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Total antioxidant activity and radical scavenging capacity of selected fruits and vegetables from South India

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Abstract

The objective of this present study was to analyse and compare the total antioxidant activity and radical scavenging capacity of selected fruits and vegetables from south India. The selected fruits and vegetables such as mulberries, papaya, red grapes, mango, guava, tomato, red onion, red cauliflower, carrot and beetroot were used in this study. The selected fruits and vegetables showed a high variation in content of total ascorbic acid (ranged from 10.83 to 68.71 mg/100 g fresh weight (FW)); total phenolics (ranged from 26.57 to 57.64 mg/ 100 g FW) and total flavonoids (ranged from 2.49 to 12.69 mg/100 g FW). Total antioxidant capacity of the selected fruits and vegetables were ranged from 31.21 to 61.11 mg/100 g FW. The higher levels of radical scavenging capacity were observed in beetroot, red onion, red cauliflower, red grapes and mulberries as compared to other fruits and vegetables ($P < 0.05$). Papaya and guava had moderate levels of radical scavenging capacity ($P < 0.05$). On the other hand, mango and tomato obtained low levels of radical scavenging capacity ($P < 0.05$). The overall, pigmented fruits and vegetables in this study contained the higher levels of antioxidant and radical scavenging capacity.

Introduction

Free radicals are continuously generated in the human body as an effect of oxidative metabolism and thus results the incidence of severe illness such as coronary heart disease, cancer, neurodegenerative ailments, diabetes mellitus, autoimmune disease and aging (Jacob and Burri, 1996; Ratnam *et al*., 2006; Stangeland *et al*., 2009). Antioxidants are substance which can protect the human body from free radicals and reactive oxygen species (ROS) induced chronic diseases (Gülçin *et al*., 2005). Antioxidants are categorized into two groups such as enzymatic and non enzymatic. Enzymatic antioxidants include superoxide dismutase (SOD), catalase (CAT) and glutathione peroxidase, endogenously produced in human systems and under normal conditions they are defense against the free radicals and ROS. However, antioxidant enzymes are weakened against radicals during the severe disease conditions (Wootton-Beard and Ryan, 2011). Therefore, the external sources of dietary antioxidants are required to strengthen the human defense system. Non enzymatic antioxidants are polyphenols, carotenoids, vitamins and minerals found rich in fruits and vegetables (Du Toit *et al*., 2001; Lim *et al.*, 2007; Isabelle *et al.*, 2010; Nurliyana *et al.*, 2010).

Fruits and vegetables can act as the good source of antioxidants; it scavenges the free radicals by inhibiting the enzymes that accountable for ROS productions and reduces the highly oxidized ROS (Du Toit *et al*., 2001; Fu *et al*., 2011). However, these scavengers are small molecules and possibly consume by ROS and, therefore, it needs in high quantity. In general, fruits and vegetables are the definite part of the human diets (Sreeramulu and Raghunath, 2010). South India produces a wide range of health beneficial fruits and vegetables, which it exports to several countries. The antioxidant properties of fruits and vegetables from south India have been investigated widely on the individual basis with different analytical methods, and it is difficult to compare and correlate. Therefore, the present study was aimed to measure and compare the total antioxidants and free radical scavenging capacity of the selected and widely consumed fruits and vegetables from south India.

Materials and Methods

Plant material

Plant material such as mulberries (*Morus nigra*, Moraceae), papaya (*Carica papaya*, Caricaceae), red grapes (*Vitus vinifera*, Vitaceae), mango (*Mangifera indica*, Anacardiaceae), guava (*Psidium guajava*, Myrtaceae), tomato (*Lycopersicon esculentum*, Solanaceae), red onion (*Allium cepa* variety cepa,

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Alliaceae), red cauliflower (*Brassica oleracea* variety botrytis, Cruciferae), carrot (*Daucus carota* subspecies *sativus*, Umbelliferae) and beetroot (*Beta vulgaris* variety *conditiva*, Chenopodiaceae) were acquired from a contact garden in Tamilnadu state, south India. Fruits and vegetables were freshly harvested in the morning and then, they were taken into the laboratory within a day at ambient temperature. The non-defected fruits and vegetables were selected and washed with distilled water and then proceed for the extraction process.

Plant material extraction

Plant materials such as papaya, mango, red onion and beetroot were homogenized without skin and remaining fruits and vegetables were extracted with the skin. Plant extractions were carried out based on the method of Lim et al (2007) with a slight modification. Triplicate samples of 25 g of each samples edible portion were used for the extraction in a mortar and pestle method at 4°C with 50 ml of 80% ethanol. Then, the homogenate was transferred to 100 ml volumetric flask and made up the volume with 80% ethanol. The mixture was shaken in the orbital shaker for 20 min and then it was filtered by muslin cloth. After that, the filtrate was used for the following experiments. All the experiments were carried out in triplicate within 2 days after the extraction process.

Determination of ascorbic acid and phenolic contents

Ascorbic acid content was analysed by an indophenols method in accordance with the Nielsen (2010) and the values were expressed as milligram of ascorbic acid per 100 gram of fresh weight. Total phenolic content was analysed in accordance with the method of Lim *et al.* (2007), and the values were expressed as milligram of gallic acid equivalents per 100 gram of fresh weight. Total flavonoids were analyzed in accordance with the method of Zhishen *et al.* (1999), and the values were expressed as milligram of catechin equivalents per 100 gram of fresh weight.

Determination of antioxidant activity

Total antioxidant capacity was determined in accordance with the method of Prieto *et al.* (1999) and the values were expressed as milligram of ascorbic acid equivalents per 100 gram of fresh weight. DPPH scavenging capacity was determined in accordance with the method of Binsan *et al.* (2008) and the values were expressed as milligram of ascorbic acid equivalents per 100 gram of fresh weight. The ferric reducing power was determined in accordance with the method of Benzie and Strain (1996) and the values were expressed as milligram of ascorbic acid equivalents per 100 gram of fresh weight. The hydroxyl radical scavenging activity was determined in accordance with the method described by Hinneburg *et al.* (2006) and the values were expressed as milligram of ascorbic acid equivalents per 100 gram of fresh weight. The superoxide anion radical scavenging activity was determined in accordance with the method of Awah *et al.* (2012), and the values were expressed as milligram of ascorbic acid equivalents per 100 gram of fresh weight.

Data analysis

Duncan's multiple range test was used to analyze the significant differences among mean values of plant extracts at the level of $P < 0.05$. Statistical analysis was performed at the Statistical Package for Social Science (SPSS for windows, SPSS Inc., Chicago, IL, USA).

Results and Discussion

Total ascorbic acid (TAA)

TAA of selected fruits and vegetables are represented in Table 1. TAA levels were ranged from 10.83 to 68.71 mg/100 g FW. As compared to other fruits and vegetables; papaya, carrot, guava and beetroot showed the higher levels of TAA with 68.71, 54.50, 48.95 and 48.40 mg/100 g FW, respectively. Ascorbic acid in the plant tissues are undergoing active growth and development and the total amount of ascorbic acid varies among species and cultivars (Lee and Kader, 2000). Tomato, red cauliflower, red onion and mulberries had the lower levels of ascorbic acid content. The lower the light intensity and fluctuation in growth temperature could be minimized the level of ascorbic acid (Harris, 1975; Lee and Kader, 2000).

Total phenolic contents (TPC)

TPC of the selected fruits and vegetables are represented in Table 1. TPC levels were ranged from 26.57 to 57.64 mg/100 g FW. The higher levels of TPC were seen in beetroot, red cauliflower, red onion and mulberries with the value of 57.64, 44.23, 42.25 and 42.12 mg/100 g FW, respectively as compared to other examined fruits and vegetables in this study ($P < 0.05$). Also, the earlier reports on beet root, red cauliflower, red onion and mulberries observed the higher levels of TPC as compared to other fruits and vegetables (Velioglu *et al*., 1998; Vinson *et al*., 1998; Fu *et al*., 2011; Lu *et al*., 2011; Li *et al*., 2012;). The

Table 1. Total ascorbic acid, total phenolics and total flavonoids of selected fruits and vegetables

Plant extract	Total ascorbic acid content (mg/100 g FW)*	Total phenolic contents (mg/100 g FW)*	Total flavonoid contents (mg/100 g FW)*
Mulberries	32.19±0.5^{d}	42.12±1.1^{f}	7.57±0.7^{f}
Papaya	68.71±1.7^{i}	35.86±1.5^{d}	2.49±0.9^{a}
Red grapes	43.97±1.1^{f}	36.08±0.8^{d}	12.69±1.1^{i}
Mango	39.84±1.2^{e}	33.44±1.7^{c}	4.64±0.5^{c}
Guava	48.95±1.0^{g}	31.97±1.0^{b}	8.67±1.0^{g}
Tomato	10.83±0.4^{a}	26.57±1.1^{a}	5.36±0.7^{d}
Red onion	28.12±1.3^{c}	42.25±1.0^{f}	3.38±0.6^{b}
Red cauliflower	22.12±0.5^{b}	44.23±2.2^{g}	6.69±0.5^{e}
Carrot	54.50±0.2^{h}	39.76±1.3^{e}	5.78±0.9^{d}
Beetroot	48.40±0.8^{g}	57.64±1.2^{h}	10.19±1.7^{h}

*The values are expressed in mean ± standard deviation. The superscript alphabets in the column shows the significant difference (P < 0.05).

Table 2. Total antioxidant and radical scavenging capacities of selected fruits and vegetables

Plant extract	Total antioxidant capacity (mg/100 g FW)*	DPPH scavenging capacity (mg/100 g FW)*	FRAP capacity (mg/100 g FW)*	Superoxide radical scavenging capacity (mg/100 g FW)*	Hydroxyl radical scavenging capacity (mg/100 g FW)*
Mulberries	45.78± 1.70^{d}	45.27±0.10^{f}	32.11±0.50^{c}	48.90±0.90^{h}	41.22±1.30^{e}
Papaya	40.05±2.50^{c}	38.24±0.90^{d}	39.72±1.00^{e}	33.71±1.20^{c}	36.50±0.50^{c}
Red grapes	48.13±1.20^{e}	44.82±0.90^{f}	32.04±0.70^{c}	42.10±1.10^{f}	45.65±1.40^{f}
Mango	31.21±1.70^{a}	28.99±1.20^{b}	33.42±0.80^{d}	30.78±1.00^{b}	28.17±1.00^{b}
Guava	41.11±1.50^{c}	39.97±0.90^{d}	31.32±0.20^{c}	40.76±2.10^{e}	38.12±0.80^{d}
Tomato	34.57±3.00^{b}	18.67±0.70^{a}	19.88±0.30^{a}	18.80±1.00^{a}	21.88±1.10^{a}
Red onion	48.78±2.40^{f}	38.12±0.10^{d}	29.23±0.50^{b}	44.14±1.50^{g}	40.47±1.50^{e}
Red cauliflower	41.29±1.80^{c}	40.53±0.50^{d}	43.81±0.60^{f}	39.37±1.00^{e}	38.87±1.80^{d}
Carrot	47.65±1.20^{e}	34.44±0.10^{c}	33.29±0.90^{d}	37.77±0.90^{d}	35.41±1.20^{c}
Beetroot	61.11±2.10^{g}	43.12±0.80^{e}	45.79±1.00^{g}	58.32±2.30^{i}	52.33±1.50^{g}

*The values are expressed in mean ± standard deviation. The superscript alphabets in the column shows the significant difference (P < 0.05).

variation in phenolics of selected fruits and vegetables could be influenced by different intrinsic and extrinsic factors such as natural characteristics, maturity and postharvest conditions (Jeffery *et al.*, 2003; Marnova *et al.*, 2005; Lim *et al.*, 2007).

Total Flavonoids (TF)

TF of selected fruits and vegetables are represented in Table 1. TF levels were ranged from 2.49 to 12.69 mg/100 g FW. This study showed that the TF values were rich in red grapes, beetroot, guava and mulberries with 12.69, 10.19, 8.67 and 7.57 mg, respectively (P < 0.05). Other fruits and vegetables in this study were having the lower levels of TF. The pigmented fruits and vegetables are having a key role in the overall expression of phenolics that includes flavonoids, anthocyanins and/or carotenoids (Chun *et al.*, 2003; Cieślik *et al.*, 2006; Lin and Tang, 2008). Although, the amount of polyphenols in fruits and vegetables may be influenced by various factors such as geographic origin, growing seasons, agricultural practices and analytical methods (Chun *et al.*, 2003).

Total antioxidant capacity (TAC)

TAC of the selected fruits and vegetables were ranged from 31.21 to 61.11 mg/100 g FW (Table 1). Beetroot, red onion, red grapes and carrot showed the higher levels of TAC with 61.11, 48.78, 48.13 and 47.65 mg/100 g FW, respectively. TAC of fruits and vegetables in this study was varied significantly among each other. The natural antioxidants are most multifunctional, and it might be contributed by the polyphenols (Ślusarczyk *et al.*, 2009; Fu *et al.*, 2011).

Free radical scavenging capacity

DPPH scavenging capacity test is used as a significant tool to identify the primary antioxidants which can donate the hydrogen to scavenge free radicals (Ajila *et al.*, 2007; Wang *et al.*, 2008; Nurliyana *et al.*, 2010). The selected fruits and vegetables were having the significant levels of DPPH scavenging activity and were ranged from 18.67 to 45.27 mg/100 g FW (Table 2). Mulberries, red grapes, beetroot, red cauliflower and guava showed the higher levels of DPPH scavenging capacity with 45.27, 44.82, 43.12, 40.53 and 39.97 mg/100 g FW, respectively. Papaya and red onion were showed the similar DPPH scavenging capacity with 38.24 and 38.12 mg/100 g FW, respectively.

The FRAP activity of selected fruits and vegetables were ranged from 19.88 to 45.79 mg/100 g FW (Table 2). Beetroot, red cauliflower, papaya and mango were having the higher FRAP activity with 45.79, 43.81, 39.72 and 33.42 mg/100 g FW, respectively (P < 0.05). The reduction of ferric ions by electron donating capacity is often used as an important indicator for phenolic antioxidant mechanism in various plant extracts (Benzie and Strain, 1996; Hinneburg *et al.*, 2006; Fu *et al.*, 2011). Uma *et al.* (2012) reported the higher flavonoids and anthocyanins were responsible for the increased DPPH and FRAP activity in many fruits and vegetables.

Superoxide radical is a precursor for more reactive oxygen species, and it is contributing the cellular and tissue damage and various diseases (Halliwell and Gutteridge, 1999). Superoxide radical scavenging activity in the selected fruits and vegetables were ranged from 18.80 to 58.32 mg/100 g FW (Table 2). Among the fruits and vegetables: beetroot, red onion, red grapes and mulberries were having the higher superoxide radical scavenging activity with 58.32, 48.90, 44.14 and 42.10 mg/100 g FW, respectively (P < 0.05). Lu *et al.* (2011) and Uma *et al.* (2012) reported, the pigmented flavonoids and related polyphenols are mainly contributed to antioxidant activities of various fruits and vegetables.

Hydroxyl radical is highly reactive and persuades the severe damage to adjacent biomolecules as compared to other reactive oxygen species (ROS) (Kubola and Siriamornpun, 2008). Hydroxyl radical scavenging activity of the selected fruits and vegetables were ranged from 21.88 to 52.33 mg/100 g FW (Table 2). Beetroot, red grapes, mulberries and red onion were having the higher levels of activity with 52.33, 45.65, 41.22 and 40.47 mg/100 g FW, respectively (P < 0.05). Red cauliflower and guava showed the similar radical scavenging activity with 38.87 and 38.12 mg/100 g FW, respectively. However, the antioxidant activity of selected fruits and vegetables in this study (Table 2) were not related with their phenolic and flavonoid contents (Table 1). This was in agreement with previously published results (Dasgupta and De, 2007).

Conclusion

The selected fruits and vegetables in this study are highly beneficial to human nutrition and health. It was revealed by their antioxidant activity and different scavenging capacity test. The pigmented fruits and vegetables such as mulberries, red grapes, beetroot and red onion were holding the higher levels of antioxidant activity as compared to other fruits and vegetables in this study. The overall information of this present data will be very useful to nutritionists, dieticians, farmers and consumers.

References

Ajila, C. M., Naidu, K. A., Bhat, S. G. and Rao, U. J. S. P. 2007. Bioactive compounds and antioxidant potential of mango peel extract. Food Chemistry 105 (3): 982-988.

Awah, F. M., Uzoegwu, P. N., Ifeonu, P., Oyugi, J. O., Rutherford, J., Yao, X., Fehrmann, F., Fowke, K. R. and Eze, M. O. 2012. Free radical scavenging activity, phenolic contents and cytotoxicity of selected Nigerian medicinal plants. Food Chemistry 131 (4): 1279-1286.

Benzie, I. F. and Strain, J. J. 1996. The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power": the FRAP assay. Analytical Biochemistry 239 (1): 70-76.

Binsan, W., Benjakul, S., Visessanguan, W., Roytrakul, S., Tanaka, M. and Kishimura, H. 2008. Antioxidative activity of Mungoong, an extract paste, from the cephalothorax of white shrimp (*Litopenaeus vannamei*). Food Chemistry 106 (1): 185-193.

Chun, O. K., Kim, D. O., Moon, H. Y., Kang, H. G. and Lee, C. Y. 2003. Contribution of individual polyphenolics to total antioxidant capacity of plums. Journal of Agricultural and Food Chemistry 51 (25): 7240-7245.

Cieślik, E., Gręda, A. and Adamus, W. 2006. Contents of polyphenols in fruit and vegetables. Food Chemistry 94(1):135-142.

Dasgupta, N. and De, B. 2007. Antioxidant activity of some leafy vegetables of India: A comparative study. Food Chemistry 101 (2): 471-474.

Du Toit, R., Volsteedt, Y. and Apostolides, Z. 2001. Comparison of the antioxidant content of fruits, vegetables and teas measured as vitamin C equivalents. Toxicology 166 (1-2): 63-69.

Fu, L., Xu, B. T., Xu, X. R., Gan, R. Y., Zhang, Y., Xia, E. Q. and Li, H. B. 2011. Antioxidant capacities and total phenolic contents of 62 fruits. Food Chemistry 129 (2): 345-350.

Gülçin, I., Berashvili, D. and Gepdiremen, A. 2005. Antiradical and antioxidant activity of total anthocyanins from *Perilla pankinensis* decne. Journal of Ethnopharmacology 101 (1-3): 287-293.

Harris, R. S. 1975. Effects of agricultural practises on the composition of food. In Harris, R. S., Karmas, E. (Eds.). Nutritional Evaluation of Food Processing, p. 33-57. AVI, Westport: CT.

Halliwell, B. and Gutteridge, J. M. C. 1999. Free radicals in biology and medicine. Oxford: Oxford University Press.

Hinneburg, I., Damien Dorman, H. J. and Hiltunen, R. 2006. Antioxidant activities of extracts from selected culinary herbs and spices. Food Chemistry 97 (1): 122-129.

Isabelle, M., Lee, B. L., Lim, M. T., Koh, W. P., Huang, D. and Ong, C. N. 2010. Antioxidant activity and profiles of common vegetables in Singapore. Food Chemistry 120 (4): 993-1003.

Jacob, R. A. and Burri, B. J. 1996. Oxidative damage and defense. The American Journal of Clinical Nutrition 63 (6): 985-990.

Jeffery, E. H., Brown, A. F., Kurilich, A. C., Keck, A. S., Matusheski, N., Klein, B. P. and Juvik, J. A. 2003. Variation in content of bioactive components in broccoli. Journal of Food Composition and Analysis 16 (3): 323-330.

Kim, M. B., Park, J. S. and Lim, S. B. 2010. Antioxidant activity and cell toxicity of pressurised liquid extracts from 20 selected plant species in Jeju, Korea. Food Chemistry 122 (3): 546-552.

Kubola. J. and Siriamornpun. S. 2008. Phenolic contents and antioxidant activities of bitter gourd (*Momordica charantia* L.) leaf, stem and fruit fraction extracts in vitro. Food Chemistry 110 (4): 881-890.

Lee, K. S. and Kader, A. A. 2000. Preharvest and postharvest factors influencing vitamin C content of horticultural crops. Postharvest Biology and Technology 20: 207-220.

Li, H., Deng, Z., Zhu, H., Hu, C., Liu, R., Young, J. C. and Tsao, R. 2012. Highly pigmented vegetables: Anthocyanin compositions and their role in antioxidant activities. Food Research International 46 (1): 250-259.

Lim, Y. Y., Lim, T. T. and Tee, J. J. 2007. Antioxidant properties of several tropical fruits: A comparative study. Food Chemistry 103 (3): 1003-1008.

Lin, J. Y. and Tang, C. Y. 2008. Strawberry, loquat, mulberry, and bitter melon juices exhibit prophylactic effects on LPS-induced inflammation using murine peritoneal macrophages. Food Chemistry 107 (4): 1587-1596.

Lu, X., Wang, J., Al-Qadiri, H. M., Ross, C. F., Powers, J. R., Tang, J. and Rasco, B. A. 2011. Determination of total phenolic content and antioxidant capacity of onion (*Allium cepa*) and shallot (*Allium oschaninii*) using infrared spectroscopy. Food Chemistry 129 (2):

637-644.
Marnova, D., Ribarova, F. and Atanassova, M. 2005. Total phenolics and total flavonoids in bulgarian fruits and vegetables. Journal of the University of Chemical Technology and Metallurgy 40: 255-260.
Nielsen, S. S. (2010). Vitamin C determination by indophenol method. In S. S.
Nielsen (Ed.). Food analysis laboratory manual. p. 55-60. USA: Springer.
Nurliyana, R., Syed Zahir, I., Mustapha Suleiman, K., Aisyah, M. R. and Kamarul Rahim, K. 2010. Antioxidant study of pulps and peels of dragon fruits: a comparative study. International Food Research Journal 17: 367-375.
Prieto, P., Pineda, M. and Aguilar, M. 1999. Spectrophotometric quantitation of antioxidant capacity through the formation of a phosphomolybdenum complex: specific application to the determination of vitamin E1. Analytical Biochemistry 269: 337-341.
Ratnam, D. V., Ankola, D. D., Bhardwaj, V., Sahana, D. K. and Kumar, M. N. V. R. 2006. Role of antioxidants in prophylaxis and therapy: A pharmaceutical perspective. Journal of Controlled Release 113 (3): 189-207.
Ślusarczyk, S., Hajnos, M., Skalicka-Woźniak, K. and Matkowski, A. 2009. Antioxidant activity of polyphenols from *Lycopus lucidus* Turcz. Food Chemistry 113 (1): 134-138.
Sreeramulu, D. and Raghunath, M. 2010. Antioxidant activity and phenolic content of roots, tubers and vegetables commonly consumed in India. Food Research International 43 (4): 1017-1020.
Stangeland, T., Remberg, S. F. and Lye, K. A. 2009. Total antioxidant activity in 35 Ugandan fruits and vegetables. Food Chemistry 113 (1): 85-91.
Uma, M. S., Jemima, B. M. and Uthira, L. 2012. Compartive study on antioxidant activity of organic and conventionally grown roots and tubers vegetables of India. Electronic Journal of Environmental, Agricultural and Food Chemistry 11(2): 136-146.
Velioglu, Y. S., Mazza, G., Gao, L. and Oomah, B. D. 1998. Antioxidant activity and total phenolics in selected fruits, vegetables, and grain products. Journal of Agriculture and Food Chemistry 46 (10): 4113-4117.
Vinson, J. A., Hao, Y., Su, X. and Zubik, L. 1998. Phenol Antioxidant Quantity and Quality in Foods: Vegetables. Journal of Agricultural and Food Chemistry 46 (9): 3630-3634.
Wang, H., Gao, X. D, Zhou, G. C., Cai, L. and Yao, W. B. 2008. *In vitro* and *in vivo* antioxidant activity of aqueous extract from *Choerospondias axillaris* fruit. Food Chemistry 106 (3): 888-895.
Wootton-Beard, P. C. and Ryan, L. 2011. Improving public health?: The role of antioxidant-rich fruit and vegetable beverages. Food Research International 44 (10): 3135-3148.
Zhishen, J., Mengcheng, T. and Jianming, W. 1999. The determination of flavonoid contents in mulberries and their scavenging effects on superoxide radicals. Food Chemistry 64 (4): 555-559.