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NUTRITIONAL AND MULTI-ELEMENTAL PROFILE OF INDIGENOUS AND UNDERUTILIZED *SOLANUM* SPECIES OF SIKKIM, INDIA

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Abstract

In the present study, three *Solanum* species (*Solanum torvum, S. aethiopicum* and *S. macrocarpon*) were evaluated using recommended methods for nutritional and multi-elemental composition. The nutritional and multi-elemental profile varied significantly among all three species. When compared with the nutritive value of close commercial relatives *i.e.,* cultivated brinjal (*Solanum melongena* L.), these crops were found better in many aspects. The result highlights the nutritional importance of lesser known though very important vegetables and also points towards the need to promote increased consumption and conserve genetic resources.

Introduction

Plant breeding and crop improvement have sustained the production and strengthened nutritional and food security (Nyadanu and Lowor 2015). The genus *Solanum* is represented by 1500 species and well represented all over the world. *Solanum torvum, S. aethiopicum* and *S. macrocarpon* are underutilized cultivated vegetables related to the common eggplant (*S. melongena* L.). Majority of the *Solanum* species are widely used in folk medicine. These crops bear edible fruits and cooked as vegetables in Northeastern part of India and also used as a constituent of traditional medicine. These crops are having great potential as the alternative crops for organic farming system in the hills of Northeastern states of India, though they are neglected yet highly remunerative in the local market.

Solanum torvum Sw., is commonly known as Turkey berry. The fruits and leaves are widely used in Cameroonian folk medicine and used for curing cough, bronchial asthma, liver and spleen enlargement and pneumonia (Jaiswal 2012). They are utilized as a vegetable and regarded as an essential ingredient in the South Indian population's diet (Jaiswal 2012). *Solanum aethiopicum* L. is commonly known as the African eggplant or Ethiopian eggplant having round shaped fruit with green strips which are eaten as raw or cooked as vegetable. Its leaves are also eaten as a vegetable. *Solanum macrocarpon* is a small tropical perennial plant that originated from Africa (Rubatzky and Yamaguchi 1997). It is cultivated either for fruits or for leaves which are used in the same way as spinach. The fruits are 3 - 10 cm in diameter, flat in shape, non-ribbed, with smooth surface and white or green coloured at the commercially mature stage (Nyadanu and Lowor 2015).

Sikkim is a Himalayan state of North East India, where these crops are found adapted up to an elevation of 5000 feet from MSL and found almost in every household as integrated backyard farm. Whole state is certified as organic state after satisfying all the norms and guideline laid down by the regulatory bodies. Though the crops are the part of every household but its nutritional and elemental composition understanding is not yet established. Mineral nutrition is a significant aspect of human life and it plays a pivotal role for healthy growth. *Solanum torvum, S. aethiopicum* and *S. macrocarpon* are the popular vegetables of North Eastern India. It is imperative to study such crops in terms of nutrition and elemental profile so as to include them in

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a vegetable basket. The attempt of analysing the nutritional and elementary profile will boost the importance of such neglected vegetables. So, present investigation was aimed at investigating nutritional and multi-elemental content of three species of *Solanum*.

Materials and Methods

Total 68 samples of edible part of three species of *Solanum*, namely *Solanum torvum*, *S. aethiopicum* and *S. macrocarpon* were collected from all the four districts of Sikkim from July, 2015 to December, 2015. Five villages and local markets were inspected from each district for the collection of samples. At least 2 kg sample of each species were collected from each sampling site. The samples were placed in a polyethene bag immediately to prevent loss of moisture and transported to the laboratory of the Department of Horticulture, Sikkim University within 24 hrs. The samples were washed 2 - 3 times with running tap water followed by sterile double distilled water at last and wiped to dry all the water around it, as recommended by Badau *et al.* (2013) and Pillai and Nair (2013). For multi-elemental profiling, half of the total samples of each species were dried in the oven at 25°C. Samples were grinded into powder after peeling the fruit except *Solanum torvum* because of its small size and thin skin. These grounded samples were used for analysis as representative samples and stored at room temperature under a dry condition in an airtight plastic container (Nair *et al.* 2013, Senga *et al.* 2013). The remaining half of the samples were stored at –20°C for further analysis. All the analysis was carried out in completely randomized design with three replication and data were presented as mean ± SE.

Total carbohydrates, total ash, crude fibre, crude fat, protein and moisture content were determined using standard methods of the Association of Official Analytical Chemists (AOAC 2005). Moisture content was determined by moisture analyser. TSS of the samples was determined by placing the juice of the representative sample placed on the lid of prism plate of Refractometer. Reading of the sample was taken as $^{\circ}$Brix and TSS was expressed at 25°C. About 2 g of the sample was measured into a previously weighed crucible for determination of total ash content. The crucible together with the sample was put in a furnace (600°C) for 2 hrs. The crucible was then removed and cooled. The total ash was expressed as a percentage of the initial weight. For crude fat determination about 2 g of the sample was transferred into a cellulose thimble. One hundred fifty ml of methanol was poured into previously dried and weighed beaker. The sample was then placed into the Soxhlet extractor. The sample was then refluxed for 4 hrs. After the extraction, the thimble was removed and the solvent recovered. The fat that was obtained was then dried together with the beaker in an oven for 30 min at 105°C. It was then cooled in a desiccator and weighed. Protein content was determined by Lowry's method by Perkin Elmer, Lamb 35 UV/VIS spectrophoto-meter. A standard curve of absorbance at 660 nm versus BSA concentration was drawn for estimation of protein in the sample and expressed in terms of percentage. For determination of fibre content, 2 g of sample was transferred into a 750 ml Erlenmeyer flask and 0.5 g of asbestos was added. Two hundred fifty ml of boiling 1.25% H_2SO_4 was added immediately and the flask was set on a hot plate and the condenser was connected. After 30 min the flask was removed and its contents were immediately filtered through a clean linen cloth. The sample was then washed repeatedly with a large volume of water until the washings were no longer acidic. 200 ml of 1.25% of boiling NaOH was added to the filtrate. It was also boiled for 30 min and washed several times until it was no longer basic. The residue was then transferred into a weighed crucible. The crucible and its content were dried and ashed for 30 min. The crucible was then cooled and weighed. The percentage crude fibre was expressed as weight loss in percentage. Total carbohydrate was determined by using anthrone reagent. One hundred mg of the representative sample was hydrolyzed for 3 hrs with 5 ml of 2.5 N HCl and cooled down to normal temperature. The acid was neutralized using sodium carbonate and volume made up to 100

ml. A suitable aliquot of the sample was taken and 4 ml of anthrone reagent was added. Heated for 8 min in a water bath and cooled rapidly. Total carbohydrate content was determined by taking absorbance at 630 nm (Perkin Elmer, Lamb 35 UV/VIS spectrophotometer) and calculated in percentage according to standard absorbance. The total starch content was determined using anthrone reagent. Five hundred mg of the representative sample was homogenized in hot 80% ethanol to remove sugars until it does not give colour with anthrone reagent. The residue was mixed with 5 ml water and 6.5 ml perchloric acid and centrifuged. A suitable volume of supernatant was taken and 4 ml of anthrone reagent was added. The mixture was heated for 8 min in a water bath and absorbance was recorded at 630 nm (Perkin Elmer, Lamb 35 UV/VIS spectrophotometer) after cooling down. The total starch content was calculated according to a standard curve in percentage. Ascorbic acid content was determined by 2,6-dichlorophenolindophenol visual titration method. 2.5 g of the representative sample was mixed with 3% HPO_3 and made up to 100 ml with HPO_3 and centrifuged to obtain a clear solution. A suitable volume of an aliquot of a HPO_3 extract of the sample was titrated with standard dye to a pink end point and ascorbic acid content was expressed in percentage.

For multi elemental profiling dried samples were subjected to microwave digestion with multi-wave digestion system (Anton Par Multi-wave 3000, India) as per following conditions *viz.*, power- 1200 W; IR -190°C; rate- 0.3 bar/sec; ramp- 5 min; hold – 7 min; sample size- 0.1 g; acids used- HNO_3 - 5 ml and HCl- 1 ml). Digested samples were then cooled and the volume was made up to 50 ml with DDW. Analysis of the samples was carried out with Inductively Coupled Plasma Mass Spectrometry (ICP-MS) (Perkin Elmer, Nex ION 300 X, USA) system with cross flow nebulizer. The instrument was calibrated using standard reference material (Peach leaves- NIST 1547). The digested samples were analysed for the ionic constitution using multi elements standards solution.

All experiments were carried out in completely randomized design in triplicate and data were expressed as the mean values ± SE. The data were statistically analysed using JMP Pro 11.One-way analysis of variance (ANOVA) was used to evaluate the experimental data. The residual plots were inspected to confirm data confirmed to normality. The significance of mean differences among the indigenous vegetables and *Solanum melongena* was evaluated at $p < 0.05$.

Results and Discussion

Table 1 shows the proximate composition of *Solanum torvum, S. aethiopicum* L. and *S. macrocarpon* L. fruits in comparison to *Solanum melongena* (USDA 2016). There were significant variations ($p < 0.005$) among all the species in the composition. *S. torvum* contained more TSS followed by *S. aethiopicum* L. and *S. macrocarpon* L. Crude fat, crude protein, crude fibre, carbohydrate and total starch were found higher in *S. aethiopicum* than *S. torvum* and *S. macrocarpon* L. fruits and also in *S. melongena* except for crude fibre. Moisture and ascorbic acid content were found to be higher in *S. macrocarpon* L. than *S. torvum* and *S. aethiopicum* L. but lesser than *S. melongena* in the case of moisture content. The relatively higher nutritional and multi-elemental composition of all the three species than its commercial counterpart *S. melongena* highlighted the nutritional potential of these crops and their importance in alleviating nutritional security among local people (Chinedu *et al.* 2011). Indigenous vegetables could contribute to improve food security as well as reduce hidden hunger, which is caused by micronutrient deficiency as a result of over-dependence on a few staple crops. The moisture content of fruits is related to its dry matter content and this can be used as an index of stability and susceptibility to fungal infection. It determines quality and freshness of fruits. The moisture content of all the three species falls in lines with the reports of many researchers. The moisture content of *S. aethiopicum*

and *S. macrocarpon* is in line with Showemimo and Olarewaju (2004) and of *S. torvum* L. is with Akoto *et al.* (2015). Gboma fruits (*S. macrocarpon*) were also reported to contain 89.0% moisture (Leung *et al.* 1968) while another worker reported 90.6% moisture for *S. aethiopicum* (Grubben and Denton 2004). Ash content is an important fruit quality because it determines the mineral composition of the fruit (Leung *et al.* 2009). Ash content was higher in *S. macrocarpon* than other two species which was reflected by their mineral content as it was also higher in same species. The ash content of *S. aethiopicum* L. and *S. macrocarpon* L. was lower than reports of ash content of 4.06 and 5.58% of total solids, respectively for round green (*S. aethiopicum*) and sweet white (*S. macrocarpon*) varieties (Showemimo and Olarewaju 2004) but slightly higher than the reported value of 0.14% in *S. torvum* reported by Akoto *et al.* (2015). The fat content of all the three species was higher than the 1.0% reported for gboma (Leung *et al.* 1968). The protein content of *S. aethiopicum* and *S. macrocarpon* was higher than the previous report *viz.*, 1.5% for *S. aethiopicum* and 1.0% for *S. macrocarpon* reported by different workers (Gbile and Adesina 1988, Grubben and Denton 2004, Leung *et al.* 1968) but lower in *S. torvum* than previous report of Akoto *et al.* (2015). *S. aethiopicum* which was significantly higher in protein content could be used to complement *Amaranthus* species and *S. torvum* which were significantly higher in iron, magnesium, phosphorus and calcium. The crude fibre content of *S. torvum* was lower than the value of 3.99% reported by Akoto *et al.* (2015); for *S. aethiopicum* L. and *S. macrocarpon* L. was higher than 2.0% and 1.5% reported for *S. aethiopicum* and *S. macrocarpon* by Grubben and Denton (2004) and Leung *et al.* (1968). Carbohydrate content of *S. aethiopicum* L.and *S. macrocarpon* L. was higher compared to 4.0% carbohydrate content reported for *S. aethiopicum* (Norman 1992) and lower for *S. torvum* reported by Akoto *et al.* (2015). Ascorbic acid was higher in *S. macrocarpon* and other two species and generally, it is higher in all the fruits which were evident from the present findings.

Table 1. Proximate analysis of the three *Solanum* species.

Proximate composition	*Solanum torvum*	*Solanum aethiopicum*	*Solanum macrocarpon*	*Solanum melongena*
Moisture (%)	84.67 ± 0.01	88.27 ± 0.03	91.53 ± 0.09	92.30
TSS (^{0}Brix)	7.20 ± 0.06	3.53 ± 0.07	3.27 ± 0.07	NA
Ash content (%)	0.17 ± 0.05	0.86 ± 0.04	1.37 ± 0.08	0.66
Crude fat (%)	1.39 ± 0.09	2.91 ± 0.11	2.23 ± 0.07	0.18
Crude protein (%)	1.56 ± 0.02	2.10 ± 0.07	1.44 ± 0.03	0.98
Crude fibre (%)	1.98 ± 0.11	3.35 ± 0.09	2.66 ± 0.12	3.0
Carbohydrate (%)	6.12 ± 0.09	7.11 ± 0.03	6.59 ± 0.16	5.88
Total starch (%)	0.37 ± 0.03	0.84 ± 0.02	0.64 ± 0.01	NA
Ascorbic acid (%)	0.26 ± 0.03	0.46 ± 0.02	0.78 ± 0.01	0.002

Source of data of *Solanum melongena*: USDA National Nutrient Database.

Data of multi-elemental profiling is presented in Table 2 for *S. torvum*, *S. aethiopicum* L. and *S. macrocarpon* L. fruits along with fruits of *S. melongena* (USDA, 2016). In *S. torvum* higher amount of K, Mg, Ca, P and Mn was observed. Similarly, a higher amount of K, Mg, Ca and P in *S. aethiopicum* and *S. macrocarpon* was recorded. All the three species under studies were having a higher amount of essential elements compared to *S. melongena*. Most of the non-essential elements were found to be higher in case of *S. macrocarpon* followed by *S. aethiopicum*. Though,

a higher amount of Al was recorded in *S. torvum.* All the species were found to be a good and rich source of all the macro elements and also of microelements which signify that these species could be the potential sources of the minerals where malnutrition, hunger, and availability of common

Table 2. Multi-elemental profile of all the three species of *Solanum* (mg/100 g of dry weight).

	Solanum torvum	*Solanum aethiopicum*	*Solanum macrocarpon*	*Solanum melongena*
Essential elements				
K	529.63	630.99	467.53	229
Ca	76.43	59.42	65.72	9.0
Mg	108.71	92.89	55.00	14
P	70.01	38.56	31.49	24
Fe	5.41	4.37	5.24	0.23
Mn	6.89	3.27	8.30	0.232
Zn	2.72	2.87	6.67	0.16
Cu	2.55	6.38	7.07	0.081
Mo	0.09	0.23	0.14	NA
Non-essential elements				
Na	1.29	2.43	2.26	2
Co	0.02	0.06	0.06	NA
Ni	1.04	5.20	4.44	NA
Ba	0.50	1.88	2.84	NA
Ag	0.004	0.011	0.016	NA
Al	2.68	1.60	2.40	NA
Be	0.0002	0.0025	0.0084	NA
Bi	0.0006	0.0077	0.01666	NA
Cd	0.007	0.010	0.005	NA
Cs	0.006	0.018	0.027	NA
Ga	0.076	0.241	0.351	NA
Li	0.108	0.237	0.373	NA
Sr	0.424	1.028	2.136	NA
U	0.0009	0.0036	0.0063	NA
Hg	0.0017	0.0351	0.0173	NA
Ce	0.0149	0.0203	0.0304	NA

Source of data of *Solanum melongena*: USDA National Nutrient Database.

food is the major constraints. Teeth and bones only comprises of about 99% of total calcium present in the human body (Beto 2015). Its deficiency causes osteoporosis in adults and rickets in children. In addition to the amount of calcium present in the diet, its absorption also determines the availability of calcium for maintenance of the skeletal system. Foods enriched with calcium could be the possible way in preventing calcium related skeletal and osteoporosis-related problems. The Dietary reference intakes (DRIs) recommends intake of 1000 mg/d of Ca with the tolerable intake level of 2500 mg/d (Sunderman 1988). High Ca content was found in all the three species, ranging from 59.42 to 76.43 mg/100 g dry weight. About 60% of the world population suffer from Fe deficiency (below 8 mg/day) that leads to anaemia, and on another side, its excess intake (above 45 mg/day) may cause cardiac and nephricmal functions. In all the species studied

having an average amount of iron makes them fit for consumption to the people of Sikkim. Manganese is also required as metalloproteins in enzymes such as pyruvate carboxylase in humans and deficiency of the metal (below 2.3 mg/d) results in severe skeletal and reproductive abnormalities in humans (Maiga *et al.* 2005). Manganese was found in good amount in all three species ranging from 3.27 to 8.30 mg/100 g dry weight. In humans, among all the studied element of human diet zinc (Zn) is the least toxic and an essential element because of its involvement in structural, catalytic and regulatory processes of the body inimmunity, brain activity and foetal growth and development. All the three species studied were found to have a higher content of zinc. According to Maiga *et al.* (2005) copper is necessary as a cofactor in many of the important enzymes *viz.*, cytochrome P450 oxidase and superoxide dismutase in humans. Cu is one of the mineral elements along with Fe, Zn, Ca and Mg that is lacking in the human diet (White and Broadley 2009). Copper was present in all the species in a good amount ranging from 2.55 to 7.07 mg/100g dry weight. Anaemia and severe fatigue may be the result of a deficiency of Co (below 0.05 mg/day) in human diet whereas its excess intake (1 mg/day) may cause angina and asthma. In all three species Co was in the range of 0.02 - 0.06 mg/100g of dry weight. Nickel is also required in humans for strong immune system and regulation of lipids and phospholipids synthesis. Its deficiency leads to depression, reproductive failure, hyperglycaemia and growth problems in humans, whereas its excess consumption leads to asthma, nausea and hypoglycaemia. It was present in all the three species in good amount.

The high moisture content, moderate ash and protein content of these *Solanum* species were typical of fleshy vegetable and desirable to remain fresh for a longer period to meet market demand. High crude fibre, low fat and low dry matter of these species may be helpful in preventing different diseases as constipation, carcinoma of the colon and rectum, diverticulitis and atherosclerosis. This may also partly account for the weight reduction effect of African eggplants (Edijala *et al.* 2005, Odetola *et al.* 2004). Further research work is needed for the presence and quantification of secondary metabolites to promote the use of these species in day to day dietary habit and to explore them as nutraceuticals.

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