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Traditional processing associated changes in chemical parameters of wild Yam (*Dioscorea*) tubers from Koraput, Odisha, India

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Wild yam tuber considered as famine food and played a prime role in the food habit of tribal people of Koraput district of Odisha, India. The tribal people employed a range of processing of these yams such as boiled, soaked and sun dried for detoxification of antinutrients in accordance with their needs. There is a scarcity of documented information on their nutrient composition/retention by traditional processing methods. The current study assessed the traditional processing (boiled, soaked and sun dried) associated changes in chemical composition and physico-functional characteristics of 6 wild and 1 cultivated *Dioscorea* tubers collected from Koraput, India. Different processing led to a significant reduction of proximate compositions and nutrient content compared to the raw tuber, whereas physico-functional parameters increased significantly ($p<0.05$). In addition, there was significant decrease in the antinutrients, minerals and vitamin content by different processing in studied yam species. Results suggested that wild *Dioscorea* tubers as safe food sources for mass consumption and should be used in boiling form, as it retains higher nutrients coupled with significant removal of antinutritional compositions.

Keywords: *Dioscorea* tubers, Nutritional composition, Proximate composition, Traditional processing

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Roots and tubers form a significant component of food in the tropics and sub-tropics of the world and it has assumed importance in the dietary habits of indigenous communities[1]. Yam (*Dioscorea*) being a high value crop, it contributes about 10% of the total root and tubers production around the world[2-3]. In the developing world, while food security is concerned, wild yams with high calorie and rich carbohydrate content occupy a prominent position[4]. *Dioscorea* are annual or perennial climber species with underground edible tuber in the family Dioscoreacea and worldwide more than 600 species are represented under the genus[5-6]. *Dioscorea* has a great diversity of species that are used as indigenous food by small and marginal rural families and forest-dwelling communities[4,7,8]. Further, because of presence various bioactive constituents, these species are regarded unique in terms of their food, medicinal and economic value[9]. In different parts of the world varieties of edible wild yam species are found to differ in their chemical composition and nutritional values[10]. Though, there are some reports on chemical compositions of the *Dioscorea* species of Nepalese[10], Indian[11] and Ghanaian[12] species but there is a dearth of information on wild edible *Dioscorea* species of Koraput.

Koraput districts in the Indian state of Odisha is one of the agro-biodiversity hotspots and a storehouse of great diversity of food crops and plant species[13]. Several cultivated and wild *Dioscorea* tubers have been used as food and medicine by the forest-dwelling communities of Koraput[9,14]. These yams were used in different forms by employing different processing, mainly fried, baked or boiled. However, their wider utilisation has been limited because of presence of many antinutritional compositions[4,8]. Most of the wild yams are acrid in nature and are caused irritation, inflammation leading to gastrointestinal disturbances[10]. The tribal/rural people collected wild tubers and have practised different traditional processing such as boiled, soaked and sun dried for detoxification of antinutrients in accordance to their needs[9]. Limited scientific information is available on the chemical parameters in the wild *Dioscorea* species and also scientifically their

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indigenous detoxification or food processing practice is not yet been studied. The knowledge on wild tuber and their uses by tribal people has the potential for addressing food security and physico-functional properties have become important for bio-prospecting of flour out of tuber in food industries[15]. The present work aims to ascertain the effect of traditional processing practices on their nutrient and antinutrient retentions in wild *Dioscorea* species of Koraput. The study aims to suggest a method to remove the antinutrient/toxins from the wild *Dioscorea* species and make these edible tubers as safe food sources for mass consumption.

Materials and methods

Collection and processing of yam tuber

Six edible wild yam species namely *Dioscorea bulbifera*, *D. glabra, D. hamiltonii, D. hispida, D. pentaphylla* and *D. pubera,* including *D. alata*, a cultivated species was used in the study. These are consumed frequently as food as well as vegetables by tribals of Koraput. The details of yam tubers and their traditional consumption practice are presented in Table 1. The matured tubers of each species were collected from the garden of Central University of Orissa, Koraput, which were grown under same ago-climatic conditions[16]. The freshly collected tubers were sliced into pieces of ~2.5 mm diameter, divided into 4 sections and subjected to different traditional processing methods, such as raw, boiled, water soaked and sun dried. The first section which was peeled, was used as raw yam; the second portion was made into small pieces followed by boiling for 30 min at 100ºC. The third portion of the raw yam which were peeled and sliced were made to soak for 24 h in distilled water and used as soaked sample. The peeled, washed and sliced raw yam in the fourth section was subjected to sun drying for 4 days. All the processed samples were dried in shade for 4-6 days. After processing the samples were grounded into powder mechanically and used for analysis.

Measurement of proximate composition

For measurement of moisture content, samples were oven dried at 105ºC for 24 h to a constant weight[17]. The determination of crude fat was done for 3 h in a lipid extractor and the solvent used petroleum ether[17]. To determine the ash content, the samples were ignited at 600ºC for a period of 3 h in muffle furnace and weight of the residue was taken[17]. Using standard methods crude fibre content were determined[17].

Measurement of physico-functional parameters

water solubility index (WSI) of *Dioscorea* tubers were carried out following the method of Anderson *et al.*[19]. Water absorption capacity (WAC) was measured following the method of Phillips *et al.*[18]. Foam capacity (FC) was determined as per the method of Coffman and Garcia [20]. Paste clarity (PC) of flour was measured following the method of Craig *et al.*[21]

Determination of nutritional Compositions

Starch, reducing sugar and amylose content of yam tuber sample were determined following the method of Sadasivam and Manickam[22]. Protein content of tubers was estimated as per the procedure of Lowry *et al.* (1951)[23]. Ascorbic acid (Vitamin C) content was measured following the method of Omaye *et al.*[24] and the value was expressed as mg/100 g on dry weight basis. The α-Tocopherol (vitamin E) was measured following the method of Baker *et al.*[25] by using α-tocopherol as standard.

Determination of anti-nutritional compositions

Diosgenin content was determined followed by the method of Uematsu *et al.*[26] by using diosgenin as

Table 1 — Details of yam species with their tribal consumption practice from Koraput, India.

Accession No	Yam species	Tribal consumption practice
CUO 001	*Dioscorea bulbifera* L.	Tubers are sliced, boiled and kept overnight to remove bitterness and cooked as curry.
CUO 002	*Dioscorea hamiltonii* Hook. f.	Tuber are boiled and used to make curry.
CUO 003	*Dioscorea pubera Blume*	Tubers are boiled and cooked as vegetable.
CUO 004	*Dioscorea hispida* Dennst.	Tubers are sliced and soaked in water for 24 h and consumed. The processed tuber slices are also sundried and used as chips.
CUO 005	*Dioscorea pentaphylla* L.	Tubers are boiled and used to make curry.
CUO 006	*Dioscorea glabra* Roxb.	Tubers are boiled and cooked to make curry.
CUO 007	*Dioscorea alata* L.	Tubers are boiled and cooked as curry.

standard. Oxalate was determined by following the method of Meena *et al.*[27] using oxalic acid as standard. Phytate content of yam sample was determined spectophotometrically as per the method described by Wheeler and Ferrel[28]. Total phenol content was determined as per the method of Sadasivam and Manickam[22] using gallic acid as standard. Tannin content of yam flour was determined by the Folin-Dennis spectrophotometric method of Sadasivam and Manickam[22] by using tannic acid as standard. The α-amylase inhibitor was measured by following the method of Alonso *et al.*[29]

Determination of mineral composition

The mineral compositions were estimated by digestion of tuber sample (1 g each) in nitric, sulphuric and perchloric acid (6:1:2) at 100ºC following the method AOAC[17]. The mineral compositions such as calcium, copper, iron, magnesium, manganese and zinc contents were measured by using Atomic Absorption Spectrophotometer[17]. The digested sample was also used for the measurement of sodium and potassium content in a Flame Photometer (Systronics-105)[17].

Data analysis

All the parameters were statistically analysed by two-way analysis of variance using the software CROPSTAT (IRRI, Philippines). The mean value of all the parameters were compared by performing the *Fisher's* LSD test.

Results

Test of significance

The test of significance of different parameters in yam tubers were subjected to different processing methods is presented in Table 2. In different parameters,

Table 2 — Sum square is the absolute value and percentage of total (in bracket) of main effect resulting from analysis of variance of studied parameters in yam tubers subjected to different processing methods.

Parameters	Source of variation		
	Species (S, *df*=6)	Processing (P, *df*=3)	Species x Processing (SxP, *df*=18)
Moisture	2300** (87.9)	210** (8.0)	107* *(4.1)
Ash	32.00** (46.9)	15.14** (22.2)	20.22** (29.6)
Crude fat	10.12** (71.0)	3.59* (25.0)	0.43 ns (3.0)
Crude fibre	11.73** (63.0)	4.70** (25.0)	2.09* (11.0)
Water absorption capacity	242344** (78.1)	2490** (12.2)	1881 ** (8.7)
Water solubility index	4022** (73.3)	1127** (20.5)	303** (5.2)
Foam capacity	2754**(77.5)	684** (19.2)	65** (1.8)
Paste clarity	12572**(92.9)	866** (6.4)	63* (2.4)
Protein	1327** (51.2)	641** (24.8)	634** (24.5)
Sugar	15388** (26.9)	24538** (42.9)	16082** (28.1)
Starch	76457** (49.7)	2919* (1.9)	59020**(38.3)
Amylose	622.11** (88.0)	69.85** (9.0)	11.94* (1.0)
Ascorbic acid	2396** (94.0)	89.81* (3.0)	53.15* (2.0)
Vitamin-E	8.65** (83.0)	1.16* (11.0)	0.52* (5.0)
Oxalate	116.79** (41.0)	110.88** (38.0)	55.25** (19.0)
Phytate	192.51** (62.0)	70.79** (23.0)	41.48**(13.0)
Diosgenin	4.65** (25.0)	11.71** (64.0)	1.88* (10.0)
Phenol	517.13** (33.0)	332.22** (21.2)	711.62** (45.4)
Tannin	74.81** (68.5)	15.10 ** (13.8)	19.01** (17.4)
Mg	719494** (55.2)	410898** (29.3)	164476**(13.0)
Ca	111580** (22.2)	390139**(61.2)	157193** (13.6)
Cu	563.70** (50.2)	426.27** (38.0)	132.62** (11.8)
Fe	55886* (8.6)	46671* (7.2)	212676** (32.6)
Mn	12467* (9.7)	9458* (7.3)	41371**(32.1)
Zn	59.90** (45.5)	52.77** (40.1)	18.86* *(14.3)
Na	254522** (69.8)	43409**(11.9)	66504** (18.2)
K	470529** (32.2)	24564** (6.5)	660824** (62.3)

df: degrees of freedom, Total df=83, The P of overall ANOVA for species, processing and Species x Processing interaction for each parameter *$p<0.05$, **$p<0.01$, ns: not significant among the replications the differences were non-significant ($p>0.05$), but in the case of different species, different traditional processing method and their interaction were statistically significant ($p<0.05$).

Proximate Composition

The proximate compositions in studied yam tubers are shown in Table 3. There was significant ($p<0.05$) differences of moisture content was observed among the studied yam species and the value ranged from 66.07 to 78.05% (Table 3). The cause of variance for moisture content was the species (87.9%), followed by processing (8.0%) and interactions of species×processing (4.1%) (Table 2). There were significant ($p<0.05$) differences of ash content, crude fibre and crude fat observed among the studied yam tubers (Table 3). The different processing methods led to a significant ($p<0.05$) decrease in ash and crude fat content compared to raw yams. Similarly, boiling and soaking led to significant decrease of crude fibre content, while in sun dried samples no significant changes was observed.

Physico-functional parameters

Different physico-functional parameters in studied yam tubers were shown in Table 3. There were significant ($p<0.05$) difference of WAC observed among the *Dioscorea* species (Table 3). Boiling of yam caused a significant ($p<0.05$) increase of WAC only in *D. bulbifera* and *D. pentaphylla* but the WAC was not significantly changed by soaking and sun drying in the studied *Dioscorea* species. In addition, foam capacity was significantly increased by boiling and soaking in comparison to the raw tuber, while FC was not significantly changed by sun drying. Paste clarity (PC) of tuber flours of all the *Dioscorea* species was significantly improved by boiling, soaking and sun drying compared to the raw tuber. Water solubility index was significantly increased by boiling compared to other processing methods.

Nutritional parameters

Different nutritional parameters in studied yam tubers are presented in Table 4. Sugar, starch and amylose content of raw tubers ranged from 54.50 to 88.00 (mg/g dry weight), 101.6 to 173.2 (mg/g dry weight) and 5.46 to 15.55 (mg/g dry weight), respectively. Significant decrease of sugar content was observed by soaking compared to the raw tuber, while sun drying significantly improved the level of sugar only in *D. glabra, D. hispida* and *D. alata*. The starch content was higher in raw sample and was

Table 3 — Proximate analysis and physico-functional parameters in different wild and cultivated species of *Dioscorea* subjected to different processing.

Species	Moisture content (%)				Ash content (%)				Crude fat (g/100 g dwt.)				Crude fibre (g/100 g dwt.)			
	Raw	Boiled	Soaked	Sun dried	Raw	Boiled	Soaked	Sun dried	Raw	Boiled	Soaked	Sun dried	Raw	Boiled	Soaked	Sun dried
D. bulbifera	74.84^{b}	78.57^{a}*	76.59^{a}*	71.25^{b}*	2.31^{b}	1.52^{b}*	1.99^{b}*	1.52^{b}*	2.29^{a}	1.27^{b}*	1.78^{a}*	2.05^{a}	1.78^{a}	0.79^{b}*	1.21^{a}*	1.64^{a}
D. hamiltoni	70.89^{c}	74.18^{b}*	72.34^{b}*	68.36^{b}*	2.52^{b}	1.16^{b}*	1.53^{b}*	1.58^{b}*	2.40^{a}	1.12^{b}*	1.16^{b}*	2.07^{a}*	1.91^{a}	0.99^{a}*	1.34^{a}*	1.61^{a}
D. pubera	66.07^{d}	69.35^{c}*	68.45^{c}*	63.14^{c}*	2.96^{a}	1.53^{b}*	1.05^{b}*	1.49^{b}*	2.47^{a}	1.06^{b}*	1.58^{a}*	2.31^{a}	1.65^{a}	0.94^{b}*	1.13^{a}*	1.44^{a}
D. hispida	72.46^{c}	73.4^{b}	74.74^{b}*	68.24^{b}*	2.58^{b}	1.53^{b}*	1.52^{b}*	1.06^{b}*	2.06^{b}	1.47^{b}*	1.64^{a}*	1.76^{b}*	1.56^{a}	0.86^{b}*	1.33^{a}*	1.43^{a}
D. pentaphylla	70.53^{c}	74.80^{b}*	72.83^{b}*	66.09^{c}*	2.30^{b}	2.20^{a}*	2.68^{a}*	2.33^{a}*	2.42^{a}	1.11^{b}*	1.61^{b}*	2.05^{a}*	1.75^{a}	1.08^{a}*	1.36^{a}*	1.58^{a}
D. glabra	78.05^{a}	78.36^{a}	79.06^{a}	74.47^{a}*	2.96^{b}	2.02^{a}*	2.56^{a}	2.58^{a}	1.87^{b}	1.65^{a}	1.86^{a}	1.74^{b}	1.04^{b}	0.41^{c}*	0.71^{b}*	0.86^{b}
D. alata	70.40^{c}	73.49^{b}*	73.86^{b}*	66.64^{c}*	3.19^{a}	2.41^{a}*	2.58^{a}*	2.98^{a}	1.38^{c}	1.07^{b}*	1.16^{c}	1.07^{c}*	0.74^{b}	0.22^{c}*	0.47^{b}*	0.64^{b}
LSD(P<0.05)	2.34				0.56				0.31				0.29			

Species	Water absorption capacity (%)				Foam capacity (%)				Paste clarity (%)				Water solubility index (%)			
	Raw	Boiled	Soaked	Sun dried	Raw	Boiled	Soaked	Sun dried	Raw	Boiled	Soaked	Sun dried	Raw	Boiled	Soaked	Sun dried
D. bulbifera	353.6^{a}	383.0^{a}*	340.5^{a}	352.7^{a}	31.8^{b}	40.2^{b}*	35.5^{b}*	32.9^{b}	48.5^{b}	60.0^{b}*	54.5^{b}*	51.5^{b}*	15.85^{c}	30.35^{d}*	25.75^{e}	19.55^{d}
D. hamiltoni	261.1^{c}	270.6^{c}	265.9^{c}	263.9^{c}	22.5^{d}	32.3^{d}*	29.2^{c}*	24.0^{d}	33.0^{f}	38.0^{e}*	36.0^{e}*	32.5^{e}	34.50^{a}	39.50^{b}*	38.00^{b}	36.25^{b}
D. pubera	216.5^{d}	227.5^{d}	220.5^{d}	213.7^{d}	37.2^{a}	44.6^{a}*	40.3^{a}*	38.3^{a}	41.0^{d}	51.5^{d}*	49.0^{d}*	44.0^{d}*	18.15^{c}	29.60^{d}*	22.50^{f}	19.60^{d}
D. hispida	144.6^{f}	161.8^{f}	150.7^{e}	146.1^{e}	16.9^{e}	26.7^{e}*	23.4^{d}*	18.3^{e}	14.5^{g}	28.5^{f}*	22.5^{f}*	18.5^{f}*	35.93^{a}	60.20^{a}*	46.50^{a}	42.75^{a}
D. pentaphylla	306.2^{b}	337.7^{b}*	314.1^{b}	311.5^{b}	25.8^{c}	35.3^{c}*	29.4^{c}*	26.4^{c}	39.5^{d}	52.0^{d}*	49.0^{d}*	44.0^{d}*	26.4^{b}	33.15^{c}*	30.15^{d}	28.55^{c}
D. glabra	255.6^{c}	268.4^{c}	265.7^{c}	262.5^{c}	16.6^{e}	22.3^{f}*	19.4^{e}*	18.5^{e}	69.7^{a}	78.0^{a}*	75.0^{a}*	70.5^{a}*	17.70^{c}	26.45^{e}*	21.10^{f}	20.35^{d}
D. alata	197.2^{e}	211.3^{e}	206.8^{d}	201.5^{d}	26.5^{c}	40.1^{b}*	36.4^{b}*	32.4^{b}*	45.5^{c}	56.0^{c}*	52.0^{c}*	48.5^{c}*	24.5b	39.10^{b}*	35.10^{c}*	29.85^{c}
LSD(P<0.05)	15.7				2.68				1.9				2.26			

Means followed by a common letter in the same column are not significantly different at $p<0.05$ level by Fisher's least significance difference (LSD) test. *: represents the significantly different from Raw at $p<0.05$.

Table 4 — Nutritional compositions of *Dioscorea* species subjected to different processing. Data are the mean of three replication (n=3).

Species	Sugar (mg/g dwt.)				Starch (mg/g dwt.)				Amylose (mg/g dwt.)			
	Raw	Boiled	Soaked	Sun dried	Raw	Boiled	Soaked	Sun dried	Raw	Boiled	Soaked	Sun dried
D.bulbifera	87.6^{a}	78.0^{a}	60.9^{a}*	96.6^{a}	172.1^{a}	107.9^{c}*	130.2^{b}*	174.6^{a}	11.06^{b}	9.35^{a}*	9.91^{b}	10.67^{b}
D.hamiltoni	89.6^{a}	79.9^{a}	67.6^{a}*	94.4^{a}	171.3^{a}	156.5^{a}	150.8^{a}*	191.1^{a}	15.55^{a}	12.38^{a}*	14.59^{a}	16.25^{a}
D.pubera	88.0^{a}	83.5^{a}	68.6^{a}*	90.8^{a}	173.2^{a}	125.1^{b}*	107.2^{c}*	189.9^{a}	15.34^{a}	11.49^{a}*	13.49^{a}	15.11^{a}
D.hispida	61.4^{c}	56.6^{b}	46.5^{b}*	71.5^{b}*	132.6^{c}	104.8^{c}*	126.1^{b}	138.3^{c}	8.84^{c}	6.65^{b}*	9.60^{b}	10.22^{b}
D.pentaphylla	54.5^{c}	46.4^{b}	41.3^{b}*	75.8^{b}*	101.6^{d}	96.2^{c}	98.6^{c}	118.5^{d}	8.57^{c}	6.55^{b}*	7.24^{c}	9.11^{b}
D. glabra	48.8^{d}	39.6^{b}	37.9^{c}*	64.0^{c}*	121.5^{c}	88.4^{d}*	86.8^{d}*	128.7^{c}	5.46^{d}	3.03^{c}*	4.59^{d}	5.87^{c}
D.alata	78.0^{b}	75.0^{a}	68.0^{a}*	81.9^{b}	151.3^{b}	147.3^{a}	145.9^{a}	156.0^{b}	10.24^{b}	6.32^{b}*	8.60^{b}	10.12^{b}
LSD(P<0.05)	10.3				18.5				2.1			

Species	Protein (mg/g dwt.)				Ascorbic acid (mg/100 g dwt.)				Vitamin-E (mg/100 g dwt.)			
	Raw	Boiled	Soaked	Sun dried	Raw	Boiled	Soaked	Sun dried	Raw	Boiled	Soaked	Sun dried
D.bulbifera	21.60^{a}	12.90^{a}*	22.65^{a}	16.75^{a}*	6.77^{b}	5.50^{a}*	5.35^{b}*	3.59^{b}*	0.450^{c}	0.350^{b}*	0.230^{b}*	0.165^{c}*
D.hamiltoni	17.55^{b}	9.65^{b}*	17.75^{b}	12.45^{b}*	5.48^{c}	3.21^{b}*	3.69^{c}*	4.02^{b}*	0.760^{a}	0.320^{b}*	0.435^{a}*	0.550^{a}*
D.pubera	14.10^{c}	8.30^{b}*	13.75^{c}	12.70^{b}*	9.85^{a}	6.63^{a}*	7.32^{a}*	8.48^{a}*	0.660^{b}	0.370^{b}*	0.515^{a}*	0.530^{a}*
D.hispida	9.40^{d}	6.25^{c}*	10.90^{d}	4.55^{d}*	1.96^{e}	0.55^{d}*	0.57^{e}*	1.60^{c}	0.740^{a}	0.540^{a}*	0.270^{b}*	0.465^{a}*
D.pentaphylla	8.80^{d}	4.85^{d}*	9.70^{d}	7.80^{c}	3.28^{d}	2.07^{c}*	2.48^{d}	2.60^{c}	0.430^{c}	0.255^{c}*	0.315^{b}*	0.395^{b}*
D. glabra	8.30^{d}	6.70^{c}*	8.50^{e}	7.20^{c}	3.61^{d}	2.21^{c}*	3.27^{c}	2.76^{c}	0.310^{d}	0.175^{c}*	0.215^{b}*	0.285^{b}
D.alata	12.95^{c}	6.10^{d}*	12.45^{c}	8.10^{c}*	4.90^{c}	3.62^{b}*	4.03^{c}	4.39^{b}	0.310^{d}	0.130^{d}*	0.220^{c}*	0.275^{b}
LSD(P<0.05)	1.57				1.2				0.09			

Means followed by a common letter in the same column are not significantly different at $p<0.05$ level by Fisher's least significance difference (LSD) test. *: represents the significantly different from Raw at $p<0.05$

significantly decreased by boiling and soaking in most of the yam tubers. Whereas, amylose content of yam tubers was significantly declined under boiling compared to raw, soaking and sundry samples. Raw yam tuber was high in protein content, ascorbic acid and vitamin-E content but significantly reduced in different processing. Significant reduction of protein content was observed in boiled sample compared to raw tuber, while ascorbic acid and vitamin-E were declined in boiled, soaked and sun-dried sample.

Antinutritional compositions

Different anti-nutritional parameters, such as diosgenin, oxalate, phytate, phenols, tannins and α-amylase inhibitor contents of studied raw and processed yam tubers were shown in Table 5. There was significant ($p<0.05$) higher levels of anti-nutrients were observed in wild yam species compared to the cultivated one. In addition, the raw yam tubers showed a very high anti-nutrient content compared to the processed sample and all the processing methods such as socked, boiled and sun-dried resulted in reduction of anti-nutrients in the tubers.

Mineral compositions

Different mineral compositions in studied yam tubers were presented in Table 6. In raw yam tubers the range of Na was 16.3 to 83.16 mg/100 g, K was 456 to 934 mg/100 g, Mg was 21.8 to 67.5 mg/100 g, Cu was 9.73 to 14.62 mg/100 g, Mn was 2.35 to 23.7 mg/100 g, Ca was 22.11 to 46.3 mg/100 g, Fe was 8.66 to 23.55 mg/100 g and Zn was 1.06 to 3.04 mg/100 g. Different processing of yam led to significant decrease of mineral contents. Based on the results, K was the abundant mineral, ranging from 465 to 934 mg/100 g dry weight, while Zn was the least abundant mineral among the studied yam tubers. Some wild yam species (*D. hamiltonii, D. pubera* and *D. bulbifera*) exhibited remarkably higher mineral compositions in comparison to the cultivated species.

Discussion

Consumption of indigenous foods is being encouraged worldwide for meeting dietary needs of people. For the studied wild edible *Dioscorea* species, there is no previous report on chemical compositions/retention in relation to different traditional processing methods. Proximate compositions such as moisture, ash, crude fat and crude fibre are the major components of food[30-31]. Boiled and soaked yam showed significantly ($p<0.05$) higher moisture content compared to the raw tuber and it may be the result of presence of water from boiling and socking, while it is decreased by sun

Table 5 — Anti-nutritional compositions in indifferent species of Dioscorea subjected to different processing (mg/100 g). Data are the mean of three replication (n=3).

Species	Diosgenin (mg/100 g dwt.)				Phytate (mg/100 g dwt.)				Oxalase (mg/100 g dwt.)			
	Raw	Boiled	Soaked	Sun dried	Raw	Boiled	Soaked	Sun dried	Raw	Boiled	Soaked	Sun dried
D.bulbifera	4.87^{a}	3.66^{a}*	2.36^{c}*	3.52^{a}*	5.30^{e}	4.44^{c}*	3.74^{b}*	4.60^{b}*	3.29^{c}	2.40^{a}*	0.54^{c}*	2.33^{b}*
D.hispida	5.05^{a}	3.67^{a}*	2.64^{c}*	3.96^{a}*	9.72^{a}	5.36^{b}*	3.47^{b}*	4.84^{b}*	4.26^{b}	2.81^{a}*	2.17^{b}*	0.95^{d}*
D.pubera	4.17^{b}	3.15^{a}*	3.18^{b}*	3.66^{a}	4.49^{f}	2.65^{d}*	3.94^{b}	3.52^{b}*	3.62^{c}	0.55^{c}*	0.49^{c}*	0.79^{d}*
D.hamiltoni	4.14^{b}	3.00^{b}*	3.17^{b}*	3.19^{b}*	5.89^{d}	2.79^{d}*	3.58^{b}*	4.64^{b}*	3.50^{c}	0.23^{c}*	0.27^{c}*	0.69^{d}*
D.pentaphylla	4.96^{a}	3.13^{b}*	4.24^{a}*	3.76^{a}*	7.64^{c}	6.28^{a}*	6.61^{a}*	5.27^{a}*	4.39^{b}	0.29^{c}*	0.55^{c}*	0.72^{d}*
D. glabra	4.93^{a}	3.63^{a}*	3.77^{b}*	3.33^{a}*	8.82^{b}	4.50^{c}*	6.64^{a}*	5.66^{a}*	7.54^{a}	1.57^{b}*	3.54^{a}*	5.82^{a}*
D.alata	3.18^{c}	2.36^{b}*	2.57^{c}	2.87^{b}	3.40^{g}	2.22^{d}*	2.41^{c}*	2.94^{d}	2.78^{d}	0.19^{c}*	0.59^{c}*	1.70^{c}*
LSD(P<0.05)	0.65				0.56				0.45			
Species	α Amylase Inhibitor (Units/ g dwt.)				Phenol (mg/ g dwt.)				Tanin (mg/100 g dwt.)			
	Raw	Boiled	Soaked	Sun dried	Raw	Boiled	Soaked	Sun dried	Raw	Boiled	Soaked	Sun dried
D.bulbifera	26.04^{a}	5.34^{b}*	4.59^{b}*	11.55^{b}*	4.12^{d}	2.98^{a}*	1.58^{b}*	3.39^{a}	2.96^{a}	0.59^{d}*	0.97^{d}*	1.25^{c}*
D.hamiltoni	22.80^{b}	6.26^{b}*	8.95^{a}*	6.27^{d}*	4.33^{d}	2.27^{a}*	3.46^{a}	2.79^{a}*	2.59^{b}	1.62^{b}*	1.28^{c}*	1.73^{a}*
D.pubera	24.72^{a}	9.46^{a}*	9.27^{a}*	13.95^{a}*	8.87^{a}	2.35^{a}*	2.25^{b}*	2.89^{a}*	3.13^{a}	2.63^{a}*	2.45^{a}*	1.50^{b}*
D.hispida	22.45^{b}	5.26^{b}*	1.38^{c}*	6.82^{c}*	5.39^{c}	2.62^{a}*	1.15^{c}*	2.93^{a}*	2.65^{b}	0.66^{d}*	0.21^{e}*	0.23^{d}*
D.pentaphylla	20.13^{c}	4.78^{b}*	3.92^{b}*	5.23^{d}*	6.57^{b}	2.35^{a}*	1.68^{b}*	3.02^{a}*	2.94^{a}	1.53^{c}*	0.96^{d}*	1.89^{a}*
D. glabra	18.48^{d}	3.73^{c}*	7.42^{a}*	15.51^{a}*	1.96^{e}	0.67^{b}*	0.92^{c}*	1.33^{b}	0.96^{c}	0.16^{e}*	0.27^{e}*	0.36^{d}*
D.alata	20.71^{c}	5.29^{b}*	5.81^{b}*	8.59^{c}*	3.64^{d}	2.87^{a}	2.16^{b}*	2.58^{a}*	2.55^{b}	1.81^{b}*	1.97^{b}*	1.82^{a}*
LSD(P<0.05)		1.99				0.88				0.21		

Means followed by a common letter in the same column are not significantly different at $p<0.05$ level by Fisher's least significance difference (LSD) test. *: represents the significantly different from Raw at $p<0.05$.

drying (Table 3). The ash content, crude fibre and fat contents in the studied raw yam tubers were higher than earlier reported value in different tropical yam tubers[10-11]. The variation of proximate compositions among the yam species may be due to their origin and genetic makeup. Various traditional processing method resulted a remarkable decrease in ash content, crude fat and crude fibre content compared to raw yams.

The physico-functional properties such as WAC, FC, PC and WSI are necessary for testing the quality tuber flour for using in food industries[15]. Boiling of yam led to significant increase of WAC and WSI, whereas soaking significantly improved the FC and PC (Table 3). Based on the results of physico-functional properties, it suggested that these wild yam tuber floors were capable of holding higher content of water because of the starch gelatinization[32]. Higher WAC of the tuber floor is useful for making various food products[15]. Similar findings also observed in other tuber flours like *C. esculenta* and potato[15]. Paste clarity is known to influence by the amylose content of the floor and some wild yam floors showed higher paste clarity and better useful in food industries[33].

The value of nutritional parameters such as sugar, starch, amylose and protein content in raw tubers were in the range of earlier reported value in yam species of Nepal[10], Ethiopia[34] and from Sri Lanka[35]. The processing of yam tuber by boiling and soaking led to the significant decrease of sugar, starch and amylose content compared to raw tuber. Adepoju *et al.* [8] and Adepoju [36] were reported that the cooking and soaking of yam tubers caused leaching of nutrient and results in decrease of carbohydrate content in processed tuber floor and its products. In contrast, significant increase of sugar content of tuber floor under sun-dried sample was believed to be due to less moisture retention in the tubers. Presence of higher protein and vitamin content in yam species such as *D. hamiltonii, D. pubera and D. oppositifolia* over the other species indicated its nutritional superiority. Different processing led to significant decline of ascorbic acid and vitamin E compared to the raw tuber.

Different anti-nutritional parameter such as diosgenin, oxalate and phytate were associated with the health implications and affect the digestion of food[30,37]. The levels of antinutrients in studied raw yam tubers were lower than the earlier reported value in tropical tubers[12]. Based on the results levels of anti-nutrients were decreased by processing of yams before consumption. Generally wild yams are consumed by employing different traditional

Table 6 — Mineral compositions of different species of *Dioscorea* subjected to different processing (mg/100 g). Data are the mean of three replication (n=3).

Species	Na (mg/100 g dwt.)				K (mg/100 g dwt.)				Mg (mg/100 g dwt.)				Cu (mg/100 g dwt.)			
	Raw	Boiled	Soaked	Sun dried	Raw	Boiled	Soaked	Sun dried	Raw	Boiled	Soaked	Sun dried	Raw	Boiled	Soaked	Sun dried
D. bulbifera	62.21^{b}	26.50^{b}*	22.63^{c}*	60.13^{b}	845.15^{a}	456.88^{a}*	431.00^{b}*	600.55^{b}*	48.15^{d}	38.55^{a}*	32.00^{c}*	45.60^{d}	12.25^{a}	3.13^{a}*	4.23^{b}*	11.15^{b}
D. hamiltoni	83.17^{a}	29.62^{b}*	47.48^{a}*	72.95^{a}	934.15^{a}	341.53^{a}*	589.85^{a}*	629.38^{b}*	52.60^{c}	23.75^{c}*	35.45^{b}*	51.01^{c}	12.78^{a}	3.94^{a}*	6.85^{a}*	12.46^{a}
D. pubera	64.35^{b}	58.50^{a}	21.77^{c}*	64.27^{b}	611.57^{b}	452.12^{a}*	356.75^{b}*	602.33^{b}	67.55^{a}	32.75^{b}*	45.51^{a}*	66.30^{a}	14.62^{a}	3.21^{a}*	6.46^{a}*	14.50^{a}
D. hispida	16.30^{f}	9.55^{d}*	10.25^{d}	15.80^{e}	465.14^{c}	315.85^{b}*	367.22^{b}*	439.84^{c}	21.85^{g}	15.25^{d}*	18.35^{d}*	20.15^{f}	12.03^{a}	4.46^{a}*	4.11^{b}*	11.94^{b}
D. pentaphylla	28.74^{e}	21.55^{c}*	22.15^{c}*	28.27^{d}	483.34^{b}	251.74^{b}*	223.30^{c}*	380.85^{c}	43.28^{e}	32.66^{b}*	38.73^{b}*	42.15^{d}	12.88^{a}	3.73^{a}*	6.22^{a}*	9.26^{d}*
D. glabra	33.17^{d}	29.27^{b}	23.47^{b}*	26.63^{d}	612.22^{b}	321.42^{a}*	456.77^{a}*	521.32^{b}	27.68^{f}	10.71^{d}*	19.40^{d}*	27.17^{e}	12.06^{b}	4.24^{a}*	6.02^{a}*	10.18^{b}
D. alata	45.00^{c}	31.04^{b}*	29.55^{b}*	43.98^{c}	645.31^{b}	342.15^{a}*	531.60^{a}*	609.39^{a}	58.66^{b}	23.99^{c}*	29.55^{c}*	58.09^{b}	9.73^{b}	3.27^{a}*	5.37^{a}*	9.23^{d}
LSD(P<0.05)	6.12				136.5				3.89				2.41			

Species	Mn (mg/100 g dwt.)				Ca (mg/100 g dwt.)				Fe (mg/100 g dwt.)				Zn (mg/100 g dwt.)			
	Raw	Boiled	Soaked	Sun dried	Raw	Boiled	Soaked	Sun dried	Raw	Boiled	Soaked	Sun dried	Raw	Boiled	Soaked	Sun dried
D. bulbifera	13.73^{c}	4.25^{b}*	7.12^{c}*	13.42^{c}*	32.64^{c}	22.43^{b}*	25.02^{b}*	31.53^{b}	23.55^{c}	13.15^{b}*	16.88^{b}*	23.07^{c}	2.83^{b}	0.90^{b}*	1.43^{b}*	2.21^{c}*
D. hamiltoni	16.68^{b}	3.57^{b}*	10.56^{b}*	16.32^{b}*	46.31^{a}	11.22^{d}*	32.61^{a}*	44.21^{a}	28.95^{b}	12.55^{b}*	19.44^{b}*	28.61^{b}	2.76^{b}	0.63^{c}*	1.15^{c}*	2.63^{b}*
D. pubera	23.77^{a}	9.37^{a}*	13.89^{a}*	23.43^{a}	34.25^{c}	28.59^{a}*	24.32^{b}*	28.43^{c}*	65.07^{a}	24.38^{a}*	43.07^{a}*	64.34^{a}	2.76^{b}	0.84^{b}*	1.79^{a}*	1.65^{d}*
D. hispida	2.13^{f}	0.50^{d}*	0.80^{e}*	1.79^{g}	25.63^{d}	13.11^{d}*	18.91^{c}*	14.37^{e}*	8.66^{e}	4.23^{c}*	5.15^{d}	8.41^{e}	1.64^{d}	0.09^{e}*	0.22^{e}*	1.55^{e}
D. pentaphylla	3.74^{e}	0.74^{d}*	1.63^{e}*	3.21^{e}	39.00^{b}	23.00^{b}*	26.12^{b}*	29.34^{b}*	12.63^{d}	11.84^{b}	8.70^{d}	4.22^{f}*	1.86^{c}	0.84^{b}*	1.32^{b}*	1.75^{d}
D. glabra	2.35^{f}	0.44^{d}*	1.03^{e}*	2.79^{f}	26.06^{d}	17.33^{c}*	10.45^{d}*	20.26^{d}*	10.34^{e}	3.24^{c}*	5.34^{d}*	9.66^{e}	1.06^{e}	0.33^{d}*	0.55^{d}*	0.86^{f}*
D. alata	7.80^{d}	2.45^{c}*	4.65^{d}*	7.37^{d}	22.11^{e}	15.12^{c}*	10.32^{d}*	20.34^{d}	16.47^{d}	7.35^{c}*	13.20^{c}	16.31^{d}	3.04^{a}	1.45^{a}*	1.31^{b}*	2.88^{a}*
LSD(P<0.05)	0.93				2.41				4.39				0.13			

Means followed by a common letter in the same column are not significantly different at *p<0.05* level by Fisher's least significance difference (LSD) test. *: represents the significantly different from Raw at *p<0.05*.

processing methods which led to removal of anti-nutrients[8,36]. The levels of antinutrients in yam tuber after processing were negligible and does not affect the bioavailability of nutritional parameters[8].

The results of mineral compositions showed that raw yam tubers were very rich in minerals, such as Na, K, Ca, Mg, Fe and Zn. The range of minerals in the studied wild yam tubers were higher than earlier reported value of cultivated species[3]. Different processing led to decrease in mineral content in studied yam tuber, However, the decrease was more pronounced by boiling and soaking due to leaching of the minerals. In the studied yam tubers potassium was the abundant mineral and the level of potassium was higher than the sodium content. This suggests that studied yam tubers are safe food and better for human health[38]. Different traditional processing methods led to significant reduction of nutrient and anti-nutrient compositions with improvement of tuber flour physico-functional parameter. Though processing of tuber by sun drying retained more nutrients and minerals compositions compared to boiling and soaking, but it is not suitable for detoxification/removal of antinutrients from the wild *Dioscorea* tubers.

Conclusion

Some wild yam species, such as *D. hamiltonii*, *D. pubera* and *D. bulbifera* showed higher nutritional and mineral compositions compared to the cultivated species. Processing of yam tuber by boiling led to greater retention of nutrients and moderate loss of minerals as well as with successive removal of anti-nutrients. Though, sun drying is also a competitive practice for retaining the maximum nutrients after processing but because of presence of anti-nutrients, it is not suitable for consumption. Hence, it is suggested that these wild yams should be consumed in boiled form. Processing of these yam tubers interestingly improves its physico-functional properties, having bioprospecting potential for food industries.

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