NUTRITIONAL AND ANTINUTRITIONAL ASSESSMENT OF SOME UNDERUTILIZED CORMS, RHIZOMES AND TUBERS †

[EVALUACIÓN NUTRICIONAL Y ANTINUTRICIONAL DE CORMOS, RIZOMAS Y TUBÉRCULOS SUBUTILIZADOS]

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SUMMARY

Background. With ever-increasing populace pressure and rapid depletion of natural resources, it has become exceptionally important to diversify the present time agriculture with the cultivation of some wild varieties of tubers, rhizomes and corms in order to meet various human nutrient needs. However, information regarding the nutritional and antinutritional composition is meager. **Objective.** To study the chemical composition and antinutritional factors of the wild edible corms, rhizomes and tubers consumed by the Palliyars and Kanikkar tribes living in South Eastern Slopes of Western Ghats, Tamil Nadu **Methodology**. The wild edible corms of *Alocasia macrorrhiza*, *Amorphophallus paeoniifolius* var *campanulatus*, *Amorphophallus sylvaticus*, *Colocasia esculenta*, *Xanthosoma sagittifolium*, *Xanthosoma violaceum*, rhizomes of *Canna indica*, *Maranta arundinacea* and tubers of *Asparagus racemosus*, *Nymphaea pubescens* and *Nymphaea rubra* were analysed for proximate and mineral composition, starch, vitamins like niacin, ascorbic acid and antinutritional factors like total free phenolics, tannins, hydrogen cyanide, total oxalate, amylase and trypsin inhibitor activities were quantified. Also, *in vitro* protein and starch digestibility were assessed. **Results.** The rhizome of *Maranta arundinacea* and tubers of *Nymphaea pubescens* contain high quantity of crude proteins. The tubers of *Asparagus racemosus* contained higher amount of crude lipids. The corms of *Alocasia macrorrhiza, Colocasia esculenta, Xanthosoma sagittifolium* and *Xanthosoma violaceum* appeared to have a higher level of potassium content compared to recommended Dietary allowances (RDA) for infants, children and adults. The corms of *Alocasia macrorrhiza, Amorphophallus sylvaticus, Xanthosoma violaceum* and rhizome of *Maranta arundinacea* were found to contain more starch. All the investigated samples had low *in vitro* protein digestibility. **Implications.** The present result highlights the potentiality of these underground plant parts as source of unconventional foods. Being wild, they also are easily accessible and cheaper. Studies on nutritional value of wild plant food are of extensive importance since it may help to recognize long forgotten food resources. **Conclusion.** Most of the wild edible corms, rhizomes and tubers were found to be a good source of protein, lipid, total dietary fiber, starch, vitamins and minerals. All the investigated samples exhibited variations in the levels of the total free phenolics, tannins, hydrogen cyanide, total oxalate, amylase and trypsin inhibitors

Key words: underutilized corms, proximate composition, vitamins, IVPD, IVSD, Antinutritional factors.

RESUMEN

Antecedentes. Con la presión cada vez mayor de la población y el rápido agotamiento de los recursos naturales, se ha vuelto excepcionalmente importante diversificar la agricultura actual con el cultivo de algunas variedades silvestres de tubérculos, rizomas y cormos para satisfacer las diversas necesidades de nutrientes humanos. Sin embargo, la información sobre su composición nutricional y antinutricional es escasa. **Objetivo.** Estudiar la composición química y factores antinutricionales de tubérculos, rizomas y cormos consumidos por las tribus de Pallyars and Kanikkar viviendo en las laderas del sudeste de Ghats occidentales, Tamil Nadu. **Metodologia.** Los cormos silvestres comestibles de *Alocasia macrorrhiza, Amorphophallus paeoniifolius var campanulatus, Amorphophallus sylvaticus, Colocasia esculenta, Xanthosoma sagittifolium, Xanthosoma violaceum*, rizomas de *Canna indica, Maranta arundinacea* y tubérculos *Asparagus racemosus, Nymphaea pubescens* y *Nymphaea rubra* fueron analizados para su composición química y mineral. Se cuantificaron almidón, vitaminas como niacina, ácido ascórbico y factores antinutricionales como fenólicos totales libres, taninos, cianuro de hidrógeno, oxalato total, amilasa y actividades inhibidoras de tripsina. Asimismo, se evaluó la digestibilidad *in vitro* de proteínas y almidones. **Resultados.** El rizoma de *Maranta arundinacea* y los tubérculos de *Nymphaea pubescens* contienen una gran cantidad de proteína cruda. Los tubérculos de *Asparagus racemosus* contenían una mayor cantidad de lípido. Los cormos de *Alocasia macrorrhiza*, *Colocasia esculenta*, *Xanthosoma sagittifolium* y *Xanthosoma violaceum* parecían tener un mayor contenido de potasio en comparación con la

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recomendación de consumo diario (RDA) para bebés, niños y adultos. Se encontró que los cormos de *Alocasia macrorrhiza, Amorphophallus sylvaticus, Xanthosoma violaceum* y el rizoma de *Maranta arundinacea* contienen más almidón. Todas las muestras investigadas fueron bajas digestibilidad de proteínas *in vitro***. Implicaciones.** El presente resultado resalta la potencialidad de estas plantas subterráneas como fuente de alimentos no convencionales. Al ser silvestres, también son fácilmente accesibles y más baratos. Los estudios sobre el valor nutricional de los alimentos de plantas silvestres son de gran importancia ya que puede ayudar a reconocer recursos alimenticios olvidados. **Conclusión.** La mayoría de los cormos, rizomas y tubérculos comestibles silvestres son una buena fuente de proteínas, lípidos, fibra dietética total, almidón, vitaminas y minerales. Todas las muestras investigadas exhibieron variaciones en los niveles de los fenólicos libres totales, taninos, cianuro de hidrógeno, oxalato total, inhibidores de amilasa y tripsina.
Palabras clave: cormos subutilizados; composición proximal; vitaminas; digestibilidad *in vitro*; factores antinutricionales.

INTRODUCTION

India has one of the largest concentrations of tribal populations in the world. The forest plays a vital role in the economy as well as daily needs of the tribals. In times of scarcity when the stable food is in short of supply tribals collect many types of wild roots and tubers to supplement their meagre food available at home (Vidyarthi, 1987). The continuing food scarcity, malnutrition and poverty plus population growth in developing countries are promoting scientists to role more esoteric plant species. Until recently emphasis in agricultural development has been on the production of stable and traditional export crops, while many other plant species whose importance and benefits are well unknown locally has been largely ignored (Rajalakshmi and Geervani, 1994). Some of the underutilized wild edible food plants have great potential for adding protein to the diet and they diet well into substitute agriculture (Nas, 1979; Janardhanan, 1990).

Data regarding the chemical and nutritional content of Indian wild edible corms, tubers and rhizomes is inadequate (Gopalan *et al*., 1976; Babu *et al*., 1990; Nair and Nair, 1992; Rajyalakshmi and Geervani, 1994; Bhandani *et al*., 2003; Shanthakumari *et al*., 2008; Udeni *et al*., 2008; Mohan and Kalidass, 2010; Shajeela *et al*., 2011). Therefore in the present investigation an attempt has been made to understand the chemical composition and antinutritional factors of the wild edible corms, rhizomes and tubers consumed by the Palliyars and Kanikkar tribes living in South Eastern Slopes of Western Ghats, Tamil Nadu. Studies on nutritional value of wild plant food are of considerable significance since it may help to identify long forgotten food resources.

MATERIALS AND METHODS

Six samples of wild edible corms (*Alocasia macrorrhiza* Schott., *Amorphophallus paeoniifolius* (Dennst.) Nicolson var. *campanulatus* (Blume ex. Decne.), *Amorphophallus sylvaticus* (Roxb.) Kunth., *Colocasia esculenta* (L.) Schott., *Xanthosoma sagittifolium* (L.) Schott. and *Xanthosoma violaceum* Schott.) two species of wild rhizomes (*Canna indica* L. and *Maranta arundinacea L.*) and three species of tubers (*Asparagus racemosus* Willd., *Nymphaea pubescens* Willd.and *Nymphaea rubra* Roxb ex Andrews) grown in sandy loam soil consumed by the tribal kanikkars/Palliyars were collected using multistage sampling technique in three consecutive rainy seasons from August 2016 to January 2017 from the South Eastern Slopes of Western Ghats, Virudhunagar district, Madurai district and Kanyakumari District, Tamil Nadu. A total of 500 g of each corm, rhizome and corm species were collected during August to December 2016, November to January 2017 and September to December 2016 respectively.

Proximate composition

The moisture content was determined by drying the transversely cut samples in an oven at 80°C for 24 h and is expressed on a percentage basis. The air-dried samples were powdered distinctly in a Wiley mill (Scientific Equipment, Delhi, India) to 60-mesh size . It is then kept in screw capped bottles at room temperature for additional analysis.

The nitrogen content was assessed by the micro Kjeldahl method (Humphries, 1956) and the crude protein content estimated asN x 6.25. Crude lipid content was estimated using Soxhlet apparatus (AOAC, 2005). The ash content was determined by heating 2g of dried sample in a silica dish at 600 °C for 6 h (AOAC, 2005). Total dietary fibre (TDF) was estimated by the non-enzymatic-gravimetric method proposed by Li and Cardozo (1994). To find the TDF, duplicate 500 mg ground samples were taken in distinct 250 ml beakers. To each beaker 25 ml water was poured and lightly stirred until the samples were carefully wetted, (i.e. no clumps were observed). The beakers were covered with Aluminium foil and allowed to stand 90 min without stirring in an incubator maintained at 37 °C. Afterwards, 100 ml 95 % ethanol was poured to each beaker and made to stand for 1 h at room temperature (25±2 °C). The residue was gathered

under vacuum in a pre-weighed crucible having filter aid. The residue was washed continuously with 10 ml of 95 % ethanol, 20 ml of 78 % ethanol and 10 ml acetone. The crucible containing the residue was dried >2 hr at 105 °C and then cooled > 2 hr in a desiccator and weighed. One crucible containing residue was utilized for ash determination at 525 °C for 5 h. The crucible containing ash was cooled for more than 2 h in a desiccator and weighed. The residue from the residual duplicate crucible was made used for crude protein determination by the micro-Kjeldahl method as mentioned previously. The TDF was found using the given formula:

TDF % = 100 x *Wr [(P+A)/100] Wr/Ws*

Where Wr is the mg residue, P is the percentage of protein in the residue; A is the percentage of ash in the residue, and Ws is the mg sample.

The nitrogen free extract (NFE) was found using their difference (Muller and Tobin, 1980). The energy value of the seed (kJ) was assessed by multiplying the percentages of crude protein, NFE and crude lipid by the factors 16.7, 16.7 and 36.7 respectively (Siddhuraju *et al*., 1996).

Minerals and vitamins analysis

Five hundred milligrams of the ground plant samples was mixed with a mixture of 10 ml concentrated nitric acid, 1 ml of concentrated sulphuric acid and 4 ml of 60 % perchloric acid. Followed by cooling, the digest was diluted through 50 ml of deionised distilled water, filtered using Whatman No. 42 filter paper and the filtrates were made up to 100 ml in a glass volumetric flask with deionised distilled water. All the minerals excluding phosphorus were checked from a triple acid digested sample using an atomic absorption spectrophotometer – ECIL (Electronic Corporation of India Ltd., India) (Issac and Johnson, 1975). The phosphorus content in the triple acid digested extract was found colorimetrically (Dickman and Bray, 1940).

Ascorbic acid and niacin content were extracted and estimated as per the method given by Sadasivam and Manickam (1992). For the extraction of ascorbic acid, 3 g air-dried powdered sample was mixed with 25 ml of 4 % oxalic acid and filtered. Bromine water was supplemented drop by drop to 10ml of the filtrate till it turned orange-yellow to eliminate the enolic hydrogen atoms. The additional bromine was excluded by blowing in air. This filtrate was mixed to 25 ml with 4 % oxalic acid and utilized for ascorbic acid approximation. Two millilitres of the extract were made up to 3 ml using distilled H_2O in a test tube. One millilitre of 2 % 2, 4-dinitrophenyl hydrazine reagent and a few drops of thiourea were added. The contents of the test tube were mixed meticulously followed by 3 h incubation at 37 °C, 7 ml of 80 % H_2SO_4 was mixed to dissolve the osazone crystals and the absorbance was calculated at 540 nm compared to a reagent blank.

For the extraction of niacin, 5 g air-dried powdered sample was steamed for 30 min with 30 ml concentrated H_2SO_4. Followed by that cooling, the suspension was made up to 50 ml using distilled H_2O and filtered. Five millilitres of 60 % basic lead acetate was mixed to 25 ml of the filtrate. The pH was balanced to 9.5 and centrifuged to accumulate the supernatant. Two millilitres of concentrated H_2SO4 was mixed with the supernatant. The mixture was allowed to stand for 1hr and centrifuged. The 5 ml of 40% $ZnSO_4$ was added to the supernatant. The pH was adjusted to 8.4 and centrifuged again. Then the pH of the collected supernatant was balanced to 7 and utilized as the niacin extract. For estimation, in a test tube, 1 ml extract was made up to 6 ml with distilled water followed by addition of 1 ml of 4 % aniline, 3 ml cyanogen bromide was mixed and shaken well. The yellow colour that appeared after 5min was calculated at 420 nm against a reagent blank. The ascorbic acid and niacin contents in the sample were calculated by comparing to a standard graph and stated as mg per 100 g of powdered samples. Starch content was determined by the method of Sadasivam and Manickam (1992).

Analysis of antinutritional compounds

The antinutritional compounds, total free phenolics (Bray and Thorne, 1954), tannins (Burns, 1971), hydrogen cyanide (Jackson, 1971) and total oxalate (AOAC, 1984) were quantified. Trypsin inhibitor activity was calculated by the enzyme assay of Kakade *et al*. (1974) by using benzoil-DL-arginin-pnitroanilide (BAPNA) as a substrate. One trypsin inhibitor unit (TIU) has been stated as an increase of 0.01 absorbance units per 10 ml of reaction blend at 410 nm. Trypsin inhibitor activity has been stated in terms of trypsin units inhibited per mg protein. Amylase inhibitor activity was determined by the method of Rekha and Padmaja (2002) by using 0.5 % soluble starch as substrate. Porcine pancreatic α-amylase (Emerck, Germany) was used as the enzymatic source uniformly throughout the study. One α-amylase unit has been defined as one mg starch hydrolysed per minute at 30 °C. One α-amylase inhibitor unit (AIU) has been defined as the amount of inhibitor that reduces the α-amylase activity by one unit. The specific amylase inhibitor unit is calculated as the AIU/mg soluble starch.

Determination of *in vitro* protein digestibility (IVPD)

Protein digestibility was assayed by the *in vitro* method described by Hsu *et al*. (1977). The enzymes used for IVPD were bought from Sigma Chemical Co., St. Louis, MO, USA. Calculated amounts of the control (casein) and sample weight were weighed out, hydrated in 10ml of distilled water and refrigerated at 5°C for 1h. The samples containing protein and enzymes were all adjusted to pH 8.0 at 37°C. The *in vitro* protein digestibility (IVPD) was determined by the sequential digestion of the samples containing protein with a multi-enzyme mixture [trypsin (porcine pancreatic trypsin–type IX with 14190 BAEE unites - chymotrypsin (bovine pancreatic∝per mg protein), chymotrypsin–type II, 60 units per mg powder) and peptidase (porcine intestinal peptidase–grade III, 40 C followed by protease°units per g powder)] at 37 °C. After 20 min of incubation, the pH (type IV from *Streptomyces griseus*) at 55°C. The pH drop of the samples from pH 8.0 was recorded after 20 min. of incubation. The IVPD was calculated according to the regression equation, Y = 234.84 – 22.56 X, where, Y is the % digestibility and X is the pH drop.

Determining of *in vitro* starch digestibility

Starch digestibility was assayed by the *in vitro* method described by Padmaja *et al*. (2001). One hundred mg of powdered sample was weighed and to this 10 ml of the 0.02 M sodium phosphate buffer (pH 6.9) was added and the contents were thoroughly mixed. Kept in boiling water bath and gelatinize the sample by stirring continuously, not allowing lump formation. The volume was made up to 20 ml using the same buffer. Then 0.5 ml of pancreatic alpha amylase solution was added to this and incubated at 30 °C for 30 min. To nullify the effect of free reducing sugars, control flasks were also set up. For this, an identical flask containing sample as above was prepared and no enzyme is added and incubate for 30 min at 30 °C. Immediately after 30 min the flasks were placed in a boiling water bath to inactivate the enzyme. On cooling, 0.2 ml aliquots from each of the test as well as control were pipette out into separate test tubes. The contents of the tubes were then made up to 1.0 ml using distilled water. The reducing sugars formed by the action of α-amylase on the starch were estimated by Nelson-Somogyi method and the absorbance was read at 520 nm. A standard graph was prepared using D-maltose. The *in vitro* starch digestibility was expressed as mg reducing group formed 1 h per g starch taken.

Statistical analysis

Proximate composition, minerals, vitamins (niacin and ascorbic acid), starch, antinutritional factors like total free phenolics, tannins, total oxalate and hydrogen cyanide were estimated in triplicate determinations. Data were analyzed using the statistical analysis system SPSS (SPSS software for windows release 11.5; SPSS Inc., Chicago IL, USA). Estimates of mean, standard error for aforesaid parameters were calculated.

RESULTS AND DISCUSSION

Proximate composition

Data on proximate composition of the edible corms, rhizomes and tubers are shown in table 1. The proximate composition reveals that the rhizome of *Maranta arundinacea* and the tuber of *Nymphaea pubescens* have more crude protein than the other samples like corms, rhizomes and tubers. The crude protein content of *Canna indica*, *Colocasia esculenta*, *Nymphaea pubescens* and *Nymphaea rubra* was found to be in agreement with the earlier studies in the same species collected from different places (Mohan and Kalidass, 2010). The crude protein content of corms of *Amorphophallus paeoniifolius* var *campanulatus*, *Amorphophallus sylvaticus*, *Xanthosoma sagittifolium* and *Xanthosoma violaceum* was found to be consonance with earlier reports on tuber of *Curculigo orchioides* (Arinathan *et al*., 2009) *Dioscorea esculenta*, *D. tomentosa* (Shajeela *et al*., 2011), *Pentaphylla* and *Cycas circinalis* (Mohan and Kalidass, 2010). The content of crude lipids in the tubers of *Asparagus racemosus* exhibited more crude lipid content than the earlier reports in the tubers of *D. oppositifolia*, *D. bulbifera*, *D. pentaphylla*, *D. rotundata* (Akissoe *et al*., 2001), *Dioscorea* spp. (Shanthakumari *et al.*, 2008; Shajeela *et al*., 2011), *D. bulbifera*; corms of *Colocasia esculenta* and *Alocasia macrorrhiza* (Pramila *et al*., 1991).

The total dietary fibre content in the presently investigated underutilized corms of *Amorphophallus paeoniifolius* var *campanulatus*, *Xanthosoma sagittifolium*, rhizome of *Canna indica* and tubers of *Asparagus racemosus* were found to be more than that in the earlier reports in *D.bulbifera* (Paramila *et al*., 1991), *D. oppositifolia*, *D. pentaphylla* (Murugasan and Ananthalakshmi, 1991), *D. alata* (Udensi *et al*., 2008; Shajeela *et al*., 2011), *D. bulbifera*, *D. deltoidea*, *D. versicolor* and *D.triphylla* (Bhandari *et al*., 2003) and some edible tubers, rhizomes, corms, roots and stems (Mohan and Kalidass, 2010). The presence of fibre in the diet is necessary for digestion and for elimination of water. The contraction of muscular walls of the digestive tract is stimulated by fibre, thus counteracting

constipation (Narasinga Rao *et al*., 1989). The World Health Organization (WHO) has recommended an intake of 22-23 kg of fibre for every 100 kcal of diet (Kanwar *et al*., 1997). The corms, rhizomes and tubers of present investigation contained high carbohydrates or Nitrogen free extractives (NFE) i.e. 73.74-86.09 %. The calorific value of all the investigated corms, rhizomes and tubers was less than that of earlier reports in the tubers of *Asparagus racemosus*, *D. bulbifera* var. *vera*, *D.oppositifolia* var *dukhumensis*, *D.tomentosa, Dolichos trilobus* (Arinathan *et al*., 2009) stem of *Caralluma alscendens* var. *attenuate*, *C.pauciflora* and tuber of *Maerua oblongifolia* (Mohan and Kalidass, 2011).

Robinson (1987) reported that a diet that needs two third of the RDA (Recommended Dietary Allowance) values is considered to be adequate for an individual. The mineral analyses (Table 3) reveals that the corms of *Alocasia macrorrhiza, Colocasia esculenta, Xanthosoma sagittifolium* and *Xanthosoma violaceum* appear to be rich sources of potassium when compared with the Recommended Dietary Allowances (RDA) of NRC/NAS (1989) for infants and children. The high content of potassium can be utilized beneficial in diets of people who take diuretics to control hypertension and suffer from excretion of potassium through the body fluid (Siddhuraju *et al*., 2001). The calcium content in the corms of *Alocasia macrorrhiza*, *Amorphophallus paeoniifolius* var. *campanulatus*, *Colocasia esculenta*, *Xanthosoma sagittifolium* and *Xanthosoma violaceum* is found to be higher than the earlier study in the corms of *Colocasia esculenta* and *Alocasia macrorrhiza* (Pramila *et al*., 1991; Agarwal *et al*., 1999) in the tuber of *D. oppositifolia,* D. *bulbifera,* D. *pentaphylla* and *D.hispida* (Rajyalakshmi and Geervani, 1994); *Dioscorea* spp (Bhandari *et al*., 2003); *D. alata, D. bulbifera, D. esculenta, D. oppositifolia* and *D. tomentosa* (Shanthakumari *et al*., 2008); *Asparagus racemosus, Curculigo orchioides*, *Dioscorea bulbifera* var. *vera, D. oppositifolia* var *dukhumensis*, *D. tomentosa* (Arinathan *et al*., 2009) and also higher than that of RDA'S of NRC/NAS (1980) for infants and children. The micro element iron content in the corms of *Alocasia macrorrhiza, Colocasia esculenta, Xanthosoma sagittifolium*, *Xanthosoma violaceum* is found to be higher when compared with the earlier reports in the tubers of *D. oppositifolia* and *D. pentaphylla* (Murugesan and Ananthalakshmi, 1991), *D. oppositifolia, D. pentaphylla, Dioscorea bulbifera* and *D. hispida* (Rajyalakshmi and Geervani, 1994). All the presently investigated corms, rhizomes and tubers have higher iron content compared to infants, children and adults RDA'S of NRC/NAS (1980). The manganese content of tubers *Asparagus racemosus* and *Maranta arundinacea* was found to be higher when compared to that of the others investigated species. All the investigated corms, rhizomes and tubers appeared to have a higher level of manganese content compared to ESADDI (Estimated Safe and Adequate Daily Dietary Intake of Minerals) of infants and children of NAC/NAS (1980). The copper content in the corms of *Alocasia macrorrhiza, Amorphophallus sylvaticus, Colocasia esculenta, Xanthosoma sagittifolium* and *Xanthosoma violaceum* appeared to be higher when compared with ESADDI of infants, children and adults (NAC/NAS, 1989).

The contents of starch and vitamins (niacin and ascorbic acid) are shown in table 3. The corms of *Alocasia macrorrhiza, Amorphophallus sylvaticus, Xanthosoma violaceum* and rhizome of *Maranta arundinacea* were found to contain more starch contents than that of earlier reports in the tubers of *Asparagus racemosus, Curculigo orchioides, D. bulbifera* var. *vera, D. oppositifolia* var *dukhumensis, D. oppositifolia* var *oppositifolia, D. pentaphylla* var *pentaphylla, D. tomentoasa*, *Dolichous trilobus* (Arinathan *et al*., 2009), *D. alata, D. bulbifera* var. *vera*, *D. oppositifolia* var. *oppositifolia*, *D. spicata* (Shajeelaa *et al*., 2011), *Ipomoea batatus* (Nair and Nair, 1992), *Manihot esculenta* (Maini and Balagopal, 1978), corms of *Amorphophallus paeoniifolius* (Moorthy *et al*., 1994) and all the tubers, rhizomes, corms, roots and stems (Mohan and Kalidass, 2010). The vitamins niacin content in the tuber of *Asparagus racemosus* was found to be higher than that of earlier reports in the tubers of *Dioscorea* spp., the pith of *Caryota urens* and shoot of *Bambusa arundinacea* (Rajyalkashmi and Geevani, 1994) tuber of *D. oppositifolia* var *dukhumensis, Dolichous trilobus* (Arinathan *et al*., 2009); and most of the edible tubers, rhizomes, corms, roots and stems (Mohan and Kalidass, 2010). Similarly the tuber of *Asparagus racemosus* was found to contain more ascorbic acid content than the earlier reports in the tubers of *D. alata* (Udenei *et al*., 2008); corms of *Colocasia esculenta* and *Alocasia macrorrhiza* (Pramila *et al*., 1991); tuber of *Cucurligo orchioides* (Arinathan *et al*., 2009) and most of the edible tubers, rhizome, corms, roots and stems (Mohan and Kalidass, 2010).

Table 3 shows the *in vitro* protein digestibility and *in vitro* starch digestibility. For all the samples examined presently, the *in vitro* protein digestibility (IVPD) is found to be very low. However, *in vitro* starch digestibility (IVSD) of the corms of *Alocasia macrorrhiza, Maranta arundinacea, Xanthosoma sagittifolium, Xanthosoma violaceum* and rhizome of *Canna indica* was found to be higher than that of *D. oppositifolia, D. bulbifera, D. pentaphylla, D. hispida* and the pith of *Caryota urens*

(Rajyalakshmi and Geevari, 1994), tubers of *D. alata, D. esculenta, D. oppositifolia* var *dukhumensis, D. oppositifolia* var *oppositifolia, D. wallichi* (Shajeela *et al*., 2011).

Antinutritional factors

The problem of plant protein digestibility has been suggested to be because of the interplay of several factors such as protease inhibitors, amylase inhibitors, phytases, oxalates, lectins, hydrogen cyanide, total free phenolics, tannins and other antinutritional factors. For this reason a preliminary evaluation of some of these factors in raw corms, rhizomes and tubers are made (Table 4). Total free phenolic constitutents of all the presently investigated samples except *Amorphophallus paeoniifolius* var. *campanulatus* and *Amorphophallus sylvaticus* were found to be low compared to earlier studies in the tuber of *Ipomoea batatus* (Adeluri and Ogandana, 1987); *Dioscorea 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 tannin content in the presently investigated corms, rhizomes and tubers were found to be lower when compared with other earlier reports in the tuber of *Dioscorea alata, D. cayenensis, D. rotundata* and *D. esculenta* (Udoerrion and Ifron, 1992). Tannins are known to inhibit the activity of digestive enzymes (Jambunathan and Singh, 1981) and hence the presence of even a low level of tannin in not desirable from nutritional point of view. The content of hydrogen cyanide level in the corms, rhizome and tubers was found to be lower when compared with the earlier reports obtained in the tuber of *Manihot utilisima* and *M. palmata* (Oke, 1975); *M. esculenta* (Nambisan and Sundarsen, 1990) and *D. alata, D. cayenensis, D. rotannata* and *D. esculenta* (Esuabana, 1992). Most of HCN (known to inhibit the respiratory chain at the cytochrome oxidase level) is lost during soaking and cooking (Kay *et al*., 1977) so that its content in the tubers poses no damages of toxicity. Among the presently investigated plant parts the corms *Amorphophallus paeoniifolius* var *campanulatus*, *Amorphophallus sylvaticus Xanthosoma sagittifolium, Xanthosoma violaceum* rhizomes of *Canna indicia* contain more total oxalate when compared with other earlier report in the tuber of *Manihot esculenta* (Oke, 1975); *Dioscorea alata, D. cayenensis, D. rotundata, D. esculenta* (Esuabana, 1982); *Dioscorea* spp (Shanthakumari *et al*., 2008; Shajeela *et al*., 2011) and edible tubers, rhizomes, corms, roots and stems (Mohan and Kalidass, 2010).

Alpha amylase inhibitors combine with alpha amylase and make them unavailable for starch digestion. Research has been carried out on the possible interference of these compounds with starch digestion in living organisms and on their physiological function (Rekha and Padmaja, 2002). The amylase inhibitor activity among the currently investigated corms, rhizomes and tubers were found to be in the range of 0.83 to 9.84 units. This range is very low when compared with the earlier reports in the tubers of *Dioscorea oppositifolia, D.bulbifera, D.pentaphylla* and *D.hispida* (Rajyalakshmi and Geevani, 1994). The presence of protease inhibitors such as trypsin and chymotrypsin inhibitors in the diet leads to the formation of irreversible trypsin enzyme-trypsin inhibitor complexes causing a decrease in trypsin in the intestine and decrease in the digestibility of dietary protein, thus leading to slower animal growth. As a result, the secreting activity of the pancreas increases, which could cause pancreatic hypertrophy and hyperplasia (Liener, 1994). The corms of *Alocasia macrorrhiza* and *Xanthosoma sagittifolium* contain more trypsin inhibitor activity when compared with earlier reports in the tubers of *Dioscorea dumetorum* and *D. rotundata* (Sasikiran *et al*, 1999); *D. alata, D. bulbifera, D. esculenta, D. pentaphylla, D. tomentosa, D. wallichi* (Shanthakumari *et al*., 2008; Shajeela *et al*., 2011). Inhibitors of alpha amylases and protein digesting enzymes interfere with the digestion of starch and protein. Boiling for sufficient time makes the tubers soft enough and inactivates all the trypsin inhibitor (Bradbary and Holloway, 1988)

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Table 1. Proximate composition of edible tubers, corms and rhizomes (mg/100g^{-1}).

Botanical Name	Moisture	Crude protein	Crude lipid	Total dietary fibre	Ash	NFE	Calorific value (KJ 100 g^{-1} DM)
Alocasia macrorrhiza (corms)	84.12 ± 1.33	4.46 ± 0.11	3.31 ± 0.03	3.78 ± 0.03	2.36 ± 0.01	86.09	1636.96
Amorphophallus paeoniifolius var. *campanulatus* (corm)	79.24 ± 1.11	9.40 ± 0.17	5.78 ± 0.05	6.36 ± 0.07	4.72 ± 0.05	73.74	1606.33
Amorphophallus sylvaticus (corms)	82.10 ± 0.76	8.36 ± 0.13	5.64 ± 0.03	5.76 ± 0.14	3.33 ± 0.01	76.91	1636.62
Asparagus racemosus (tubers)	81.62 ± 0.82	7.24 ± 0.08	7.36 ± 0.11	6.42 ± 0.06	4.12 ± 0.04	74.86	1648.53
Canna indica (Rhizome)	89.04 ± 0.33	6.30 ± 0.04	3.52 ± 0.04	6.13 ± 0.03	2.78 ± 0.02	81.27	1595.11
Colocasia esculenta (Corm)	44.36 ± 0.17	4.98 ± 0.16	4.33 ± 0.03	3.96 ± 0.03	4.12 ± 0.06	82.61	1625.98
Maranta arundinacea (rhizome)	78.68 ± 1.04	12.64 ± 0.10	2.72 ± 0.01	3.78 ± 0.01	2.36 ± 0.07	78.50	1624.57
Nymphaea pubescens (tuber)	82.35 ± 1.12	10.34 ± 0.09	3.96 ± 0.01	3.33 ± 0.09	4.12 ± 0.03	78.25	1628.73
Nymphaea rubra (tuber)	80.46 ± 0.96	9.68 ± 0.03	5.36 ± 0.01	3.86 ± 0.02	3.38 ± 0.05	77.72	1661.64
Xanthosoma sagittifolium (corms)	72.16 ± 0.76	9.68 ± 0.05	6.32 ± 0.12	6.30 ± 0.06	4.68 ± 0.08	73.02	1581.64
Xanthosoma violaceum (corms)	84.33 ± 0.73	8.76 ± 0.13	4.56 ± 0.07	4.36 ± 0.04	3.54 ± 0.05	78.78	1633.82

All values are mean of three determinations expressed in dry weight basis
± denotes standard error

Table 2. Mineral composition of edible tubers, corms and rhizomes (mg/100g^{-1}).

Botanical Name	Na	K	Ca	Mg	P	Zn	Mn	Fe	Cu
A. macrorrhiza	184.62 ± 1.21	1832.26 ± 0.84	578.40 ± 2.26	184.10 ±1.34	129.46 ± 0.76	2.26 ± 0.07	3.78 ± 0.04	56.41 ± 0.11	6.36 ± 0.03
A. paeoniifolius var. *campanulatus*	84.36 ± 2.34	1214.14 ± 1.66	514.10 ± 1.52	104.02 ±1.03	144.16 ± 0.45	4.38 ± 0.11	4.94 ± 0.03	24.26 ± 0.21	3.36 ± 0.03
A. sylvaticus	76.21 ± 1.04	1324.10 ± 1.26	438.78 ± 1.32	94.38 ± 0.28	126.00 ± 0.33	5.14 ± 0.11	3.34 ± 0.11	32.10 ± 0.33	4.76 ± 0.05
A. racemosus	35.76 ± 0.76	736.00 ± 0.79	136.42 ± 0.81	321.40 ±0.70	89.76 ± 0.21	2.46 ± 0.04	9.34 ± 0.07	31.20 ± 0.30	2.20 ± 0.04
C. indica	52.36± 0.33	1124.08 ± 1.22	236.64 ± 0.52	176.30 ± 0.38	132.16 ± 0.56	2.10 ± 0.01	1.36 ± 0.01	9.36 ± 0.24	2.06 ± 0.01
C. esculenta	212.04 ± 0.79	1968.34 ± 1.28	558.36 ± 0.72	186.30 ± 0.24	148.14 ± 0.17	2.12 ± 0.03	4.16 ± 0.12	72.40 ±0.12	4.39 ±0.07
M. arundinacea	32.14 ± 0.79	946.30 ± 0.84	384.32 ± 0.21	362.10 ± 0.62	96.30 ± 0.26	4.14 ± 0.21	6.30 ± 0.07	22.10 ± 0.09	1.04 ± 0.03
N. pubescens	66.08 ± 0.53	968.31 ± 0.94	336.16 ± 0.31	114.78 ± 0.11	66.70 ± 0.14	1.33 ± 0.09	1.28 ± 0.03	36.14 ± 0.05	1.36 ± 0.01
N. rubra	48.54 ± 0.26	846.42 ± 0.72	366.76 ± 0.52	136.32 ± 0.12	98.41 ± 0.45	1.78 ± 0.01	1.56 ± 0.01	32.08 ± 0.30	1.14 ± 0.01
X. sagittifolium	158.36 ± 1.31	2148.10 ± 2.34	596.76 ± 0.92	212.04 ± 0.33	136.11 ± 0.21	2.2 ± 0.03	3.33 ± 0.01	61.30 ± 1.11	6.94 ± 0.05
X. violaceum	202.18 ± 2.26	2016.08 ± 2.76	612.64 ± 1.72	208.16 ± 0.41	112.66 ± 0.26	2.56 ± 0.03	4.20 ± 0.07	74.16 ± 0.84	5.92 ± 0.03

All values are mean of three determinations expressed in dry weight basis
± denotes standard error

Table 3. Starch, Vitamins (niacin and ascorbic acid) content[a], *in vitro* protein and *in vitro* starch digestibility of edible tubers, corms and rhizomes[b]

Botanical Name	Starch g/100g^{-1}	Niacin mg/100g^{-1}	Ascorbic acid mg/100g^{-1}	*In vitro* protein digestibility[c]	*In vitro* starch digestibility[d]
A. macrorrhiza	52.36 ± 0.01	5.23 ± 0.01	11.48 ± 0.51	3.24	53.33
A. paeoniifolius var. *campanulatus*	49.38 ± 0.33	6.13 ± 0.07	13.56 ± 0.31	3.74	48.10
A. sylvaticus	52.56 ± 0.41	5.58 ± 0.05	14.33 ± 0.21	4.21	44.04
A. racemosus	29.46 ± 0.36	26.32 ± 0.15	31.40 ± 0.20	3.06	32.40
C. indica	41.04 ± 0.52	8.36 ± 0.14	15.56 ± 0.17	4.55	64.21
C. esculenta	23.46 ± 0.17	11.21 ± 0.21	9.36 ± 0.09	3.03	40.20
M. arundinacea	62.36 ± 0.14	4.33 ± 0.33	7.37 ± 0.06	4.28	57.20
N. pubescens	9.74 ± 0.07	10.01 ± 0.61	21.06 ± 0.40	3.71	28.24
N. rubra	21.32 ± 0.13	6.87 ± 0.12	18.32 ± 0.23	4.68	21.64
X. sagittifolium	39.42 ± 0.16	9.36 ± 0.09	13.00 ± 0.14	6.31	54.34
X. violaceum	56.30 ± 0.21	8.13 ± 0.07	15.66 ± 0.36	5.27	62.11

a- All values are means of three determinations expressed on dry weight ± denotes standard error
b- Means of two independent analysis
c- 1 Unit = g amino acid released per 100 g sample (DM)
d – 1 Unit = mg reducing groups 1 hour/g sample

Table 4. Antinutritional factors of edible tubers, corms and rhizomes (mg/100g^{-1}).

Botanical Name	Total phenolics g/100g^{-1}	Tannin g/100g^{-1}	Hydrogen cyanide mg/100g^{-1}	Total oxalate g/100g^{-1}	Amylase Inhibitors AIU	Trypsin Inhibitors TIU
A. macrorrhiza	0.72 ± 0.11	0.42 ± 0.08	0.23 ± 0.03	0.68 ± 0.04	9.84	10.36
A. paeoniifolius var. *campanulatus*	1.39 ± 0.01	0.96 ± 0.14	0.18 ± 0.01	1.96 ± 0.07	5.78	1.33
A. sylvaticus	1.56 ± 0.03	0.86 ± 0.08	0.21 ± 0.02	1.58 ± 0.11	5.64	0.76
A. racemosus	0.38 ± 0.05	0.21 ± 0.02	0.12 ± 0.01	0.10 ± 0.01	0.83	1.23
C. indica	0.64 ± 0.02	0.13 ± 0.01	0.09 ± 0.01	3.54 ± 0.06	4.60	1.48
C. esculenta	0.32 ± 0.03	0.14 ± 0.02	0.06 ± 0.01	0.24 ± 0.02	2.34	0.93
M. arundinacea	0.16 ± 0.02	0.52 ± 0.01	0.06 ± 0.01	0.33 ± 0.04	2.79	4.24
N. pubescens	0.48 ± 0.03	0.26 ± 0.06	0.10 ± 0.02	0.31 ± 0.06	3.27	2.36
N. rubra	0.36 ± 0.01	0.21 ± 0.04	0.09 ± 0.02	0.42 ± 0.11	3.66	2.14
X. sagittifolium	0.32 ± 0.06	0.16 ± 0.01	0.13 ± 0.01	1.34 ± 0.07	3.36	12.64
X. violaceum	0.17 ± 0.01	0.26 ± 0.03	0.09 ± 0.01	1.12 ± 0.01	1.12	3.36

All values are means of three determinations expressed on dry weight ± denotes standard error

CONCLUSION

Based on the nutritive evaluation studies on the wild edible corms, rhizomes and tubers 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, total dietary fiber, starch, vitamins and minerals. All the investigated samples exhibited variations in the levels of the total free phenolics, tannins, hydrogen cyanide, total oxalate, amylase and trypsin inhibitors.

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