed was isolated from the fruit by manually removing the flesh while kernel was removed by physically breaking the seed coat. Dimensional properties were measured by a digimatic calliper (CD-6″CS, Mitutoya, Japan) to an accuracy of 0.01 mm. The weight of fruit, seed and kernel were measured by an electronic balance to an accuracy of 0.001 g. Geometric mean diameter (D_g) and sphericity (Ø) values were determined using the following formula [14, 15].

$$D_g = (LWT)^{0.333}$$

$$Ø = (LWT)^{0.333}/L \times 100$$

Color attributes of apricot seed and kernel were measured using a color comparison device (PocketSpec ColorQA, Denver, Co). Results originally in RGB color scale, were expressed as L* (lightness) using a web-based software (www.easyrgb.com).

Preparation of the Extracts

Two cycles of extraction, hydrophilic and lipophilic, were performed. Hydrophilic extraction was performed with methanol while lipophilic extraction was done with acetone. Apricot kernels were shade dried at room temperature for 30 days and then crushed to powder using

a pestle and mortar. Powdered apricot kernels (0.5 g) were extracted for 12 hrs with 20 ml methanol in a capped bottle in an orbital shaker at 180 rpm at room temperature. The sample was centrifuged at 10,000 rpm for 10 min and the supernatant was recovered. The residue was mixed with 20 ml acetone and the process was repeated as described above. TPC and TAC were measured directly in the methanolic and acetone fractions.

Determination of Total Phenolic Content

The Folin-Ciocalteu reagent assay was used to determine the TPC. An aliquot of the samples (0.3 ml) was introduced into test tubes followed by 1.5 ml Folin-Ciocalteu reagent which was previously diluted with distilled water (1:10) and 1.2 ml sodium carbonate (7.5%, w/v). The tubes were vortexed, covered with parafilm and allowed to stand for 30 min. Absorbance at 765 nm was recorded in a spectrophotometer (T80+, PG Instruments Ltd., Earl Shilton, Leicester, UK). TPC was expressed in gallic acid equivalents (GAE mg per 100 g kernel). The calibration equation for gallic acid was $y=0.008x-0.071$ ($R^2=0.996$) where y is the absorbance at 765 nm and x is the concentration of gallic acid in mg/l. For each sample, extraction and TPC determination were done in triplicate.

Determination of Antioxidant Capacity

Determination of Ferric Reducing Antioxidant Potential FRAP assay was conducted using the method previously described [16]. A total of 75 μl of extract and 225 μl of distilled water were added to 2.25 ml of freshly prepared FRAP reagent (10 parts of 300 mM sodium acetate buffer at pH 3.6, one part of 10 mM 2,4,6-tri (2-pyridyl)-s-triazine (TPTZ) solution and one part of 20 mM $FeCl_3.6H_2O$) and the reaction mixture was incubated for 30 min. The increase in absorbance was measured at 593 nm. The antioxidant potential of the kernel extract was determined based on a calibration curve plotted using $FeSO_4.7H_2O$ at a concentration ranging between 20 and 100 μg/ml.

Determination of Antioxidant Activity by DPPH Free Radical Scavenging Method The method developed by Brand-Williams et al. [17] was followed with minor modification. A 0.1 mM solution of DPPH in methanol was prepared and 4 ml of the solution was treated with 0.2 ml of the combined hydrophilic and lipophilic extracted sample. A control was treated with 0.2 ml of solvent instead of the extract. The mixture was left to stand at room temperature for 30 min before the decrease in absorbance at 517 nm was recorded. Antioxidant value was expressed as IC_{50}, the amount of sample extracted into 1 ml solution necessary to decrease by 50% the initial DPPH concentration. IC_{50} was derived from the % disappearance vs. concentration plot (concentration means mg of kernel on DW basis extracted into 1 ml solution).

Statistical Analysis

All the experiments were performed in triplicate. Correlation analysis of seed quality parameters, TAC and TPC was performed using one way ANOVA with 2-sided Tukey's HSD at $p\leq0.05$ and 2-tailed Pearson correlation using SPSS for Windows 17.0 version. For multivariate analysis, a similarity matrix was created first by using Gower's [18] general coefficient similarity with the help of Multivariate Statistical Package ver. 3.2. Principal component analysis (PCA) was conducted on all data points to understand the covariance structure and identify relationship between the variables.

Results and Discussion

Physical Properties of Pit and Kernel

The physical properties of fruit, seed and kernel determined for 14 cultivars are shown in Table 1. Wide variation in physical properties was observed among the examined cultivars. Significant differences in physical properties of fruit, seed and kernel suggest variation between local cultivars.

Total Phenolic Content

TPC in the first cycle of extraction with methanol showed significantly lower value than the second extraction cycle with acetone (Table 2). Acetone was superior to methanol in extracting phenolics, which agrees with the results from almond [19] and berries [20]. The TPC ranged from 92.2 to 162.1, with the mean value of 128.5 mg of GAE/100 g DW kernel (Table 2). In comparison, dry hazelnut, walnut and pistachios with seed coat contain 425, 589 and 461 mg GAE/100 g, respectively [21]. The major phenolic compounds in almond are catechin, caffeic acid, epicatechin, gallic acid, quercetin, α-coumaric acid, chlorogenic acid and kaempferol [19]. Of the 14 apricot cultivars studied, the TPC in the combined extract varied greatly from 1 to 1.7 fold difference in kernel. The highest value was observed for the Raktsey Karpo Chenmo cultivar (162.1±5.02 mg GAE/100 g), which had 1.7 fold higher value than the Turtuk CP-2 cultivar (92.2±3.19 mg GAE/100 g) that showed the lowest TPC value among the examined cultivars. Collectively, our data suggest that a large variation in TPC in apricot kernel is attributed to genotype.

Table 1 Physical properties of seed, pit and kernel of fourteen apricot cultivars of Trans-Himalayan Ladakh region

Cultivar/genotype	Fruit	[1]Wt (g)		[2]D_g (mm)		[3]Ø (%)		[4]Color (L*)	
		Seed	Kernel	Seed	Kernel	Seed	Kernel	Pit	Kernel
Safeda	24.3±1.82^{c}	1.8±0.10^{cd}	0.5±0.03^{bcd}	16.6±0.31^{def}	9.9±0.16^{ab}	72.7±1.18^{c}	66.5±1.65^{bc}	18.0±1.43^{a}	29.1±3.81^{a}
Selection-73	34.0±4.67^{d}	1.6±0.17^{bc}	0.4±0.04^{ab}	16.6±0.80^{ef}	9.4±0.37^{a}	77.4±1.46^{def}	65.5±3.76^{bc}	24.6±0.10^{b}	16.0±4.44^{a}
Hanu Selection-3	15.3±0.74^{ab}	1.3±0.05^{a}	0.5±0.01^{abc}	15.6±0.18^{bc}	10.0±0.15^{ab}	74.9±1.09^{cde}	61.7±2.28^{b}	19.8±0.26^{ab}	18.6±6.97^{a}
Garkhond Selection-1	24.1±2.17^{c}	1.8±0.12^{cd}	0.5±0.05^{cde}	17.2±0.49^{fg}	10.2±0.34^{ab}	79.5±1.93^{fg}	65.8±1.52^{bc}	19.4±0.52^{ab}	21.9±3.82^{a}
Selection-21	13.0±0.90^{a}	1.3±0.11^{ab}	0.4±0.11^{ab}	15.1±0.48^{b}	9.5±0.89^{a}	83.3±2.64^{g}	77.7±3.68^{e}	16.0±0.16^{a}	20.1±8.10^{a}
Tokpopa	35.5±3.01^{d}	2.0±0.18^{e}	0.7±0.10^{f}	18.3±0.70^{h}	11.3±0.74^{c}	67.8±2.75^{b}	56.1±4.07^{a}	17.4±0.09^{a}	20.4±11.05^{a}
Saspol Selection-3	11.9±0.78^{a}	1.2±0.08^{a}	0.5±0.03^{cde}	15.2±0.34^{bc}	10.8±0.21^{bc}	79.4±1.39^{fg}	73.7±1.68^{de}	14.2±0.72^{a}	22.7±5.04^{a}
Turtuk CP-2	14.6±1.74^{a}	1.2±0.18^{a}	0.3±0.12^{a}	15.8±0.79^{bcde}	9.5±1.24^{a}	78.7±2.96^{ef}	69.7±5.79^{cd}	17.2±0.22^{a}	15.3±4.01^{a}
Selection-13	18.6±1.42^{b}	1.4±0.07^{ab}	0.5±0.07^{abc}	15.7±0.27^{bcd}	10.2±0.39^{ab}	75.0±2.37^{cde}	66.9±2.29^{bc}	17.4±0.04^{a}	18.3±3.28^{a}
Achinathang-5	18.5±1.48^{b}	1.4±0.21^{ab}	0.5±0.05^{abc}	16.0±0.57^{cde}	9.9±0.37^{ab}	75.1±2.51^{cde}	65.7±0.99^{bc}	15.2±1.25^{a}	15.0±3.15^{a}
Charmagz	14.6±2.65^{a}	1.2±0.25^{a}	0.4±0.04^{abc}	15.5±0.85^{bc}	10.1±0.37^{ab}	78.4±3.54^{ef}	67.5±3.33^{c}	19.6±0.68^{ab}	15.8±5.22^{a}
Raktsey Karpo	18.7±1.36^{b}	1.9±0.21^{de}	0.7±0.22^{ef}	18.0±0.40^{gh}	11.6±0.27^{c}	73.5±3.17^{cd}	64.6±0.89^{bc}	48.2±4.42^{c}	27.0±2.12^{a}
Halman	13.0±0.90^{a}	1.2±0.26^{a}	0.4±0.05^{abc}	15.5±0.85^{bc}	9.8±0.27^{a}	78.4±3.54^{ef}	64.9±4.00^{bc}	17.8±0.20^{a}	18.6±7.18^{a}
Raktsey Karpo Chenmo	42.6±4.44^{e}	1.9±0.17^{de}	0.6±0.18^{def}	7.7±0.38^{a}	11.6±1.10^{c}	60.2±3.86^{a}	67.1±6.69^{c}	47.0±2.35^{c}	27.5±1.09^{a}
Total mean	21.3±2.01	1.5±0.33	0.5±0.14	15.6±2.47	10.3±0.92	75.3±6.09	66.7±5.88	22.3±10.86	20.5±6.08

Values represented as mean ± SD (n=40); For each column, different lowercase letters indicate significantly different at $p<0.05$, as measured by 2-sided Tukey's HSD between cultivars

[1] Wt, Weight in g; [2] D_g, Geometric mean diameter; [3] Ø, Sphericity; [4] L*; Color in lightness

Table 2 Phenolic content and total antioxidant capacity of dried kernels of 14 apricot cultivars of Trans-Himalayan Ladakh region

Cultivar/genotype	[1]TPC (mg GAE/100 g DW)			Total antioxidant capacity			
				[2]FRAP ($FeSO_4.7H_2O$ μg/ml)			[3]IC_{50} (mg/ml)
	Hydrophilic	Lipophilic	[4]Combined	Hydrophilic	Lipophilic	[4]Combined	[5]Combined
Safeda	48.6±0.50^{c}	94.7±1.74^{fg}	144.3±2.22^{ef}	74.9±2.24^{cd}	125.4±4.29^{de}	200.3±6.49^{d}	54.7±3.08^{cde}
Selection-73	59.3±1.33^{d}	90.0±0.78^{efg}	149.3±2.05^{f}	121.0±3.02^{g}	122.7±2.10^{de}	243.6±4.96^{f}	66.7±0.45^{gh}
Hanu Selection-3	35.1±0.89^{ab}	65.3±2.95^{ab}	100.4±3.51^{ab}	58.3±1.82^{b}	131.0±8.38^{e}	189.4±10.09^{cd}	59.4±2.46^{ef}
Garkhond Selection-1	46.4±1.63^{c}	73.6±0.51^{c}	120.1±1.86^{c}	70.9±1.51^{cd}	127.6±2.23^{de}	198.4±3.73^{cd}	84.8±1.45^{i}
Selection-21	48.4±1.40^{c}	83.0±2.08^{de}	131.3±3.44^{d}	69.2±2.76^{c}	127.2±4.58^{de}	196.4±7.32^{cd}	47.8±4.52^{abc}
Tokpopa	58.3±0.78^{d}	83.7±4.66^{de}	142.0±4.28^{ef}	98.1±3.07^{ef}	108.3±4.61^{abc}	206.4±2.69^{de}	51.1±1.32^{bcd}
Saspol Selection-3	37.6±0.52^{b}	59.8±0.43^{a}	97.4±0.93^{ab}	78.4±1.91^{d}	102.7±2.11^{ab}	181.1±4.00^{bc}	68.3±1.09^{h}
Turtuk CP-2	32.9±2.26^{a}	59.3±0.94^{a}	92.2±3.19^{a}	49.0±3.56^{a}	106.3±2.24^{abc}	155.2±5.77^{a}	69.1±2.52^{h}
Selection-13	48.2±0.99^{c}	81.9±2.58^{d}	130.1±1.83^{d}	57.9±2.39^{b}	105.9±2.72^{ab}	163.8±5.1^{ab}	64.3±3.41^{fgh}
Achinathang-5	58.3±0.95^{d}	88.1±1.54^{def}	146.4±2.46^{f}	105.8±4.50^{f}	115.5±2.39^{bcd}	221.3±6.70^{e}	43.8±1.22^{a}
Charmagz	38.6±0.96^{b}	67.7±0.66^{bc}	106.3±1.20^{b}	50.7±0.66^{ab}	103.5±1.71^{ab}	154.1±2.33^{a}	55.2±2.58^{de}
Raktsey Karpo	49.4±0.77^{c}	85.9±4.94^{de}	135.3±5.30^{de}	93.2±2.61^{c}	108.7±8.42^{abc}	201.9±10.92^{d}	123.4±1.88^{g}
Halman	57.4±1.05^{d}	85.0±1.80^{de}	142.4±2.84^{ef}	102.4±1.78^{f}	96.3±2.51^{a}	198.7±4.29^{cd}	59.9±1.14^{efg}
Raktsey Karpo Chenmo	65.5±2.19^{e}	96.6±3.03^{g}	162.1±5.02^{g}	74.4±1.95^{cd}	119.0±4.30^{cde}	193.4±6.19^{cd}	46.3±2.48^{ab}
Total mean	48.9±9.87	79.6±12.23	128.5±21.41	78.9±21.70	114.3±11.46	193.1±24.28	63.9±19.91

Values represented as mean ± SD (n=40); for each column, different lowercase letters indicate significantly different at $p<0.05$, as measured by 2-sided Tukey's HSD between cultivars

[1] TPC: Total phenolic content

[2] FRAP: Ferric reducing antioxidant potential

[3] IC_{50}: Inhibitory concentration, the amount of sample extracted into 1 ml solution necessary to decrease by 50% the initial DPPH concentration.

[4] Combined: Values of hydrophilic and lipophilic extract combined mathematically

[5] Combined: Values of combined hydrophilic and lipophilic extract measured

Variables such as soil nutrient status, cultural practices, weather conditions and geographical locations have been minimized in the present study, which otherwise may account for variation in the TPC of the apricot kernel. It has been previously demonstrated that the effect of genotype is stronger than that of cultivation conditions for TPC and antioxidant in strawberry [22]. Similarly, variability among genotypes in TPC and TAC has been reported in fresh apricot fruit [5, 10, 12, 13], almond [19], blackberry, hybridberry [23] and lupin [24].

Antioxidant Capacity

Antioxidant Activity by the FRAP Method The ability of the kernel extracts to reduce ferric ions was determined using the FRAP assay. In the present study, the extraction of antioxidants was done with methanol followed by acetone. It was observed that the first extraction solvent retains significantly higher TAC in the sample, which was removed by the second extraction (Table 2). The mean FRAP value of 78.9 $FeSO_4.7H_2O$ μg/ml was observed in the first extraction cycle while the FRAP value was 114.3 $FeSO_4.7H_2O$ μg/ml in the second extraction cycle with acetone. It was observed in different samples such as commercial extracts from cocoa or red grape seeds, that after the first extraction cycle, the sample retained significant TAC, which was removed by a second extraction [25]. Higher ferric reducing antioxidant potential with acetone suggests that apricot kernel contains significantly higher lipophilic than hydrophilic antioxidants. Higher lipophilic antioxidants in kernel in contrast to apricot fruit [5, 26] could be due to higher phenolic content in kernel oil. Similar results have been reported in embryo extracts of *Melicoccus bijugatus* Jacq. fruits [27].

A large range of values was obtained for ferric reducing activity (Table 2). The combined ferric reducing activity in methanolic and acetone extracts ranged from 154.1 to 243.6 $FeSO_4.7H_2O$ μg/ml. The difference in FRAP value between the genotypes showing the highest and lowest value was 1–1.6 folds, which underlines the importance of genetic background for determining ferric reducing antioxidant potential of apricot kernel.

Table 3 Pearson's correlation for total phenolic contents, antioxidant capacity, physical properties of seed, pit and kernel of 14 apricot cultivars

Variables	Kernel						Seed		
	[1]TPC	[2]FRAP	[3]IC_{50}	Wt (g)	[4]Ø	[5]L*	Wt (g)	[4]Ø	[5]L*
[1]TPC	1	.671[a]	−.188	.628[b]	−.554[b]	.417	.259	−.266	.338
[2]FRAP		1	−.002	.443	−.144	.156	.073	−.280	.108
[3]IC_{50}			1	.258	.162	.477	.334	−.082	.292
Kernel wt (g)				1	−.679[a]	.580[b]	.732[a]	−.543[b]	.642[b]
Kernel Ø					1	−.607[b]	−.676[a]	.528	−.492
Kernel L*						1	.563[b]	−.153	.563[b]
Seed wt (g)							1	−.553[b]	.525
Seed Ø								1	.007
Seed L*									1

[a] Correlation is significant at the 0.01 level (2-tailed)

[b] Correlation is significant at the 0.05 level (2-tailed)

[1] TPC: Total phenolic content

[2] FRAP: Ferric reducing antioxidant potential

[3] IC_{50}: Inhibitory concentration, the amount of sample extracted into 1 ml solution necessary to decrease by 50% the initial DPPH concentration.

[4] Ø: Sphericity

[5] L*: Color in lightness

Antioxidant Activity by the DPPH Method Table 2 showed the free radical-scavenging activity values measured using DPPH in terms of IC_{50} (mg/ml extract) of the examined apricot kernel. A large range of values was obtained for free radical-scavenging activity in terms of IC_{50} values in the combined extracts ranging from 43.77 to 123.35 mg/ml among the examined kernel. The 1–2.8 fold variation in IC_{50} values highlighted unexploited variability among the cultivated apricot genotypes. The kernel of cultivar Achinathang-5 had the lowest IC_{50} value (43.8 mg/ml) followed by Raktsey Karpo Chenmo (46.3 mg/ml). The order of cultivar in terms of TAC by the two different antioxidant assays was different. FRAP measure the ability of a sample to reduce metals while DPPH measures free radical scavenging capacity [25]. The change in order in different assays may be due to presence of compounds having different affinity to react with DPPH and FRAP. Antioxidant compounds such as polyphenols may be more efficient reducing agents for ferric ion but some may not scavenge DPPH free radicals as efficiently due to stearic hindrance [28].

Correlation Between Physical Properties, TPC and Antioxidant Capacity

Table 3 displayed the correlation among physical parameters, TPC and TAC of the combined extracts. The TPC was significantly correlated with stone weight (r=0.628) and stone sphericity (r=−0.554). A negative correlation between strawberry fruit size and nutritional parameters (TPC, FRAP, TEAC) has been reported [22]. However, no significant correlation was found in apricot kernel. Similarly, unlike a negative correlation between color (L*) and TPC in strawberry [22], no significant correlation was found in this study.

Significant correlation (r=0.671) between ferric reducing power and TPC of apricot kernel was observed. However, no correlation was found between TPC and IC_{50} value tested by DPPH assay, and between values obtained from FRAP and DPPH assays. Several studies focused on the relationship between the antioxidant activity and TPC of plant materials showed different relations. The study by Scalzo et al. [5] found no correlation between antioxidant capacity and phenolic content whereas the opposite was found by Drogoudi et al. [12]. A strong

Table 4 Eigenvalues and proportion of total variability among 14 apricot cultivars as examined by first three principal components

Eigenvalues	Principal Components		
	*PC1	*PC2	*PC3
Eigenvalues	918.14	457.48	219.24
% variance	54.41	27.11	12.99
Cummulative %	54.41	81.52	94.51

*PC: Principal component

Table 5 Eigenvectors in first three principal components from PCA

Eigenvectors	Variables										
	Kernel							Seed			
	[1]TPC	[2]FRAP	[3]IC_{50}	[4]Wt	[5]D_g	[6]Ø	[7]L*	[4]Wt	[5]D_g	[6]Ø	[7]L*
[8]PC1	.652	.738	−.085	.001	.003	−.051	.037	.006	−.006	−.076	.115
[8]PC2	−.088	.137	.938	.002	.013	−.028	.075	.005	.042	.021	.292
[8]PC3	.562	−.606	−.007	.003	.029	−.016	.147	.007	−.101	−.256	.467

[1] TPC: Total phenolic content

[2] FRAP: Ferric reducing antioxidant potential

[3] IC_{50}: Inhibitory concentration, the amount of sample extracted into 1 ml solution necessary to decrease by 50% the initial DPPH concentration

[4] Wt: Weight in g

[5] D_g: Geometric mean diameter

[6] Ø: Sphericity

[7] L*: Color in lightness

[8] PC: Principal component

correlation between total phenolics and antioxidant activity of apricot fruit [26], nectarines, peaches and plum was reported [29].

Principal Component Analysis

Principal component analysis (PCA) was performed to understand how TPC, TAC, seed and kernel physical properties contribute to genotypic variability among the apricot cultivars. Eigenvectors resulting from PCAs show that more than 81.5% of the variation is explained by the first two principal components (Table 4). PC1 represents mainly FRAP and TPC (0.738 and 0.652, respectively) while PC2 was dominated by IC_{50} (0.938). The result demonstrated that genotypic effect is more important towards TPC and TAC content in apricot kernel while contribution of seed and kernel physical properties are not highly significant (Table 5).

Conclusions

The importance of genotype in determining antioxidant capacity in selected fruits has been demonstrated. However, TAC and TPC as a function of genotype have not been deeply investigated in kernel. The present investigation represents to our knowledge the first preliminary comparative study in apricot kernel to demonstrate the effects of genotypes on TPC and TAC. From this study, it emerged that plant genotype influence TPC and TAC in apricot kernel. But further investigations on the effect of genotype on TPC and TAC in apricot kernel on long term basis are needed. Results obtained in this study can be considered for selection of genotype for large scale cultivation to use kernel for nutraceutical purpose.

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