International Journal of Botany Studies
ISSN: 2455-541X; Impact Factor: RJIF 5.12
Received: 01-08-2019; Accepted: 03-09-2019
www.botanyjournals.com
Volume 4; Issue 6; November 2019; Page No. 01-08

Investigations on Essesntial and non-essential compounds changes during treatments of wild tubers of *dioscorea* species

Dr. Mariappan Senthilkumar
Assistant Professor in Botany, Postgraduate and Research Department of Botany, Government Arts College, Dharmapuri , Tamil Nadu, India

Abstract
The wild yam is common name for the genus *Dioscorea*, which is used as staple food of people in the tropics, but certain wild varieties are inedible because of the toxic substances present, some of which have pharmaceutical properties. The tubers consumed by the tribal Malayali's of Dharmapuri district (*Dioscorea bulbifera*, *D. deltoidea*, *D. hispida*, *D. oppositifolia*, and *D. pentaphylla*) were evaluated for its nutritional quality. Present study reveals the proximate composition, mineral profiles, total protein, carbohydrate, fat, vitamin C, β-carotene, starch and total soluble sugar content. The toxic principles like phenols, tannins, hydrogen cyanide, oxalate, amylase inhibitor activity and trypsin inhibitor activity were also analyzed using standard methods. Household treatments like soaking, cooking and autoclaving and their effects on changes toxic principles were investigated in five tuber samples. Soaking in distilled water and sodium bicarbonate solution were reduced the levels of anti-nutrients up to 33% and 50%, respectively whereas cooking and autoclaving (30 min.) reduced the toxic contents to a greater extent (58% and 75%). The amylase and trypsin inhibitor activity showed only slight reduction (upto 51%) in toxic principles after treatments. There is a significant difference (p<0.05) of values were observed among the *Dioscorea* species and were found to have high nutrient and low antinutrient values.

Keywords: antinutritional, *dioscorea*, moisture, nutrients, phytochemicals

1. Introduction
Nature has endowed plants with the genetic capacity to synthesize substances that are toxic and thus to ensure their survival against predators whether they be insects, fungi or animals including humans. Humans have learnt which foods are safe to eat or how such foods can be treated in order to destroy their toxicity. [1] India has one of the largest 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 staple food is in short of supply tribals collect many types of wild roots and tubers to supplement their meagre food available at home. 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. [2] Numerous wild edible plant species have been used by different tribal communities in tropical countries, mainly as supplement to conventional foods. [3] However, the biodiversity is threatened through replacement of forests with agricultural expansion and deforestation without cultivation and domestication of potential species. These situations could exacerbate local food shortages and aggravate widespread malnutrition in the country. Edible wild and traditional vegetables have played an important role in supplementing staple foods by supplying trace elements, vitamins, and minerals. [4]
Several sources revealed that edible wild plant and traditional vegetable species increase the nutritional quality by providing minerals, fiber, vitamins, and essential fatty acids and enhance taste and color in rural diets. [5] Underutilized green leafy vegetables are a good source of many nutrients like iron, calcium, ascorbic acid, and *β*-carotene that could help in overcoming micronutrient malnutrition and easily accessed by the community at a low cost. Because micronutrient deficiencies (such as vitamin A) are associated with low intake of foods such as vegetables, as opposed to starchy (energy rich) staples which provide the majority of energy intake, increment in energy production and consumption will likely do little to ameliorate the problem of micronutrient deficiency unless identification, proper evaluation, and domestication of nutritionally potential lesser known vegetables are integrated into the diets of the population. Moreover, the roles of edible wild plants and lesser known crops in human nutrition are potentially valuable to maintain a balance between population growth and agricultural productivity, particularly in the tropical and subtropical areas of the world. [6] Hence, continuous search for new source of nutrient especially from plant foods is a basis for selecting promising species for further studies on green leafy vegetables to meet the nutritional requirements. Evaluation of the nutrient and antinutrient compositions of wild edible plants helps to identify foods rich in minerals and acquiring knowledge on the methods of appropriate preparation to enhance bioavailability of nutrients. The presence of antinutritional factors that limits the optimal utilization of wild and traditional vegetables and the extent to which the household food preparation methods could reduce them need investigations. [7]
Dioscorea, an important medicinal plant belonging to the family Dioscoreaceae, comprises 600 species and divided into 23 sections based on the stem twining, leaf morphology, inflorescence, seed wings, bulbil formation, tuber morphology and chemical content. [8] *Dioscorea* species have constitutes a staple food crop for over 100

million people in Africa, Latin America, and Asia. Modern researchers have showed that yam extracts can reduce blood sugar [9] and inhibit microbe activity. [10] Yam also has pharmaceutical usage as they contain a steroid sapogenin compound called diosgenin, which can be extracted and used as a base for drugs such as cortisone and hormonal drugs. Yams are also known to contain some antinutritional components that may have adverse effects on human nutrition [11] despite their high nutritional values. Most yam tubers are acrid and they are associated with irritation and inflammation of the buccal cavity and throat; consumption can result in gastrointestinal disturbances, vomiting, and diarrhea especially when large amounts are ingested into the human body. These are mainly tannins, phenols, and phytic acid. However, bitter principles may be polyphenols or tannin-like compounds [12] while phytic acid (inositol hexaphosphate) is an organic acid found in plant materials which combines with some essential elements such as iron, calcium, zinc and phosphorus to form insoluble salts called phytate which is not absorbed by the body thereby reducing the bioavailability of these elements.

Hou *et al*. [13] have reported that dioscorin from *D. batatas* reacted with antibody raised against trypsin inhibitor from sweet potato tubers, although the two proteins have no known sequence homology, and showed that dioscorins from *D. batatas*, *D. alata*, *D. pseudojaponica* and showed low activity as trypsin inhibitors. Diosgenin is the most abundant sapogenin and the main component used for chemical or microbial conversion. [14] About 70% of that production was based on diosgenin as the initial raw material, about 19% used the diosgenin epimers. [15] So, considering all the above facts the study is to understand the nutritional and antinutritional composition of five *Dioscorea* species were collected and analysed.

2. Material and Methods

Five samples of wild yam tubers (*Dioscorea bulbifera* L., *Dioscorea deltoidea* wall. Ex Griseb., *Dioscorea hispida* Dennst., *Dioscorea oppositifolia* L., and *Dioscorea pentaphylla* L.) grown in sandy red soil consumed by the tribal Malayali's were collected using multistage sampling technique in three consecutive rainy seasons during August and January from Vathal hills, Dharmapuri district, Tamil Nadu. Moisture content was determined by drying the samples in an oven at 80°C for 24 hrs and was expressed on a percentage basis. The samples were powdered in Willey mill 60 mesh size and stored in screw cap bottles at room temperature for further analysis. Nitrogen content was estimated by the micro-kjeldhal method [16] and crude protein was calculated (N x 6.25).

The contents of crude lipid, crude fibre and ash were estimated by AOAC [17] methods. Nitrogen free extract was obtained by difference method by subtracting the sum of the protein, fat, ash and fibre form the total dry matter. [18] The energy value of the corm 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. From the triple acid digested sample, sodium, potassium, calcium, magnesium, iron, copper, zinc and manganese were analysed using an atomic absorption spectrophotometer. Phosphorus was estimated colorimetrically. [19] The total soluble protein of the extract was estimated by the method of Lowry *et al*. [20]. The total starch and sugar content were determined by the titrimetric method of Moorthy and Padmaja [21]. The anti-nutritional factors, total free phenolics, [22] tannins, hydrogen cyanide; [23] total oxalate [24]; trypsin inhibitor activity [25] and amylase inhibitor activity. [26]

2.1 Proximate analysis of nutrient and antinutrient: Spectrophotometrically (UV/VIS Spectrophotometer, Model-Optizen POP, Korea) determination Sadasivam and Manickam, [27] method for carbohydrate, starch and total soluble sugar using anthrone reagent at wavelength 630 nm, protein content using Folin-Ciocalteau reagent at wavelength 660 nm, β-carotene content at wavelength 452 nm, total phenol content using Folin-Ciocalteau reagent at wavelength 650 nm and tannin content using Folin-Denis reagent at wavelength 700 nm. Estimation of fat is done by using organic solvents and quantification by gravimetric method. [28] Ascorbic acid was determined by the titration method using 2, 6 dichlorophenol indophenol solution as described by Sadasivam and Manickam [29]. Trypsin inhibitor using casein reagent at wavelength 660 nm. The subsequent analysis for oxalate content was made following the methods of AOAC [30]. Holloway *et al*. [31] reported that the water extraction gave soluble oxalates, and extraction with acid gave total oxalates. The difference between them equated the amount of calcium oxalate.

2.2 Processing methods

All the five samples were subjected to treatments like soaking, cooking and autoclaving in three replications.

2.3 Soaking

The peeled yam tubers were chipped using hand operated chipping machine (1-3cm) and soaked in distilled water and 0.02% (w/v Sodium bicarbonate ($NaHCO_3$) solution (pH 8.6) for 3, 6, 9 and 12 hours in the ratio of 1:10 (w/v). The water was drained off and the samples were dried at 55°C.

2.4 Cooking

Separate batches of the samples were cooked in distilled water (100°C) in the ratio of 1:10 (w/v) for 10, 20 and 30 minutes. The cooked samples were rinsed and dried.

2.5 Autoclaving

The samples were autoclaved at 15lbs. pressure (121°C) in distilled water (1:10 w/v) for 5, 10, and 15 min. The samples were rinsed with distilled water and dried at 55°C.

2.6. Statistical analysis

Data were analysed using the statistical analysis system SPSS (SPSS Software for windows release 10.0; SPSS Inc., Chicago, IL, USA). Analysis of variance and mean separations were calculated by the general linear model procedures.

3. Results and Discussion

Proximate composition of the nutritional and antinutritional composition of the five species of *Dioscorea* tubers were extensively studied and recorded their values in Table 1. Among the five species the moisture content and dry matter content were estimated initially they varies significantly each species. *Dioscorea bulbifera* recorded highest moisture 93.3% and correspondingly lowest dry matter 25.5% followed by in *D. pentaphylla* 91.1%, 27.6%; *D. oppositifolia* 88.5%, 29.4%; *D. deltoidea* 87.7%, 32.1% of moisture content and dry matter, respectively. While *D.*

hispida showed the lowest moisture and highest dry matter content of 86.2% and 33.2%, respectively. The values recorded were almost similar to the findings of Shajeela *et al*. [32]; Kouakou *et al*. [33]. Overall, *Dioscorea bulbifera* had higher moisture content than *Dioscorea hispida*, while in dry matter, *Dioscorea hispida* were greater than *Dioscorea bulbifera*. These findings were in agreement with the work of Polycarp *et al*. [34]. The dry matter portion of tubers was mostly composed of carbohydrates, which exist primarily in the form of starch and sugars. [35] The proximate composition reveals that the crude protein, crude lipid, crude fibre, ash and NFE content were found to be higher when compared with the earlier reports. [36, 37]

Carbohydrate content was recorded highest in the tubers of *Dioscorea hispida* (81.6%), followed by *D. oppositifolia* (78.2%), *D. deltoidea* (73.2%), *D. pentaphylla* (72.4%). The least amount in *D. bulbifera* (70.1%) which was in agreement with the report of FAO [38] which showed high carbohydrate content of *Dioscorea* tubers ranging from 83-87%. Ezeocha *et al*., [39] who worked on water yam reported carbohydrate content of 76.57% and Polycarp *et al*. [34] who worked on Ghanaian yam also reported high carbohydrate content ranging from 77-87.3%. Comparing at the species level, the carbohydrate content of *Dioscorea hispida* was found greater than *Dioscorea bulbifera* which correlates the findings of Frank and Kingsley [40]. The total carbohydrate consists of sugars, dextrins, starches, pectins, hemicelluloses, celluloses, and lignin. The carbohydrate constitutes the major component of yam tubers. [41] Nutritionally root crops are rich in carbohydrates especially the starches and sugars. Starches are made up of amylase, a straight chain glucose polymer which usually constitutes about 10 to 30 % of the total, and amylopectin. [42]

Starch and total sugar contents were highest in *Dioscorea oppositifolia* (64.28, 5.48 g/100g) followed by *D. pentaphylla* (61.24, 3.27 g/100g), *D. hispida* (60.21, 3.28 g/100g) and *D. deltoidea* (56.26, 3.02 g/100g), respectively. The least contents were observed in *Dioscorea bulbifera* (44.23, 2.75 g/100g). The values recorded were in agreement with the findings of Alamu *et al.* [43]. Crude protein and soluble protein content were observed in maximum level (14.15%, 2.18%) in *D. bulbifera* followed by (13.64%, 1.65%) in *D. oppositifolia*, (11.20%, 1.22%) in *D. hispida* (10.28%, 1.18%) in *D. deltoidea* and minimum level of (5.54%, 1.13%) in *D. pentaphylla*. Our result findings such as crude protein and soluble protein content which correlates with the findings of Knoth [44] where the protein content was 1.1-2.8% for *Dioscorea alata* and 1.1-2% for *Dioscorea rotundata*, [41] who reported yam protein ranging from 1.4-3.5%. Compared the five species under this study *D. bulbifera* showed greater protein level than other species which agrees with the report of Polycarp *et al*. [34]. The protein content of yams from available literature also showed considerable variation among species, a finding which has been attributed to factors such as climate, cultural practices, maturity at harvest and the length of storage time. [51] *Dioscorea* tubers are rich sources of carbohydrate and protein. The protein content is rather low, ranging from 1-2% of the fresh weight. [45]

Crude lipid content was highest in *Dioscorea bulbifera* (7.10 g/100g) and lowest in *D. deltoidea* (2.15 g/100g). Low-fat content (<%) was quite reasonable as all root crops contain very low lipid. [46] Crude fibre content was varied in each species form that *Dioscorea oppositifolia* shoved maximum amount of crude fibre (8.47 g/100g) content followed by *D. hispida* (7.48 g/100g), *D. pentaphylla* (7.13 g/100g) and *D. deltoidea* (6.56 g/100g). The minimum amount of crude fibre content was recorded in *D. bulbifera* (3.69 g/100g). Higher amount of ash content was in tubers of *D. hispida* (8.47 g/100g) followed by *D. deltoidea* (6.15 g/100g), *D. oppositifolia* (6.08 g/100g) and *D. bulbifera* (2.85 g/100g). Lower amount of ash content was observed in *D. pentaphylla* (2.63 g/100g). Nitrogen and gross energy content were estimated, among the five species *Dioscorea pentaphylla* (80.11 g/100g, 1734.50 KJ.100^{-1} DM) showed the higher values followed by *D. hispida* (72.31 g/100g, 1590.35 KJ.100^{-1} DM), *D. deltoidea* (71.21 g/100g, 1564.68 KJ.100^{-1} DM) and *D. bulbifera* (68.34 g/100g, 1490.55 KJ.100^{-1} DM), respectively. The lower values of nitrogen and gross energy was observed in *D. oppositifolia* (65.96 g/100g, 1472.35 KJ.100^{-1} DM) respectively.

Tannin content was highest (85.24 mg/100g) in *Dioscorea bulbifera* followed by (52.21 mg/100g) in *D. deltoidea*, (44.57 mg/100g) in *D. pentaphylla* and (37.81 mg/100g) and least in *D. hispida* (25.61 mg/100g) these results were correlates with the findings of Polycarp *et al.* (2012) were tannin content ranges from 10.75-13.2 mg/100 g for *D. alata*, but lower than the values as reported by Ezeocha and Ojimelukwe [47] in *D. alata* which is 21 mg/100 g and 41 mg/100 g respectively. Alamu *et al.* [43] has reported the tannin content for *D. rotundata* varieties of Nigeria ranging from 62-118 mg/100g while Shanthakumari *et al.* [48] reported range between 20 mg/100 g dry matter in *D. rotundata* and 75 mg/100 g dry matter in *D. alata*. Tannins are phenolic compounds and they usually interfere with iron absorption through a complex formation with iron when it is in the gastrointestinal lumen which decreases the bioavailability of iron. Phytates and tannins bind with protein and minerals to form a soluble complex, thereby reducing protein and mineral bioavailability. [49] The level of tannins is found to be lower when compared with the earlier reports of the tubers of *Dioscorea alata*, *D. cayenensis*, *D. rotundata* and *D. esculenta*. The tubers of *D. oppositifolia* contain more trypsin inhibitor activity when compared with earlier reports in the tubers of *Dioscorea dumetorum* and *D. rotundata*. [50] Tannins have shown potential antibacterial activity. [51] Tannins have also been reported to exert other physiological effects, such as to accelerate blood clotting, reduce blood pressure, decrease the serum lipid level, produce liver necrosis and modulate immune responses. [52] It has been reported that tannins are known to inhibit the activities of digestive enzymes [53] and hence the presence of even a low level of tannin is not desirable from nutritional point of view.

Total oxalate, water soluble oxalate and calcium oxalate contents were recorded maximum (0.96, 0.56 and 0.42 mg/100g) in the tubers of *D. bulbifera* followed by (0.84, 0.52 and 0.32 mg/100g) in *D. deltoidea*, (0.79, 0.50 and 0.29 mg/100g) in *D. hispida* and (0.75, 0.50 and 0.29 mg/100g) in *D. oppositifolia* and minimum was recorded in *D. pentaphylla* (0.71, 0.46 and 0.25 mg/100g), respectively. Sodium content was maximum (112.35 mg/100g) in the tubers of *D. oppositifolia* followed by (83.66 mg/100g) in *D. pentaphylla*, (62.24 mg/100g) in *D. bulbifera* and (52.15 mg/100g) in *D. hispida* and minimum was recorded in *D. deltoidea* (31.12 mg/100g), respectively. Similarly, potassium and calcium content were higher 1645.24 and 561.25 mg/100g in the tubers of *D. hispida* followed by

(1551.05 and 336.15 mg/100g) in *D. deltoidea*, (1548.11 and 234.15 mg/100g) in *D. bulbifera* and (1462.23 and 226.14 mg/100g) in *D. oppositifolia* and minimum was recorded in *D. pentaphylla* (1230.21 and 124.35 mg/100g), respectively. The tubers are found to contain more than the adequate level of potassium compared to RDA's of infants and children (<800mg). Apart from being an item of food, yam is becoming increasingly important medicinally because of the toxic principles present.

Magnesium, phosphorus and zinc contents were estimated in all the tuber of *Dioscorea* species, from that maximum amount (565.04, 136.23 and 3.33 mg/100g) in the tubers of *D. pentaphylla* followed by (548.66, 125.24 and 1.48 mg/100g) in *D. hispida*, (431.02, 122.25 and 1.32 mg/100g) in *D. bulbifera*, (398.22, 112.02 and 1.24 mg/100g) in *D. deltoidea* and minimum amount was recorded in *D. oppositifolia* (333.21, 99.34 and 1.20 mg/100g), respectively. Manganese, iron and copper contents were recorded higher (10.25, 78.65 and 19.26 mg/100g) in *D. bulbifera* followed by (8.25, 32.23 and 16.25 mg/100g) in *D. deltoidea*, (5.63, 24.54 and 14.20 mg/100g) in *D. hispida* (4.54, 19.26 and 12.74 mg/100g) in *D. oppositifolia* and minimum amount was recorded in *D. pentaphylla* (2.24, 13.65 and 10.34 mg/100g), respectively.

Table 1: Quantification of nutritional and anti-nutritional composition in tubers of *Dioscorea* species.

	D. bulbifera	***D. deltoidea***	***D. hispida***	***D. oppositifolia***	***D. pentaphylla***
Proximate composition (g/100g)					
Moisture	93.26±0.87	87.65±0.54	86.22±0.33	88.54±0.91	91.13±0.55
Dry matter	25.5±0.30	32.1±0.27	33.2±0.21	29.4±0.20	27.6±0.15
CHO	70.1±0.67	73.5±0.71	81.6±0.75	78.2±0.75	72.4±0.70
Starch	44.23±1.42	56.26±0.14	60.21±0.52	64.28±0.63	61.24±0.23
Total sugar	2.75±0.23	6.02±0.31	3.28±0.27	5.48±0.08	3.27±0.31
CP	14.15±0.11	10.28±0.15	11.20±0.06	13.64±0.11	5.54±0.09
SP	2.18±0.21	1.18±0.08	1.22±0.10	1.65±0.12	1.13±0.14
Crude lipid	7.10±0.02	2.15±0.02	2.48±0.02	6.45±0.12	4.21±0.03
Crude fibre	3.69±0.03	6.56±0.14	7.84±0.05	8.47±0.11	7.13±0.06
Ash	2.85±0.02	8.47±0.05	6.15±0.12	6.08±0.03	2.63±0.04
Nitrogen	68.34±0.60	71.21±0.68	72.31±0.70	65.96±0.61	80.11±0.75
Gross energy	1734.50	1472.35	1490.55	1564.68	1590.35
Mineral composition (mg/100g)					
Tannin	84.24±6.41	52.21±4.81	25.61±1.12	37.81±2.63	44.57±3.32
Total oxalate	0.98±0.001	0.84±0.002	0.79±0.003	0.75±0.003	0.71±0.001
WSO	0.56±0.003	0.52±0.002	0.50±0.005	0.48±0.004	0.45±0.005
CO	0.42±0.003	0.35±0.002	0.29±0.004	0.27±0.003	0.26±0.002
Sodium	62.24±0.24	31.12±0.21	52.15±0.25	112.35±0.34	83.66±0.45
Potassium	1548.11±0.82	155.05±1.21	1645.47±0.24	1462.23±0.25	1230.21±0.56
Calcium	234.15±0.65	336.15±0.12	561.25±0.47	226.14±0.08	124.35±0.36
Magnesium	431.02±0.45	398.22±0.12	548.66±0.42	333.21±1.30	565.04±0.03
Phosphorus	122.25±0.07	112.02±0.16	125.24±0.24	99.34±0.12	136.23±0.13
Zinc	1.32±0.06	1.24±0.01	1.48±0.02	1.20±0.05	3.33±0.03
Manganese	10.25±0.03	8.25±0.24	5.63±0.02	4.54±0.02	2.24±0.01
Iron	78.65±0.24	32.23±0.05	24.54±0.02	19.26±0.04	13.65±0.03
Copper	19.26±0.07	16.25±0.03	14.20±0.21	12.74±0.08	10.34±0.06
β-carotene	0.42±0.002	0.22±0.001	0.20±0.001	0.24±0.002	0.37±0.002
Vitamin C	8.72±0.06	7.25±0.05	6.73±0.05	7.57±0.06	8.26±0.07
HC	1.22±0.002	0.45±0.004	0.34±0.002	0.60±0.002	0.96±0.002

Note: Values are mean of triplicate determinations expressed on dry weight basis, ± standard error.

CHO - Carbohydrates, CP - Crude protein, SP - Soluble protein, WSO - Water soluble oxalate; CO - Calcium oxalate, AIU - Amylase inhibitor; TIU - Trypsin inhibitor; HC - Hydrogen cyanide.

Beta-carotene, vitamin C and hydrogen cyanide contents were recorded higher (0.42, 8.72 and 1.22 mg/100g) in *D. bulbifera* followed by (0.37, 8.26 and 0.96 mg/100g) in *D. pentaphylla*, (0.24, 7.57 and 0.60 mg/100g) in *D. oppositifolia* and (0.22, 6.73 and 0.45 mg/100g) in *D. deltoidea* and minimum amount was recorded in *D. hispida* (0.24, 7.25 and 0.34 mg/100g), respectively. It was found to be low in all the yam species, though low it varies significantly. Osagie [54] reported that beta-carotene in yam ranges from 0.0-10.0 mg/ 100 g. The range of vitamin C content in yam tubers as reported by Udensi *et al*. [55] which is 16.7-28.4 mg/100 g, on fresh weight basis. Natural vitamin C levels of most yam varieties are between 6.5 and 11 mg/100 g of the tuber, but some are found to contain as small as 4.5 mg and as much as 21.5 mg/100 g. Ascorbic acid (Vitamin C) is a natural antihistamine which prevents histamine release and increase the detoxification of histamine. [56] Vitamin C may also be useful in lowering serum uric acid levels resulting in a correspondingly lower incidence of gout [57] and an oxidized version that can cross the blood-brain barrier may reduce neurological deficits and mortality following a stroke. [58]

The effect of different treatment of tubers of *Dioscorea* species showed the reduction of anti-nutritional factors like total free phenolics, tannins, hydrogen cyanide, total oxalate, amylase inhibitor and trypsin inhibitor activities are presented in Table 2. In raw tubers samples showed different amount of total free phenolics ranged from 0.43 to 1.48 g/100g among species. When the samples were treated with different household method to reduce all antinutritional factors. In raw, *Dioscorea hispida* tubers showed highest values of total free phenolic content (1.48 g/100g), tannin

(1.75 g/100g), hydrogen cyanide (0.19 mg/100g) and total oxalate (1.11g /100g) followed by *D. bulbifera* (1.38, 1.54, 0.16 and 0.97), *D. oppositifolia* (1.12, 0.54, 0.15 and 0.91) and *D. deltoidea* (0.86, 0.51, 0.13 and 0.66) respectively. The lowest amount was observed in *D. pentaphylla* (0.43, 0.22, 0.12 and 0.23) respectively. These raw sample antinutritional contents were gradually decreased in soaking in distilled water 12 hrs then soaking in sodium bicarbonate solution 12 hrs, cooking 30 min and autoclaving 15 min. When compared to all the treatments the antinutritional contents were greatly reduced by autoclaving in 15 min method. Phenolic compounds inhibit the activity of digestive as well as hydrolytic enzymes such as amylase, trypsin, chymotrypsin and lipase. [59] The total free phenolics content in raw samples 1.48 mg/100g in the tubers of *Dioscorea hispida* and *D. pentaphylla* is lower (0.43 mg/100g) than that of the earlier studies in the tubers of *D. alata.* [54]

Table 2: Estimation of anti-nutritional activity in different treatments in *Dioscorea bulbifera, D. deltoidea, D. hispida, D. oppositifolia* and *D. pentaphylla*.

	Samples	Total free phenolics g/100g	Tannin g/100g	Hydrogen cyanide mg/100g	Total oxalate g/100g	Amylase inhibitor AIU	Trypsin inhibitor TIU
T1	S1	1.38±0.003	1.54±0.014	0.16±0.001	0.97±0.002	9.12	3.23
	S2	0.86±0.002	0.51±0.002	0.13±0.002	0.66±0.002	8.34	2.15
	S3	1.48±0.004	1.75±0.007	0.19±0.002	1.11±0.003	12.23	5.96
	S4	1.12±0.002	0.54±0.004	0.15±0.006	0.91±0.002	9.56	2.92
	S5	0.43±0.001	0.22±0.001	0.12±0.003	0.23±0.002	3.02	1.88
T2	S1	1.08±0.001 (-21)	1.32±0.001 (-14)	0.12±0.002 (-25)	0.85±0.006 (-12)	8.64 (-5)	2.66 (-17)
	S2	0.62±0.007 (-27)	0.44±0.008 (-13)	0.10±0.002 (-23)	0.56±0.002 (-15)	7.23 (-13)	2.10 (-2)
	S3	1.33±0.003 (-10)	1.38±0.006 (-21)	0.16±0.001 (-15)	0.96±0.001 (-13)	11.27 (-7)	5.22 (-12)
	S4	0.92±0.005 (-17)	0.47±0.003 (-12)	0.11±0.001 (-26)	0.82±0.003 (-9)	8.54 (-10)	2.47 (-15)
	S5	0.38±0.003 (-11)	0.19±0.002 (-13)	0.08±0.001 (-33)	0.20±0.002 (-13)	2.71 (-10)	1.45 (-22)
T3	S1	1.02±0.002 (-26)	1.24±0.003 (-19)	0.10±0.001 (-37)	0.80±0.006 (-17)	8.02 (-12)	2.45 (-24)
	S2	0.58±0.003 (-32)	0.37±0.001 (-27)	0.08±0.001 (-38)	0.52±0.004 (-21)	6.63 (-20)	1.95 (-9)
	S3	1.28±0.002 (-13)	1.33±0.001 (-24)	0.14±0.001 (-26)	0.81±0.006(-27)	10.21 (-16)	4.73 (-20)
	S4	0.87±0.005 (-22)	0.44±0.004 (-18)	0.09±0.001 (-40)	0.77±0.004 (-15)	7.23 (-24)	2.31 (-20)
	S5	0.36±0.002 (-16)	0.17±0.001 (-22)	0.06±0.001 (-50)	0.17±0.001 (-26)	2.23 (-26)	1.12 (-40)
T4	S1	0.91±0.002 (-34)	1.05±0.001 (-31)	0.08±0.002 (-50)	0.73±0.004 (-24)	7.70 (-15)	2.21 (-31)
	S2	0.47±0.001 (-45)	0.32±0.002 (-37)	0.06±0.001 (-53)	0.48±0.004 (-27)	6.18 (-25)	1.65 (-23)
	S3	1.05±0.002 (-29)	1.22±0.001 (-30)	0.12±0.003 (-36)	0.77±0.003 (-30)	9.02 (-26)	3.82 (-35)
	S4	0.72±0.002 (-35)	0.38±0.003 (-29)	0.07±0.001 (-53)	0.62±0.002 (-31)	6.64 (-30)	2.01 (-31)
	S5	0.30±0.001 (-30)	0.14±0.001 (-36)	0.05±0.001 (-58)	0.15±0.002 (-34)	1.92 (-36)	0.92 (-51)
T5	S1	0.82±0.005 (-40)	0.97±0.002 (-37)	0.07±0.001 (-56)	0.58±0.003 (-40)	7.22 (-20)	2.01 (-37)
	S2	0.40±0.002 (-53)	0.26±0.001 (-49)	0.04±0.001 (-69)	0.44±0.002 (-33)	5.61 (-32)	1.32 (-38)
	S3	0.93±0.006 (-37)	1.06±0.005 (-39)	0.10±0.001 (-47)	0.70±0.002 (-36)	9.54 (-21)	3.13 (-47)
	S4	0.66±0.002 (-41)	0.33±0.001 (-38)	0.05±0.002 (-73)	0.57±0.002 (-37)	6.42 (-32)	1.94 (-33)
	S5	0.28±0.002 (-34)	0.10±0.001 (-54)	0.03±0.001 (-75)	0.13±0.001 (-43)	1.82 (-39)	0.67 (-64)

Note: T1 - Raw sample; T2 - Soaking in distilled water 12 hrs; T3 - Soaking in sodium bicarbonate solution 12 hrs; T4 - Cooking 30 min; T5 - Autoclaving 15 min.
S1 - *D. bulbifera*; S2 - *D. deltoidea*; S3 - *D. hispida*; S4 - *D. oppositifolia*; S5 - *D. pentaphylla*.
Values are mean of triplicate determinations expressed on dry weight basis, ± standard error (P<0.01).

Recent researches report that the phenolic compound is the main human dietary antioxidant and has a decreased incidence of chronic diseases. A number of polyphenolic compounds are present in plants, which contribute towards the defense mechanism of plants. Although these are considered earlier as antinutritional compounds, under the present nomenclature phenols fall under the category of nutraceuticals, offering many nutritional advantages to man. [60] The decrease in the content of total free phenolics and tannins during soaking may be due to leaching out of the phenolic substances in soaking under the influence of concentration gradient. A lot of HCN (known to inhibit the respiratory chain at the cytochrome oxidase level) is lost during soaking and cooking [61] so that its content in the tubers poses no danger of toxicity. When the yam tubers were subjected to soaking, cooking for 30 min and autoclaving for 15 min significant reduction (P<0.05) has been observed in the levels of hydrogen cyanide and total oxalate.

Amylase inhibitor (AIU) and trypsin inhibitor units (TIU) were recorded maximum (12.23 and 5.96) in raw tubers of *Dioscorea hispida* followed by *D. bulbifera* (9.12 and 3.23), *D. oppositifolia* (9.56 and 2.92), and *D. deltoidea* (8.34 and 2.15), respectively. The minimum amount was observed in *D. pentaphylla* (3.02 and 1.88) respectively. These enzymes inhibitor levels were gradually decreased in *D. hispida* with soaking in distilled water 12 hrs followed by soaking in sodium bicarbonate solution 12 hrs, cooking 30 min and autoclaving 15 min. Higher level of reduction were observed in autoclaving in 15 min method followed by cooking 30 min, soaking in sodium bicarbonate 12 hrs and lesser level of reduction recorded in soaking in distilled water for 12 hrs. Inhibitors of alpha amylases and protein digesting enzymes interfere with the digestion of starch and protein. Hence, attempt has been made to eliminate these inhibitors. Boiling for sufficient time makes the tubers soft enough and inactivates all the trypsin inhibitor. Many foods including the root crops cannot be digested in their natural state and hence requires cooking, which increases the palatability, the keeping qualities and the safety of the foods from potentially toxic substances. [62] Soaking of tubers of *Dioscorea bulbifera* and *D. hispida* in distilled water and sodium bicarbonate solution (0.02%w/v for 12 hrs.) showed only 6-10% of reduction in the level of phenolics favouring health benefits. However, excess of phenolics and tannins should be removed. Pressure cooking resulted in maximum loss of phenolics, tannins and total oxalate (P<0.01 in *D. oppositifolia* and *D. bulbifera* and P<0.05 in *D. alata*)

followed by cooking and soaking.

4. Conclusion

All the studied species of *Dioscorea* tubers have low levels of phenols, tannins, oxalates and trypsin inhibitors so can be safely used. The determination of the anti-nutritional substances was of interest because of their toxicity in tubers, negative effects on mineral bioavailability and their pharmacological effect. Based on the nutritive evaluation studies on the wild edible tubers consumed by the tribal Malayalis, it can be summarized that most of them are found to be a good source of protein, lipid, crude fibre, starch and minerals. Various processing methods showed that autoclaving seems to be the best for the removal / inactivation of anti-nutritional factors as there is significant reduction ($P<0.05$) in amount of antinutrients thus improving digestibility. Comparing at species level *D. hispida* was high in dry matter, carbohydrate and starch while *D. oppositifolia* were high in moisture, protein, fat, vitamin C, tannin and TIA.

5. Acknowledgements

The author is greatly thankful to the Principal and Head of the Department, PG and Research Department of Botany, Government Arts College, Dharmapuri - 636705, Tamil Nadu, India for providing the laboratory facilities to carry out this research work.

6. References

1. Ugwu FM. The potentials of roots and tubers as weaning foods. Pakistan Journal of Nutrition. 2009; 8:1701-1705.
2. Vidyarthi LP. Role of forest in tribal life. Tribals and Foress. Ed. SP Sinha, Bihar Tribal Welfare Research Institute, Ranchi, 1987, 323.
3. Getachew GA, Asfaw Z, Singh V, Woldu Z, Baidu-Forson JJ, Bhattacharya S. Dietary values of wild and semi-wild edible plants in Southern Ethiopia. African Journal of Food, Agriculture, Nutrition and Development. 2013; 13(2):121-141.
4. Romojaro A, Botella MA, Obon C, Pretel MT. Nutritional and antioxidant properties of wild edible plants and their use as potential ingredients in the modern diet. International Journal of Food Sciences and Nutrition. 2013; 64(8):944-952.
5. Yildirim E, Dursun A, Turan M. Determination of the nutrition contents of the wild plants used as vegetables in Upper Coruh Valley. Turkish Journal of Botany. 2001; 25(6):367-371.
6. Gupta S, Jyothi Lakshmi A, Manjunath MN, Prakash J. Analysis of nutrient and antinutrient content of underutilized green leafy vegetables. LWT-Food Science and Technology. 2005; 38(4):339-345.
7. Umeta M, West CE, Fufa H. Content of zinc, iron, calcium and their absorption inhibitors in foods commonly consumed in Ethiopia. Journal of Food Composition and Analysis. 2005; 18(8):803-817.
8. Wanasundera JPD, Ravindran G. Nutritional assessment of yam (*Dioscorea alata*) tubers. Plant Food Hum Nutr, 1994; 46:33-39.
9. Undie AS, Akubue PI. Pharmacological evaluation of *Dioscorea dumetorum* tuber used in traditional antidiabetic therapy. Journal of Ethnopharmacology. 1986; 15:133-144.
10. Kelmanson JE, Jager AK, Van SJ. Zulu medicinal plants with antibacterial activity. Journal of Ethnoparmacology, 2000; 69:241-246.
11. Dipak HD, Mukherjee KD Functional properties of rapeseed protein products with varying phytic acid contents. J Agric Food Chem., 1986; 34:775-780.
12. Coursey DG. Cassava as Food: Toxicity and Technology. In: Nestel B, and R MacIntyre, (Eds.), *Chronic Cassava Toxicity*, Ottawa, Canada, IDRC, IDRC-10e, 1973, 2736.
13. Hou WC, Chen HJ, Lin YH. Dioscorins from different *Dioscorea* species all exhibit both carbonic anhydrase and trypsin inhibitor activities. Botanical Bulletin of Academia Sinica. 2000; 41:191-196.
14. Xu GJ, Xu LS. Species systematization and quality evaluation of commonly used Chinese traditional drugs, 1997, II. Fuzhou: Fujian Science and Technology Press.
15. Shewry P. Tuber storage proteins. Ann Bot (Lond). 2003; 91:755-769.
16. Humphries EC. Mineral components and ash analysis. In: Paech K; Tracey MV (Eds.). Modern methods of

plant analysis. Berlin: Springer,.1956; 1:468-502.
17. AOAC - Association of Official Analytical Chemists. Official methods of analysis. 11. ed, 1970.
18. Muller HG, Tobin G. Nutrition and Food Processing. Croom Helm Ltd., London, 1980.
19. Issac RA, Johnson WC. Collaborative study of wet and dry ashing techniques for the elemental analysis of plant tissue by Atomic Absorption Spectrophotometer. Journal of the Association of Official Analytical Chemists. 1975; 58:436-440.
20. Lowry OH, Rosebrough NJ, Farr AL, Randall RJ. Protein measurement with Folin-Phenol reagent. Journal of Biological Chemistry. 1951; 193:263-275.
21. Moorthy SN, Padmaja G. A rapid titrimetric method for the determination of starch content of cassava tubers. Journal of Root Crops. 2002; 28:31-38.
22. Dickman SR, Bray RH. Colorimetric determination of Phosphate. Industrial and Engineering Chemistry, Analytical Education. 1940; 12:665-668.
23. Jackson ML. Cyanide in plant tissue. In: Soil Chemical Analysis. Asia Publishing House, New Delhi, India, 1967, 337.
24. AOAC. Official Methods of Analysis of the Association of Official Analytical Chemists. 18th Ed., Association of Official Analytical Chemists, Gaithersburg, MD, 2005.
25. Sasikiran K, Padmaja G. Inactivation of trypsin inhibitors in sweet potato and taro tubers during processing. Plant Foods for Human Nutrition. 2003; 58: 153-163.
26. Rekha MR, Padmaja G. Alpha-amylase inhibitor changes during processing of sweet potato and taro tubers. Plant Foods for Human Nutrition, 2002; 57: 285-294.
27. Sadasivam, Manickam. Biochemical Methods. New age International publishers. 3rd edition, 2011.
28. Folch J, Lees M, Sloane Stanley GHS. A simple method for the isolation and purification of total lipids from animals. J BiolChem. 1957; 226:497-509.
29. Sadasivam S, Manickam A, (Eds.) Biochemical Methods. New Age International (P). Limited. Publishers. New Delhi. India, 1996, 1-250.
30. AOAC. Official Methods of Analysis (14th edn.) Association of Official Analytical Chemist, Washington. DC, 1984.
31. Holloway WD, Argall ME, Jealous WT, Lee JA, Bradbury JH. Organic acid and calcium oxalate in tropical root crops. J Agric and Food Chem. 1989; 37:337-341.
32. Shajeela PS, Mohan VR, Louis JL, TresinaSoris P. Nutritional and antinutritional evaluation of wild yam (*Dioscorea* spp.). Tropical and Subtropical Agroecosystems. 2011; 14:723-730.
33. Kouakou DM, Dabonne S, Tagro GS, Patrice KL. Monitoring some biochemical parameters of two yam species (*Dioscorea* spp.) tubers parts during post harvest storage. Advance Journal of Food Science and Technology. 2010; 2(3):178-183.
34. Polycarp D, Afoakwa EO, Budu AS, Otoo E. Characterization of chemical composition and anti-nutritional factors in seven species within the Ghanaian yam (*Dioscorea*) germplasm. Int Food Res J. 2012; 19(3):985-992.
35. Ikediobi CO, Oti E. Some biochemical changes associated with post-harvest storage of white yam (*Dioscorea rotundata*) tubers. Journal of the Science of Food and Agriculture. 1983; 34:1123-1129.
36. Oyenuga VA. Nigeria's Food and Feeding Stuffs, Ibadan University Press, Ibadan, Nigeria, 1968, 99.
37. Rajyalakshmi P, Geervani P. Nutritive value of the foods cultivated and consumed by the tribals of South India. Plant Foods for Human Nutrition. 1994; 46:53-61.
38. FAO. Food and Agriculture organization of the United Nations: Production, Rome, Italy, 2001.
39. Ezeocha VC, Ojimelukwe PC. The impact of cooking on the proximate composition and anti-nutritional factors of water yam (*Dioscorea alata*). J Stored Products and Postharvest Res. 2012; 3(13):172-176.
40. Frank OC, Kingsley AC. Proximate Composition, Physiological Changes during Storage, and Shelf Life of Some Nigerian Varieties of Yams (*Dioscorea* spp.). Journal of Scientific Research and Reports. 2014; 3(4):553-562.
41. Osagie AU. The yam tuber in storage. Post-Harvest Research Unit, University of Benin, Nigeria. 1992; 107-173.
42. Treche S. Tropical root and tuber crops as humans staple food. Conference presentee au I Congresso Latino Americano de Raizes Tropicais. 1996, 4.
43. Alamu E, Oladeji, Maziya D, Bussie Okonkwo, Cristian C, Asiedu R. Physicochemical and bioactive properties of selected white yam (*Dioscorea rotundata*) varieties adapted to riverine areas of Nigeria. Afr J Food Sci. 2014; 8(7):402-409.
44. Knoth J. Traditional storage of yams and cassava and its improvement. *Deutsche Gesellschaft für Technische Zusammenarbit (GTZ)* post-harvest project. Hamburg Germany, 1993.
45. Martin FW. Composition, nutritional value and toxic substances of the tropical yams. In Tropical Foods: Chemistry and Nutrition. 1979; 1:249-264.
46. Mandal RC. Yams: Chemical Composition. In: Tropical Root and Tuber Crops. Agrobios (India), 2006, 326-327.
47. Ezeocha VC, Ojimelukwe PC. The impact of cooking on the proximate composition and anti-nutritional factors of water yam (*Dioscorea alata*). J Stored Products and Postharvest Res., 2012; 3(13):172-176.
48. Shanthakumari S, Mohan VR, Britto J. Nutritional evaluation and elimination of toxic principles in wild yam (*Dioscorea* spp.). Tropical and Subtropical Agroecosystems. 2008; 8(3):319-325.
49. Liener IE. Miscellaneous toxic factor: In Toxic Constituents of Plant Food stuff(Ed), Academic press, London, 1980, 430-469.
50. Sasikaran K, Padmaja G, Easwari Amma CS, Sheela MN. Trypsin and Chymotrypsin inhibitor activities of sweet potato and yam tubers. Journal of Root Crops. 1999; 25:195-199.
51. Kolodziej H, Kiderlen AF. Antileishmanial activity and immune modulatory effects of tannins and related compounds on Leishmania parasitized RAW 264.7 cells. Phytochemistry. 2005; 66:205671.
52. Archana A, Bele Varsha, M Jadhav Kadam. Potential of Tannins: A review. Journal of Plant Sci. 2010; 9:209-214.
53. Jumbunathan R, Singh U. Grain quality of pigeon pea.

In: Proceeding of the International workshop on pigeon pea. Vol. I, ICRISAT, Hyderabad, Andhrapradesh, India, 1981, 351-356.
54. Osagie AU, Opoku AR. Enzymatic browning of yams. Nigerian Journal of Biochemistry. 1994; 1:25-29.
55. Udensi EA, Oselebe HO, Iweala OO. The investigation of chemical composition and functional properties of water yam (*Dioscoreaalata*): effect of varietal differences. Pakistan Journal of Nutrition. 2008; 7(2):342-344.
56. Jihnston CS, Martin LJ, Cai X. Antihistamine effect of supplemental ascorbic acid and neutrophil chemitaxis. Am. Coll. Nutr. 1992; 11:172-176.
57. Choi HK, Gao X, Curhan G, Xiang Gao Curhan G. Vitamin C intake and the risk of gout in men. Archivesof Internal Medicine. 2009; 169:502-507.
58. Huang JA, Agus DB, et al. Dehydroascorbic acid, a blood-brain barrier transportable from of vitamin C, mediates potent cerebroprotection in experimental stroke. Proceedings of the National Academy of Sciences. 2001; 98:11720-11724.
59. Salunkhe DK, Sathe SK, Reddy NR. Legume Lipids. In: Chemistry and Biochemistry of Legumes (Ed.) Arora SK Oxford and IBH Publishing Co, New Delhi, India, 1982, 51-107.
60. Padmaja G, Moorthy SN, Nambisan B, Babu L, Sundaresan S, Sajeev MS, Nanda SK, Susan John K, Rajalekshmy L, Sudha Devi KS, Manikantan Nair M. Digestibility of Starch and Protein. In: Analytical Methodologies for Tropical Tuber Crops. Eds: Central Tuber Crops Research Institute, Kerala, 2005, 34-38.
61. Kay T, Ogunsona VA, Eka OU. The prevention of beany taste development and the elimination of bitter taste in preparing soyabean food in the rural community in Nigeria. Samuru Agricultural News Letter. 1977; 19:11.
62. Bradbury JH, Holloway WD. Chemistry of tropical root crops: Significance for nutrition and agriculture in the Pacific, Australian Centre for International Agricultural Research, Canberra, 1988, 89-133.