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Functional Properties of Fruits of Selected Five Solanum Species in Sri Lanka

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FUNCTIONAL PROPERTIES OF FRUITS OF SELECTED FIVE SOLANUM SPECIES IN SRI LANKA

Abstract: Solanaceae is an economically and medicinally important family consisting of many species. The fruits of *Solanum spp*. have a significantly high number of secondary metabolites. Therefore, used in the treatment of numerous ailments and it has a lot of attention as a functional food. The present study aims to determine the total phenolic content (TPC), total flavonoid content (TFC), and total antioxidant capacity (TAC) of fruits of five selected *Solanum spp*. namely; *Solanum melongena* (brinjal), *Solanum torvum* (*thibbatu*), *Solanum violaceum* (*thiththa thibbatu*), *Solanum insanum* (prickly calyx; *local elabatu*) and *Solanum insanum* (non-prickly calyx; *thai elabatu*) in Sri Lanka. Homogenous, representative fresh samples in the harvesting stage were collected from home gardens situated in North Western and Southern Provinces in Sri Lanka. TPC, TFC and TAC were determined using the Folin-Ciocalteu method, colorimetric method and ferric-reducing antioxidant power (FRAP) assay respectively. Data were analyzed using analysis of variance (ANOVA) followed by the Turkey Multiple Range Test using SAS. *Solanum torvum* was reported the significantly higher TPC (13.17 ± 0.23 mg GAE /g DW), TFC (51.96 ± 1.34 mg RE /g DW) and TAC (20.05 ± 1.83 mg TE / g DW). Other selected species were recorded TPC, TFC and TAC as *Solanum melongena* with seeds (12.17 ± 0.47 mg GAE /g DW, 35.74 ± 0.95 mg RE /g DW, 10.78 ± 1.14 mg TE / g DW), *Solanum violaceum* with seeds (5.27 ± 0.34 mg GAE /g DW, 8.63 ± 1.07 mg RE /g DW, 6.03 ± 0.63 mg TE / g DW), the flesh of *Solanum insanum* (prickly calyx) (5.07 ± 0.30 mg GAE /g DW, 10.63 ± 2.00 mg RE /g DW, 5.24 ± 0.33 mg TE / g DW), *Solanum insanum* (prickly calyx) with seeds (8.68 ± 0.30 mg GAE /g DW, 17.74 ± 1.84 mg RE /g DW, 9.69 ± 0.81 mg TE / g DW), the flesh of *Solanum insanum* (non-prickly calyx) (6.32 ± 0.63 mg GAE /g DW, 14.18 ± 1.59 mg RE /g DW, 5.86 ± 0.37 mg TE / g DW) and *Solanum insanum* (non-prickly calyx) with seeds (11.08 ± 0.93 mg GAE /g DW, 32.96 ± 2.00 mg RE /g DW, 11.10 ± 3.34 mg TE / g DW) respectively. Moreover, this study showed positive correlations of TAC with TPC ($R^2 = 0.7699$) and TFC ($R^2 = 0.8935$). The results of the present study concluded that fruits of all selected *Solanum* species exhibited a marked amount of bioactive compounds and antioxidant capacity.

Keywords: Antioxidant capacity, Flavonoids, Phenolics, Solanaceae, Solanum spp.

Introduction

Solanaceae is an economically and medicinally important family consisting of many species (around 3,000). The family is quite diverse, with species living in both perennial trees and annual herbaceous habitats, ranging from deserts to rainforests (Gebhardt, 2016). The majority of species in the family Solanaceae are found in the genus Solanum (around 102 genera) (Jeyakumar *et al.*, 2016).

This crop is mostly cultivated especially in tropical and subtropical countries and cultivars produce wide crop diversity with different colors, shapes, and sizes (Niño-Medina *et al.*, 2017). Selected *Solanum spp*. are normally referred to as “Eggplant” (in English) "Batu" (in Sinhala) and "Kaththiri" (in Tamil) in Sri Lanka (Jeyakumar *et al.*, 2016).

The fruits of *Solanum spp*. are already consumed often as foods and nutritional supplements. Fruits and vegetative plant parts, such as roots, stalks, and leaves are used especially in the modern pharmaceutical industry and traditional medicine due to their amazing therapeutic qualities (Wijesooriya *et al.*, 2015; Aldhahani *et al*., 2022). As well as used for various purposes such as the biofuel industry, religious rites, and as an ornament (Fraikue, 2016; Ahmed *et al*., 2022).

The fruits of Solanum spp. have a significant amount of linoleic acids, flavonoids, alkaloids, tannins, saponins, vitamins, high anthocyanin content in the peel and a high phenolic acid content in the flesh with delphinidin derivatives and chlorogenic acid isomers as well as high antioxidant. Therefore, brinjal is among the top ten vegetables with higher antioxidant activity. Also contains fiber and elements that humans need, such as magnesium, manganese, potassium, copper, etc. Therefore, Solanum spp. is used in the treatment of numerous ailments such as amenorrhea, prenatal anemia, premenstrual syndrome, stroke, cardiac arrest, heart diseases, obesity, asthma, allergic rhinitis, nasal catarrh, skin infections, swollen joint pains, gastroesophageal reflux, constipation, dyspepsia, diabetes etc. (Igwe *et al.*, 2003; Odetola *et al.*, 2004). Due to these reasons, recently, eggplant has much attention as a functional food (Niño-Medina *et al.*, 2017).

The importance of medicinal plants has increased in modern medicine, and the medicinally beneficial Solanaceous species are crucial in this regard. According to the World Health Organization (WHO), the value of the trade-in medicinal plants has reached 500 million USD and is expected to rise to more than five trillion USD in the coming years because herbal medicines are known to be less toxic and have fewer side effects than synthetic drugs (WHO, 2013). Since many farmed Solanaceous plants are rich in the phytochemicals diosgenin and solasodine and employed in the steroid industry, they are frequently used for medicinal purposes (Gbile & Adesina, 1988). "Eggplant is the medicinal vegetable of the modern world," said Avicenna, the founder of modern medicine (Sekara *et al.*, 2007).

So far, there are no comprehensive studies to evaluate the bioactive compounds and antioxidant capacity of locally available Solanum spp. Therefore, this study was undertaken to investigate the antioxidant capacity, bioactive compounds, and proximate composition of selected Solanum spp. in Sri Lanka.

Methodology

Location

This study was carried out in the laboratories of the Department of Plantation Management, Faculty of Agriculture and Plantation Management, and Department of Food Science and Technology, Faculty of Livestock Fisheries and Nutrition, Wayamba University of Sri Lanka, Makandura, Gonawila (NWP) during the period from November 2022 to March 2023.

Plant Materials

Five *Solanum spp*. (Table 1) were selected for this study.

Table 1. Common and scientific names of five selected Solanum spp.

Common Name	Scientific Name
Wambatu (Brinjal)	*Solanum melongena* (L.)
Thibbatu	*Solanum torvum* Sw.
Thiththa thibbatu	*Solanum violaceum* Ortega.
Local *Elabatu* (P)	*Solanum insanum* (L.)
Thai *Elabatu* (NP)	*Solanum insanum* (L.)

P-Prickly calyx, NP-Non-prickly calyx

Collection of Sample

Homogenous, representative fresh samples of Solanum spp. in the harvesting stage were collected from selected home gardens situated in North Western and Southern Provinces in Sri Lanka. Solanum melongena, Solanum torvum, Solanum insanum (Prickly) and Solanum insanum (Non-Prickly) were collected from both North Western and Southern Provinces in Sri Lanka. Solanum violaceum was collected only from the Southern Province of Sri Lanka.

Preparation of Sample

All collected samples were washed with tap water to remove any impurities attached to the fruits. Then, samples were cut into small pieces and air-dried at room temperature (28 ± 2 ˚C) for three days. All dried samples were powdered using a coffee grinder. Ground samples were sieved through a 0.25 mm mesh.

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Extraction of Phytochemicals

Powdered samples (0.1g) were mixed with 5 mL of 80 % methanol and vortexed for 15 min. Then, it was placed in a water bath at 60 ^{0}C for 40 min and the vortexed procedure was repeated at 10 min intervals. After centrifugation at 4,000 rpm for 5 min, the supernatant was decanted into a 15 mL centrifuge tube. The remaining was re-extracted with 5 mL of 80 % methanol. Supernatants were pooled and stored at -20 ^{0}C until analysis. All samples were analyzed in triplicates.

Determination of Total Phenolic Content (TPC)

The total phenolic content was determined by using a modified Folin-Ciocalteu method (Abeysinghe *et al.*, 2007). It follows 4 mL of distilled water and 0.5 mL of methanolic extract of essential oil was added into a test tube. Then the 0.5 mL of 0.5 N Folin-Ciocalteu reagent was added into the test tube and allowed to react for 3 minutes. Then 1 mL of saturated sodium carbonate solution was mixed and samples were incubated in a water bath for 2 hours at 30 ˚C. The absorbance was measured at 760 nm using a spectrophotometer with 80% methanol used as a control. TPC was calculated by using the standard gallic acid curve and expressed as milligrams of gallic acid equivalents (GAE) per g of DW.

Determination of Total Flavonoid Content (TFC)

A colorimetric method was used with slight modifications (Li *et al.*, 2022). A volume of 0.5 mL of methanolic extract of essential oil was added to a centrifuge tube containing 3.5 mL of distilled water. Then the solution was mixed with 0.3 mL of 5% $NaNO_2$. 0.3 mL of 10% $Al(NO_3)_3.6H_2O$ solution was added after 6 minutes. The mixture was allowed to stand for another 6 minutes and then 2 mL of 2M NaOH was added. The reaction mixture was diluted with 1.4 mL of distilled water and the absorbance of the mixture was measured by using a spectrophotometer at 510 nm wavelength with 80% methanol used as a control. TFC was calculated by using the standard rutin curve and expressed as milligrams of rutin equivalents (RE) per g of DW.

Determination of Total Antioxidant Capacity (TAC)

The total antioxidant capacity of extracted essential oil samples was determined using the ferric ion reducing antioxidant power (FRAP) assay described by Benzie and Strain (1996) with slight modifications. Briefly, mix 100 µl of methanolic extract of essential oil sample was mixed with 900 µl of freshly prepared FRAP (Mixing 25 mL of 300 mM Sodium acetate buffer, 2.5 mL of 10 mM TPTZ solution and 2.5 mL of 20 mM ferric chloride solution) reagent of pH 3.6 and incubate for 4 minutes. Then, measured the absorbance at 593 nm using a spectrophotometer. Used 80% methanol as a control. Total antioxidant capacity was calculated using the standard Trolox curve and expressed as milligrams of Trolox Equivalents (TE) per g of DW.

Statistical Analysis

Parametric variables were analyzed using analysis of variance (ANOVA) followed by the Turkey Multiple Range Test using SAS (SAS Version 9.5). Means and standard deviation were reported.

Results and Discussion

Total Phenolic Content (TPC)

TPC of fruits of selected *Solanum spp*. are shown in Table 4.1. According to the results, the TPC of tested varieties ranged from 5.07 ± 0.30 to 13.17 ± 0.23 mg GAE /g DW. The highest TPC was observed in *Solanum torvum* (13.17 ± 0.23 mg GAE /g DW) followed by brinjal (12.17 ± 0.47 mg GAE /g DW) and *Solanum insanum* non-prickly with seeds (11.08 ± 0.93 mg GAE /g DW). However, there was no significant difference between the mean value of *Solanum torvum* and Brinjal. The flesh of *Solanum insanum* prickly (5.07 ± 0.30 mg GAE /g DW) was recorded as the lowest TPC value among tested samples.

Solanum insanum non-prickly with seeds (11.08 ± 0.93 mg GAE /g DW) recorded significantly highest TPC than *Solanum insanum* prickly with seeds (8.68 ± 0.30 mg GAE /g DW). However, no significant difference was found between the mean value of the flesh of both *S. insanum* prickly and *S. insanum* non-prickly.

Koubaa and Mohamed (2014) reported that the secondary metabolites and antioxidant capacity are high in seeds of *Solanum spp.* According to that, the quantity of secondary metabolites in the seeds of *Solanum spp*. is higher than in the flesh of *Solanum spp*. Therefore, the TPC is higher in seeds. This may be due to the significantly higher TPC recorded with seeds in both *S. insanum* prickly and *S. insanum* non-prickly than without seeds (only Flesh).

The results for the TPC of brinjal in the present study agreed with the study of Nino-Medina *et al.* (2017). According to Samarakoon *et al.* (2018), *S. insanum* prickly and *S. insanum* non-prickly had a high amount of TPC. The present study also recorded a similar finding. The results for TPC of *Solanum violaceum* and *Solanum torvum* agreed with the findings of Raju *et al.* (2013) and Yousaf *et al.* (2013) respectively.

Total Flavonoid Content (TFC)

As demonstrated in Table 4.1, the significantly highest TFC was reported in *Solanum torvum* (51.96 ± 1.34 mg RE /g DW) followed by brinjal and *S. insanum* non-prickly with seeds (35.74 ± 0.95 and 32.96 ± 2.00 mg RE /g DW, respectively). However, there was no significant difference between brinjal and *S. insanum* non-prickly with seeds. The lowest TFC recorded in *Solanum violaceum* was 8.63 ± 1.07 mg RE /g DW.

The flesh of *S. insanum* non-prickly (14.18 ± 1.59 mg RE /g DW) recorded higher TFC than the flesh of *S. insanum* prickly (10.63 ± 2.00 mg RE /g DW). However, there is no significant difference. *S. insanum* non-prickly with seeds showed significantly higher TFC than *S. insanum* prickly with seeds.

When considering with seeds and without seeds in both *S. insanum* non-prickly and *S. insanum* prickly*,* with seeds recorded significantly higher TFC than those without seeds (only flesh). This may be due to the presence of high content of secondary metabolites in seeds of *Solanum spp*. (Koubaa & Mohamed, 2014). The previous studies have also recorded a considerable amount of TFC for fruits of selected *Solanum spp.* (Khalighi *et al.*, 2012).

Total Antioxidant Capacity (TAC)

As demonstrated in Table 4.1, the TAC of all tested samples ranged from 5.24 ± 0.33 to 20.05 ± 1.83 TAC mg TE / g DW. The significantly highest and lowest TAC was recorded in *Solanum torvum* and flesh of *S. insanum* prickly respectively. The flesh of *S. insanum* non-prickly (5.86 ± 0.37 TAC mg TE / g DW) recorded significantly higher TAC than the flesh of *S. insanum* prickly (5.24 ± 0.33 TAC mg TE / g DW).

Furthermore, *S. insanum* prickly and *S. insanum* non-prickly with seeds show higher TAC than flesh. This finding is in line with Koubaa and Mohamed (2014) and Musyimi *et al.* (2021) who reported that the seeds of *Solanum spp*. were the valuable part that contains high antioxidant activity. The results of the TAC of Brinjal were similar to the study of Somawathie *et al.* (2014). When compared to previous studies (Yousaf *et al.*, 2013) of TAC in *S. torvum*, the present study also reported high TAC in *S. torvum.*

Table 2. Total phenolic content (TPC), total flavonoid content (TFC) and total antioxidant capacity (TAC) of selected Solanum spp.

Solanum spp.	**Fruit part**	**TPC (mg GAE /g DW)**	**TFC (mg RE /g DW)**	**TAC (mg TE / g DW)**
S. melongena	Flesh with seeds	12.17 ± 0.47 [ab]	35.74 ± 0.95 [b]	10.78 ± 1.14 [b]
S. torvum	Flesh with seeds	13.17 ± 0.23 [a]	51.96 ± 1.34 [a]	20.05 ± 1.83 [a]
S. violaceum	Flesh with seeds	5.27 ± 0.34 [d]	8.63 ± 1.07 [e]	6.03 ± 0.63 [cd]
S. insanum (P)	Flesh	5.07 ± 0.30 [d]	10.63 ± 2.00 [de]	5.24 ± 0.33 [d]
S. insanum (P)	Flesh with seeds	8.68 ± 0.30 [c]	17.74 ± 1.84 [c]	9.69 ± 0.81 [bc]
S. insanum (NP)	Flesh	6.32 ± 0.63 [d]	14.18 ± 1.59 [cd]	5.86 ± 0.37 [cd]
S. insanum (NP)	Flesh with seeds	11.08 ± 0.93 [b]	32.96 ± 2.00 [b]	11.10 ± 3.34 [b]

Mean denoted by the same letters in a column represent non-significant differences (P <0.05), TE-Trolox equivalent, GAE- Gallic Acid Equivalent, RE- Rutin equivalent, DW- Dry weight, NP-Non-prickly calyx, P-Prickly calyx

Correlation between TAC with Bioactive Compounds

In this study, positive strong correlations were observed in TAC with TFC ($R^2 = 0.8935$; $P <0.05$) (figure 4.1) and TPC ($R^2 = 0.7699$; $P <0.05$) (figure 4.2). These strong correlations indicated that the bioactive compounds mainly contribute to the total antioxidant capacity of fruits of selected *Solanum spp*.

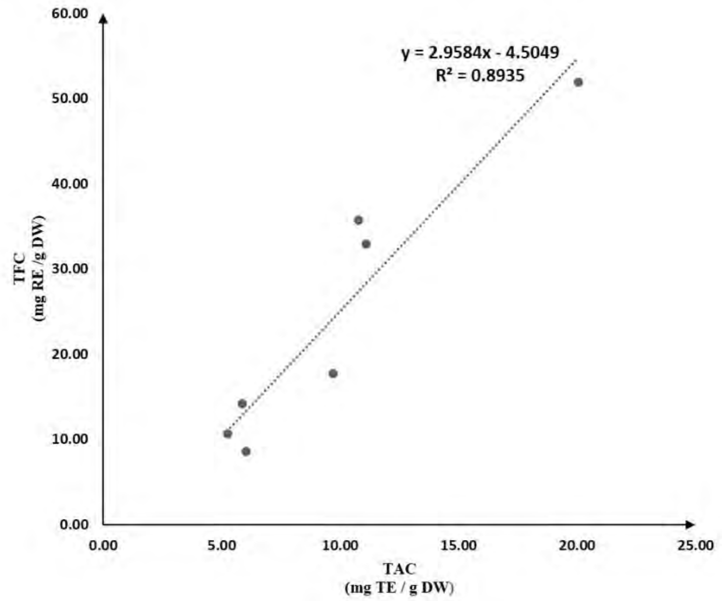

Figure 1 Correlation between TAC and TFC

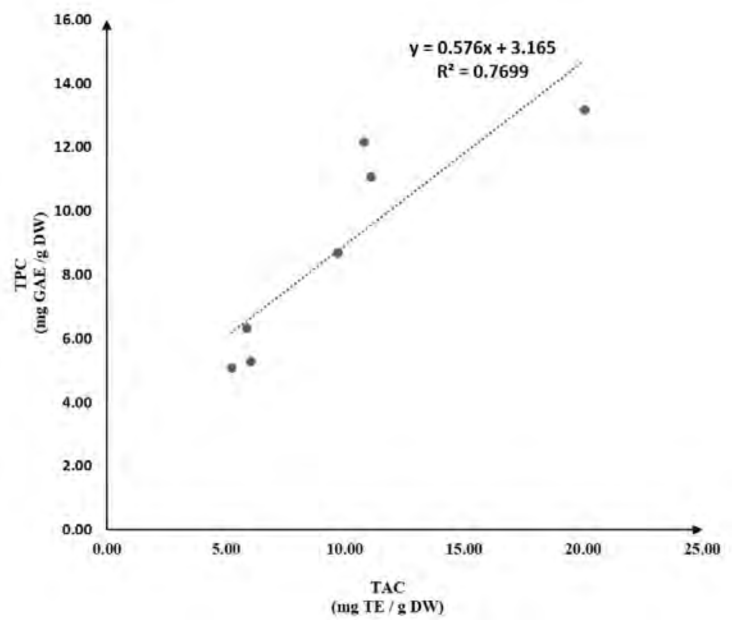

Figure 2 Correlation between TAC and TPC

Conclusions

The results of the present study conclude that all tested varieties exhibited a marked amount of bioactive compounds and antioxidant capacity.

Solanum torvum has the significantly highest TPC, TFC and TAC among all tested species. Both *Solanum insanum* prickly and *Solanum insanum* non-prickly with seeds contained a significantly higher amount of bioactive compounds and antioxidant capacity than flesh. These selected fruits of *Solanum spp*. can be used as a good antioxidant supplement. These *Solanum spp*. could be recommended as vegetables having high bioactive compounds, and antioxidant and nutritive properties.

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