NUTRITIONAL AND ANTINUTRITIONAL EVALUATION OF WILD YAM (*Dioscorea* spp.)

[EVALUACIÓN DEL VALOR NUTRICIONAL Y FACTORES ANTINUTRICIONALES DE *Dioscorea* spp. SILVESTRE]

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SUMMARY

The wild yam tubers consumed by the tribes Kanikkars / Palliyars of South- Eastern slopes of Western Ghats, Tamil Nadu (*Dioscorea alata, D. bulbifera* var *vera, D. esculenta, D. oppositifolia* var *dukhumensis, D.oppositifolia* var. *oppositifolia, D. pentaphylla* var. *pentaphylla, D. spicata, D. tomentosa* and *D. wallichi*) were evaluated for its nutritional quality. From the present investigation, it is observed that most of the wild edible yams were found to be a good source of protein, lipid, crude fibre, starch, vitamins and minerals. Antinutritional substances like total free phenolics, tannins, hydrogen cyanide, total oxalate, amylase and trypsin inhibitor activities were quantified.

Key words: Proximate and mineral composition; vitamins; in vitro digestibility; antinutrients.

RESUMEN

Los tubérculos de variedades silvestres de Dioscorea spp. Son consumidos por las tribus Kanikkars / Palliyars de la región sur y oriental de los Ghats Occidentales de Tamil Nadu. *Dioscorea alata, D. bulbifera* var *vera, D. esculenta, D. oppositifolia* var *dukhumensis, D.oppositifolia* var. *oppositifolia, D. pentaphylla* var. *pentaphylla, D. spicata, D. tomentosa* y *D. wallichi* fueron evaluados en cuanto a su calidad nutricional. Se encontró que fueron una buena fuente de protein, lípidos, fibra cruda, almidón, vitaminas y minerales. Adicionalmente se cuantificó el contenido de fenoles totales libres, taninos, cianuro de hidrógeno y oxalatos totales. Se cuantificó también la actividad de los inhibidores de amilasa y tripsina.

Palabras claves: composición próximal; contenido de minerales; vitaminas; digestibilidad in vitro.

INTRODUCTION

With ever-increasing population pressure and fast depletion of natural resources, it has become extremely important to diversify the present-day agricultural in order to meet various human needs (Janardhanan *et al*., 2003). The world food crisis has been and will continue to be a major obstacle to humanity. The observed interest in search for alternative / additional food and feed ingredients is of paramount importance mainly for two reasons, one is the low production of oil seeds and grains and another is the stiff competition between man and the livestock industry for existing food and feed materials (Siddhuraju *et al*., 2000). Root and tubers are the most important food crops since time immemorial in the tropics and subtropics (Behera *et al*., 2009). Roots and tubers refers to any growing plant that stores edible material in subterranean root, corm and tuber. The nutritional value of roots and tubers lies in their potential ability to provide one of the cheapest sources of dietary energy in the form of carbohydrates in developing countries (Ugwu, 2009).

Yams (*Dioscorea*) belong to Dioscoreaceae family. They are herbaceous plants with twine. Approximately 600 *Dioscorea* species are eaten in various parts of the world. (Agbor-Egbe and Treche, 1995). Yams, the edible starchy tubers, are of cultural economic and nutritional importance in the tropical and subtropical regions of the world (Coursey, 1967). Yam has been suggested to have nutritional superiority when compared with other tropical root crops. They are reported as good sources of essential dietary nutrients (Baquar and Oke, 1976; Bhandari *et al*., 2003; Shanthakumari *et al.*, 2008; Maneenoon *et al*., 2008; Arinathan *et al.,* 2009). Earlier reports have also pointed out that a few yam species contain some toxic compounds and can impact serious health complications (Anthony, 2004). Some species of wild yams, particularly wild forms, are toxic and / or unpalatable, taste bitter and cause vomiting and diarrhoea when large amount are ingested without proper processing or if eaten raw (Webster *et al*., 1984).

These wild yams make a significant contribution in the diets of the tribal people of India. The tubers were found with a high amount protein, a good proportion of essential amino acids and appeared as a fairly good source of many dietary minerals. However, their wider utilization is limited due to the presence of some toxic and antinutritional factors. In India the cooked wild tubers are known to be consumed by the Palliyar and Kanikkar tribes (Arinathan *et al*., 2007; Shanthakumari *et al*., 2008) living in South-Eastern slopes of Western Ghats, Tamil Nadu. Information regarding the chemical and nutritional content of wild edible tuber is meager (Babu *et al*., 1990; Nair and Nair, 1992; Rajyalakshmi and Geervani, 1994; Shanthakumari *et al.*, 2008; Alozie *et al*., 2009; Arinathan *et al*., 2009). Studies of nutritional value of wild plant food are of considerable significance since it may help to identify long forgotten food resources. In this context, an attempt was made to understand the chemical composition and antinutritional factors of the under utilized tubers of nine species of *Dioscorea* to suggest ways and means to remove the antinutritional / toxins and make the edible tubers as the safe food sources for mass consumption.

MATERIALS AND METHODS

Nine samples of wild yam tubers (*Dioscorea alata, D. bulbifera* var *vera, D. esculenta, D. oppositifolia* var *dukhumensis, D.oppositifolia* var. *oppositifolia, D. pentaphylla* var. *pentaphylla, D. spicata, D. tomentosa and D. wallichi*) grown in sandy loam soil consumed by the tribal Kanikkars / Palliyars were collected using multistage sampling technique in three consecutive rainy seasons during August and January 2009 from the South Eastern Slopes of Western Ghats, Virudhunagar district, Madurai district and Kanyakumari district, Tamil Nadu.

Moisture content was determined by drying the samples in an oven at 80°C for 24hrs and was expressed on a percentage basis. The samples were powdered in Willey mill 60 mesh sizes and stored in screw cap bottles at room temperature for further analysis. Nitrogen content was estimated by the micro-kjeldhal method (Humphries, 1956) and crude protein was calculated (N x 6.25).

The contents of crude lipid, crude fibre and ash were estimated by AOAC (2005) methods. Nitrogen free extract was obtained by difference method by subtracting the sum of the protein, fat, ash and fibre from the total dry matter (Muller and Tobin, 1980). The energy value of the tuber was estimated (KJ) by multiplying the percentages of crude protein, crude lipid and NFE by the factors 16.7, 37.7 and 16.7 respectively (Siddhuraju *et al*., 1996). From the triple acid digested sample, sodium, potassium, calcium, magnesium, iron, copper, zinc and manganese were analyzed using an atomic absorption spectrophotometer (Perkin Elmer Model 5000) (Issac and Johnson, 1975). Phosphorus was estimated colorimetrically (Dickman and Bray, 1940). The total starch was determined by the titrimetric method of Moorthy and Padmaja (2002). The antinutritional factors, total free phenolics (Sadasivam and Manickam, 1996), tannins (Burns, 1971), hydrogen cyanide (Jackson, 1967), total oxalate (AOAC, 1984), trypsin inhibitor activity (Sasikaran and Padmaja, 2003) and amylase inhibitor activity (Rekha and Padmaja, 2002). *In vitro* protein digestibility was determined using the multi-enzyme technique (Hsu *et al*., 1977) and *in vitro* starch digestibility was assayed by Padmaja *et al*. (2001).

RESULTS AND DISCUSSION

The crude protein (Table 1) content of the various species of *Dioscorea* tubers investigated in the present study was found to be in agreement with the earlier investigation in the species of *Dioscorea* tubers (Onyilagha and Lowe, 1985; Rajyalakshmi and Geervani, 1994; Akissoe *et al*., 2001; Shanthakumari *et al.*, 2008; Alozie *et al.*, 2009; Arinathan *et al*., 2009). Among the two varieties of *D. oppositifolia* tubers, the variety *dukhumensis* contained more crude protein than the variety *oppositifolia*. This value is found to be consonance with earlier reports (Arinathan *et al*., 2009). The crude lipid content of *D. oppositifolia* var *dukhumensis* was found to be higher when compared to the presently investigated other *Dioscorea* species. The content of crude lipids in the tubers of *Dioscorea* species exhibited more crude lipid content than the earlier reports in the tubers of *D. alata* (Udensi *et al*., 2008); *D. oppositifolia, D, bulbifera, D. pentaphylla, D. hispida* (Rajyalakshmi and Geervani, 1994) *and D. rotundata* (Akissoe *et al*., 2001); *D. calicola, D. daunea, D.wallichi, D. stemonoides* and *D. glabra* (Maneenoon *et al*., 2008). The crude fibre content in the presently investigated tubers of *D. esculenta, D. oppositifolia* var *oppositifolia, D. pentaphylla var pentaphylla, D.spicata* and *D. wallichi* were found to be more than that in the earlier reports in *D. bulbifera* (Pramila *et al*., 1991); *D. oppositifolia, D. pentaphylla* (Murugesan and Ananthalakshmi, 1991); *D. alata* (Udensi *et al*., 2008); *D. bulbifera,* D. *deltoidea*, *D. versicolor* and *D. triphylla* (Bhandari *et al*., 2003). The nitrogen free extractives (NFE) in the tubers of *D. alata, D. bulbifera* var *vera, D. pentap*hylla var *pentaphylla, D. spicata* and *D. tomentosa* were higher (above 75%).

Table 1 Proximate composition of tubers of *Dioscorea* spp ($g100g^{-1}$) [a]

Botanical Name	Moisture content	Crude protein	Crude lipid	Crude fibre	Ash	NFE	Calorific value ($kJ100\ g^{-1}DM$)
D. alata	82.91 ± 0.41	7.57 ± 0.11	5.28 ± 0.18	3.96 ± 0.11	3.56 ± 0.02	79.63	1655.30
D. bulbifera var *vera*	86.70± 0.23	7.28 ± .14	6.14 ± 0.11	3.48 ± 0.17	3.31 ± 0.04	79.79	1685.55
D. esculenta	83.37 ± 0.25	9.76 ± 0.23	4.68 ± 0.14	6.62 ± 0.21	5.17 ± 0.05	73.77	1571.387
D. oppositifolia var *dukhumensis*	92.01 ± 0.18	13.42 ± 0.26	7.42 ± 0.10	4.92 ± 0.14	2.60 ± 0.11	71.64	1700.24
D. oppositifolia var *oppositifolia*	89.39 ± 0.27	8.44 ± 0.33	4.40 ± 0.31	7.69 ± 0.21	5.39 ± 0.07	74.08	1543.96
D. pentaphylla var *pentaphylla*	90.14 ± 0.47	6.48 ± 0.09	6.24 ± 0.07	7.24 ± 0.06	3.36 ± 0.04	76.68	1624.02
D. spicata	81.46 ± 0.42	8.20 ± 0.21	3.26 ± 0.04	6.31 ± 0.11	5.20 ± 0.01	77.03	1546.24
D. tomentosa	84.52 ± 0.31	9.54 ± 0.20	6.04 ± 0.21	3.54 ± 0.21	3.40 ± 0.01	77.48	1680.94
D. wallichi	76.36 ± 0.27	10.76 ± 0.18	3.34 ± 0.04	7.48 ± 0.13	6.36 ± 0.05	72.06	1509.01

[a] All values are means of three determinations expressed in dry weight basis.
± denotes standard error.

Table 2 Mineral composition of tubers of *Dioscorea* spp ($mg100g^{-1}$) [a]

Botanical name	Na	K	Ca	Mg	P	Zn	Mn	Fe	Cu
D. alata	44.56±0.31	786.30±0.14	448.36±0.11	656.31±0.07	140.14±0.14	2.26±0.01	6.36±0.21	24.30±0.19	11.20±0.14
D. bulbifera var *vera*	78.24±0.07	1554.36±0.36	338.15±0.09	396.20±1.07	154.42±0.53	1.48±0.03	9.40±0.14	19.20±0.20	2.14±0.04
D. esculenta	86.40±0.14	1594.31±1.34	314.01±0.33	436.06±0.54	138.10±0.14	1.76±0.04	5.46±0.11	11.48±0.11	3.40±0.01
D. oppositifolia var *dukhumensis*	168.24±0.78	1624.30±1.21	294.15±0.24	540.10±0.64	114.10±0.09	1.56±0.05	7.42±0.36	32.16±0.04	14.56±0.06
D. oppositifolia var *oppositifolia*	124.00±0.24	1534.21±1.78	646.20±0.13	634.14±0.71	124.12±0.11	6.26±0.01	9.04±0.24	40.76±0.31	7.62±0.04
D. pentaphylla var *pentaphylla*	96.20±0.63	1441.00±0.98	444.24±0.09	532.12±0.56	158.18±0.21	3.42±0.01	3.46±0.21	66.32±0.14	13.26±0.05
D. spicata	66.34±0.54	1136.12±0.74	234.10±0.58	324.16±0.24	166.30±0.27	2.56±0.04	6.70±0.14	24.10±0.26	7.41±0.11
D. tomentosa	46.14±0.30	1245.56±1.14	266.36±0.16	321.04±0.14	104.06±0.09	5.40±0.02	2.10±0.11	28.50±0.07	2.46±0.14
D wallichi	63.01±0.27	1361.70±1.01	748.31±0.32	578.06±0.19	106.40±0.11	6.66±0.01	3.31±0.05	20.14±0.04	2.46±0.08

[a] All values are means of three determinations expressed in dry weight basis.
± denotes standard error.

This value was found to be higher than that of the previous studies in the *Dioscorea* spp (Rajyalakshmi and Geervani, 1994; Akissoe *et al*., 2001; Pramila *et al*., 1991). The calorific value of all the investigated *Dioscorea* spp. was less than that of earlier studies in the tubers of *Dioscorea* spp. (Arinathan *et al*., 2009). Robinson (1987) reported that a diet that meets two-third of the RDA (Recommended Dietary Allowance) values is considered to be adequate for an individual. The tubers of *D. oppositifolia* var. *oppositifolia* and *D. wallichi* were found to contain higher calcium content than that of RDA's of NRC/NAS, (1980) for infants and children. The magnesium content of *D. alata* was found to be more when compared to that of the other *Dioscorea* species.All the investigated tubers were found to contain higher magnesium content than that of RDA's of NRC/NAS (1980) for infants and children. The tubers of *D. bulbifera* var *vera, D. esculenta, D. oppositifolia* var *dukhumensis and D. oppositifolia* var *oppositifolia* were found to contain higher level of potassium when compared with RDA's of infants and children (<1550mg) (NRC/NAS, 1980). The high content of potassium can be utilized beneficially in the diets of people who take diuretics to control hypertension and suffer from excessive excretion of potassium through the body fluid (Siddhuraju *et al*., 2001). The manganese content of *D. bulbifera* var *vera* was found to be high when compared to that of the other investigated *Dioscorea* species. All the investigated tubers appeared to have a higher level of manganese content compared to ESADDI of infants, adults and children of NRC/NAS (1989).

The amount of starch (Table 3) estimated in the tubers of *Dioscorea* sp. were higher than that of the earlier reports in the species of *Dioscorea* (Rajyalakshmi and Geervani, 1994; Arinathan *et al*., 2009). The niacin content in the tubers of *Dioscorea alata, D. bulbifera* var *vera, D, esculenta, D. oppositifolia* var *oppositifolia, D. pentaphylla* var *pentaphylla, D. spicata* and *D. wallichi* were found to be higher than in the tubers of *Dioscorea* species (Rajyalakshmi and Geervani, 1994; Arinathan *et al*., 2009). The starch content of *D. bulbifera* var *vera, D. oppositifolia* var *dukhumensis, D. pentaphylla* var *pentaphylla* and *Dioscorea tomentosa* was found to be more when compared with the earlier reports of same wild edible yams (Arinathan *et al* ., 2009). This difference may be due to some edaphic factors. Among the investigated tubers *D. bulbifera* var *vera, D. oppositifolia* var *dukhumensis* and *D. pentaphylla* var *pentaphylla* registered the highest ascorbic acid content than the earlier studied tubers of *D. alata* (Udensi *et al*., 2008).

The antinutritional factors like total free phenolics, tannins, hydrogen cyanide, total oxalate, amylase inhibitor and trypsin inhibitor activities are presented in Table 4. Phenolic compounds inhibit the activity of digestive as well as hydrolytic enzymes such as amylase, trypsin, chymotrypsin and lipase (Salunkhe, 1982). Among the various species of *Dioscorea*, the tubers of *D. bulbifera* var *vera* contained more free phenolics (Table 4). This value was found to be higher than that of the earlier studies in the tubers of *Ipomoea batatus* (Adelusi and Ogundana, 1987). *D. esculenta, D. alata, D. rotundata* (Babu *et al*., 1990; Sundaresan *et al*., 1990); *Manihot esculenta and Ipomoea batatus* (Babu *et al*., 1990). Recently phenolics have been suggested to exhibit health related functional properties such as anticarcinogenic, antiviral, antimicrobial, anti-inflammatory, hypotensive and antioxidant activity (Shetty, 1997). The level of tannins, hydrogen cyanide and total oxalate were found to be lower when compared with the earlier reports of the tubers of *Dioscorea alata, D. cayenensis, D. rotundata and D. esculenta* (Esuabana, 1982). The tubers of *D. oppositifolia* var *dukhumensis* and *D. oppositifolia* var *oppositifolia* contained more trypsin inhibitor activity when compared with earlier reports in the tubers of *D. dumetorum* and *D. rotundata* (Sasikiran *et al*., 1999). The phenolics and tannins are water soluble compounds (Uzogara *et al*., 1990) and as such can be eliminated by soaking followed by cooking (Singh, 1988; Murugesan and Ananthalakshmi, 1991; Kataria *et al*., 1989; Singh and Singh, 1992; Shanthakumari *et al*., 2008). A lot of hydrogen cyanide (known to inhibit the respiratory chain at the cytochrome oxidase level) is lost during soaking and cooking (Shanthakumari *et al*., 2009) so that its content in the tubers posses no danger of toxicity. Boiling for sufficient time makes the tuber soft enough and inactivates all the trypsin inhibitor (Bradbury and Holloway, 1988).

Table 5 shows the data of *in vitro* protein digestibility and *in vitro* starch digestibility. In all the presently investigated samples, the *in vitro* protein digestibility (IVPD) is found to be very low. The *in vitro* protein digestibility of *D. oppositifolia* var. *oppositifolia* and *D. spicata* was found to be higher when compared with the earlier reports of *D. oppositifolia* var. *dukhumensis*, *D. pentaphylla* var. *pentaphylla, D. tomentosa and D. spicata* (Mohan and Kalidas, 2010). However, *in vitro* starch digestibility (IVSD) of the tubers *Dioscorea bulbifera* var *vera, D. pentaphylla* var. *pentaphylla, D. spicata and D. tomentosa* is found to be higher than that of the previous reports of *D. oppositifolia, D. bulbifera, D. pentaphylla, D. hispida* and the pith of *Caryota urens* (Rajyalakshmi and Geervani, 1994).

Table 3 Starch and vitamins (Niacin and Ascorbic acid) content of tubers of *Dioscorea* spp[a]

Botanical name	**Starch ($g100g^{-1}$)**	**Niacin ($mg100g^{-1}$)**	**Ascorbic acid ($mg100g^{-1}$)**
D. a alata	49.13 ± 0.21	36.20 ± 0.24	74.56 ± 1.21
D. bulbifera var *vera*	38.10 ± 0.17	33.74 ± 0.21	91.04 ± 0.86
D. esculenta	62.40 ± 0.44	41.36 ± 0.35	84.06 ± 0.24
D. oppositifolia var *dukhumensis*	52.24 ± 0.31	37.14 ± 0.32	96.42 ± 0.37
D. oppositifolia var *oppositifolia*	46.04 ± 0.15	44.30 ± 0.51	90.51 ± 0.54
D. pentaphylla var *pentaphylla*	55.98 ± 0.51	62.14 ± 0.14	96.56 ± 0.34
D. spicata	41.33 ± 0.33	54.36 ± 0.09	76.03 ± 0.36
D. tomentosa	51.36 ± 0.27	74.12 ± 0.21	65.20 ± 0.21
D. wallichi	59.30 ± 0.24	52.40 ± 0.37	88.30 ± 0.29

[a] All values are means of three determinations expressed in dry weight basis.
± denotes standard error.

Table 4 Antinutritional factors of tubers of *Dioscorea* spp[a]

Botanical name	**Total free phenolics ($g100g^{-1}$)**	**Tannins ($g100g^{-1}$)**	**Hydrogen cyanide ($mg100g^{-1}$)**	**Total oxalate ($g100g^{-1}$)**	**Amylase inhibitor[b] AIU/mg soluble starch**	**Trypsin inhibitor[b] TIU/mg protein**
D. alata	0.68±0.04	0.41±0.01	0.17±0.01	0.58±0.03	6.21	3.65 ± 0.04
D. bulbifera var *vera*	2.20 ± 0.01	1.48±0.10	0.19±0.01	0.78±0.01	1.36	1.21 ± 0.01
D. esculenta	0.79 ± 0.07	0.20±0.01	0.21±0.03	0.33±0.02	7.80	1.92 ± 0.07
D. oppositifolia var *dukhumensis*	0.36 ± 0.01	0.24±0.07	0.24±0.02	0.36±0.01	2.46	13.30 ± 0.09
D. oppositifolia var *oppositifolia*	0.56 ± 0.01	0.36±0.11	0.33±0.04	0.46±0.07	2.10	11.26 ± 0.12
D. pentaphylla var *pentaphylla*	0.48 ± 0.05	0.09±0.06	0.18±0.01	0.58±0.05	2.46	3.66 ± 0.09
D. spicata	0.26 ± 0.01	0.10±0.05	0.18 ±0.01	0.44±0.07	3.31	1.26 ± 0.12
D. tomentosa	0.41 ±0.01	0.06±0.01	0.34 ±0.03	0.31±0.11	4.64	1.41 ± 0.11
D. wallichi	0.33 ±0.02	0.04±0.02	0.16 ±0.05	0.26±0.01	5.27	2.48 ± 0.07

[a] All the values are means of triplicate determinations expressed on dry weight basis; ± denotes standard error. [b] Means of two independent determination.

Table 5 *In vitro* protein digestibility and *in vitro* starch digestibility of tubers of *Dioscorea* spp[a]

Botanical name	***In vitro* protein digestibility (%)**	***in vitro* starch digestibility [b]**
D. alata	5.23	39.40
D. bulbifera var *vera*	4.61	56.84
D. esculenta	4.21	46.26
D. oppositifolia var *dukhumensis*	5.29	41.24
D. oppositifolia var *oppositifolia*	6.74	43.25
D. pentaphylla var *pentaphylla*	4.57	74.17
D. spicata	5.86	69.24
D. tomentosa	5.01	59.40
D. wallichi	4.31	49.36

[a]Means of two independent determinations.
[b]1 unit = mg reducing groups1hr/g sample

CONCLUSIONS

Based on the nutritive evaluation studies on the wild edible yams consumed by the tribals Kanikkars and Palliyars, it can be summarized that most of them were found to be a good source of protein, lipid, crude fibre, starch, vitamins and minerals. All the investigated samples exhibited variations in the levels of total free phenolics, tannins, hydrogen cyanide, total oxalate, amylase and trypsin inhibitors. Except phenolics, tannins, hydrogen cyanide, total oxalate, amylase and trypsin inhibitors, these antinutritional can be inactivated by moist heat treatments. Phenolics, tannins, hydrogen cyanide and total oxalate can be eliminated by soaking followed by cooking before consumption. It is recommended as a means of removing harmful effects of these antinutritional.

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