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Evaluation of the nutritional and antinutritional components of twelve *Dioscorea* cultivars

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Abstract
The present study determines the proximate nutritional and antinutritional compositions of twelve yam cultivars collected at full mature stage i.e. nine months after planting, from All India Coordinated Research Project on Tuber Crops, grown in the research field at Mondouri, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal, India. Samples were quantified for proximate contents such as carbohydrate, starch, total soluble sugar, protein, fat, vitamin C, β-carotene, antioxidant, phenol, tannin, oxalate and trypsin inhibitor using standard methods. A significant difference ($p<0.05$) existed between the means of the proximate compositions among the yam cultivars and were found to have high nutrient and low antinutrient values. Antioxidant activities of all the cultivars were high and range from (78.6–85.7)%. The *Dioscorea alata* cultivars show comparatively higher carbohydrate, protein, fat, vitaminC, β-carotene, and antioxidant activities than *D. rotundata* and within the *D. alata,* the cultivar BCDA-5 shows comparatively higher nutritional values and highest antioxidant activity. Therefore, *Dioscorea* tubers and especially *D. alata,* and cultivars BCDA-5 and BCDA-8 can be recommended as a reliable food and energy security crops.

Keywords: Antinutrient, antioxidant, cultivars, *Dioscorea*, nutrient, tuber

Introduction
Yam (*Dioscorea* sp.) constitutes a staple food crop for over 100 million people in Africa, Latin America, and Asia. Over 90% of world yam production occurs in the yam belt of West and Central Africa with Nigeria alone accounting for about 68% of the world's total (FAO, 2013) [11]. Yams are an excellent source of carbohydrate, energy, vitamins (especially vitamin C), minerals and protein. Compared to about 1% in cassava, some cultivars of yam tuber have been found to contain protein levels of (3.2–13.9)% of dry weight (Knoth, 1993) [22]. Modern researchers have showed that yam extracts can reduce blood sugar (Undie and Akubue, 1986) [37] and blood lipid (Araghiniknam *et al.*, 1996) [3], inhibit microbe activity (Kelmanson *et al.*, 2000) [21] and show antioxidant activity (Farombi *et al.*, 2000) [12]. 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 (Opara, 1999) [28]. Yams are also known to contain some antinutritional components that may have adverse effects on human nutrition (Dipak and Mukherejee, 1986) [7] despite their high nutritional values. Bhandari and Kawabata (2004) [4] reported that 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 (Coursey, 1973) [6] while phytic acid (inositol hexaphosphate) is an organic acid found in plant materials (Heldt, 1997) [15] 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. So, considering all the above facts the study is to understand the nutritional and antinutritional composition of the twelve cultivars of yam collected.

Materials and Methods
Raw materials: Twelve cultivars of Yam were collected from “All India Coordinated Research Project on Tuber Crops”, grown in the research field at Mondouri, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal, India. Among the 12 yam cultivars 3 cultivars [I-212, I-146 and T3(1)] belongs to *D. rotundata* and remaining 9 (BCDA-1, BCDA-2, BCDA-3,

BCDA-4, BCDA-5, BCDA-6, BCDA-7, BCDA-8 and BCDA-9) belongs to *D. alata*. Harvesting was done nine months after planting (full mature stage) and quantitative analysis was done in the laboratory of Department of Post-Harvest Technology, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal, India.

Proximate analysis of nutrient and antinutrient: Moisture and dry matter content were determined using AOAC (2005) [2] method. Spectrophotometrically (UV/VIS Spectrophotometer, Model-Optizen POP, Korea) determination (Sadasivam and Manickam, 2011) [32] 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 700nm. The antioxidant activity (scavenging of DPPH i.e.1,1-diphenyl-2-picrylhydrazyl radical) was carried out according to the method described by Hsu *et al*. (2003) [17]. Estimation of fat is done by using organic solvents and quantification by gravimetric method (Folch *et al*., 1957) [13]. Ascorbic acid was determined by the titration method using 2, 6 dichlorophenol indophenol solution as described by Sadasivam and Manickam (2011) [32]. Trypsin inhibitor (Sumathi and Pattabiraman, 1975) [35] using casein reagent at wavelength 660 nm. The subsequent analysis for oxalate content was made following the methods of AOAC (2005) [2]. Holloway *et al.* (1989) [16] 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.

***Statistical Analysis*:** CRD (Completely Randomized Block Design) at level 5% was done on IBM SPSS STATISTICS 19 software.

Results and Discussion

Proximate composition of the nutritional and antinutritional composition of the twelve yam cultivars under two species *Dioscorea rotundata* and *Dioscoreaalata* are shown in Table 1 and 2 and described as follows:

Among the twelve cultivars under study, moisture and dry matter content varies significantly. Of the cultivars, BCDA-5 recorded the highest moisture content (83.5%) and correspondingly the lowest dry matter (16.5%) while cultivar I-212 recorded the lowest moisture and highest dry matter content of 63.9% and 36.1% respectively. The values recorded were almost similar to the findings of Shajeela *et al*. (2011) [33]; Kouakou *et al*. (2010) [23] and Bolanle *et al*. (2012) [5]. Overall, *Dioscorea alata* cultivars had higher moisture content than *Dioscorea rotundata* cultivars, while in dry matter, *Dioscorea rotundata* cultivars were greater than *Dioscorea alata* cultivars. These findings were in agreement with the work of Bolanle *et al*. (2012) [5]; Polycarp *et al*. (2012) [30] and Frank and Kingsley (2014) [14]. The dry matter portion of yam tubers was mostly composed of carbohydrates, which exist primarily in the form of starch and sugars (Ikediobi and Oti, 1983) [18].

Carbohydrate content was recorded highest in cultivar I-212 (82.3%) followed by I-146 (81.9%) and the least in BCDA-2 (71.2%) which was in agreement with the report of FAO (2001) [10] which showed high carbohydrate content of yam tubers ranging from 83-87%. Ezeocha and Ojimelukwe (2012) [9] who worked on water yam reported carbohydrate content of 76.57% and Polycarp *et al.* (2012) [30] 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 rotundata* was found greater than *Dioscorea alata* which correlates the findings of Polycarp *et al.* (2012) [30] and Frank and Kingsley (2014) [14]. The total carbohydrate consists of sugars, dextrins, starches, pectins, hemicelluloses, celluloses, and lignin. The carbohydrate constitutes the major component of yam tubers (Osagie, 1992) [29].

Starch content was highest in *Dioscorea rotundata* cultivars I-212 (27.5%) followed by T3(1) (26.4%) and the least in *Dioscorea alata* cultivar BCDA-5 (11.2%). Total Sugar content was highest in BCDA-8 (6.8%) and the least in BCDA-4 (1.8%) as shown in Table 1. The values recorded were in agreement with the findings of Bolanle *et al.* (2012) [5] and Alamu *et al.* (2014) [1].

Protein content was highest in BCDA-6 (2.7%) cultivar and lowest in I-146 (1.2%), which correlates with the findings of Knoth (1993) [22] where the protein content was 1.1-2.8% for *Dioscorea alata* and 1.1-2% for *Dioscorea rotundata* and Osagie (1992) [29], who reported yam protein ranging from 1.4 – 3.5%. Comparing the two species under study *D. alata* showed greater protein than which agrees with the report of Polycarp *et al*. (2012) [30] and FAO (2001) [10]. The protein content of yams from available literature also showed considerable variation among species and between cultivars, a finding which has been attributed to factors such as climate, cultural practices, maturity at harvest and the length of storage time (Martin, 1979) [25].

Fat content was highest in BCDA-6 (0.46%) and lowest in I-212 (0.22%). Low-fat content (<%) was quite reasonable as all root crops contain very low lipid (Ekpeyong, 1984) [8]. The values recorded correlate the findings of Polycarp *et al.* (2012) [30] and FAO (2001) [10] where *D. alata* cultivars content higher fat than *D. rotundata* which ranges from 0.24-0.82 and 0.17-0.46%, respectively.

The cultivars vary significantly in Vitamin C content, expressed in mg/ 100 g and was highest in cultivars BCDA-4 (9.4) and the least in T3(1) (6.5) which fall within the range of 4–18 mg/ 100 g as reported by Osagie (1992) [29] but lower than the range of vitamin C content in yam tubers as reported by Udensi *et al*. (2008) [36] 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.

Beta-carotene was found to be low in all the yam cultivars, though low it varies significantly and showed highest in BCDA-6 (0.52 mg/ 100 g) and the least in BCDA-4 (0.22 mg/ 100 g). Osagie (1992) [29] reported that beta-carotene in yam ranges from 0.0-10.0 mg/ 100 g.

Antioxidant activity was observed very high in all the yam cultivars under study. BCDA-5 recorded the highest (85.7%) while BCDA-9 the least (78.6%). These values recorded were almost similar to the findings of Yi *et al*. (2008) [38] who worked on Taiwan yam variety. The high antioxidant activity of yam (*Dioscorea* spp.) extracts has been reported by Kaur and Kapoor (2002) [20], who states that yam has more than 70% antioxidant activity and are placed in the vegetable group with a high antioxidant activity. The importance of antioxidant constituents of plant materials in maintaining health and in protecting against coronary heart diseases and cancer is raising interest among scientist, food manufacturers and consumers as the trend of the future are moving towards functional food with specific health effects (Kahkonen *et al.*,1999) [19]. So, the presence of a high antioxidant in yam tubers is desirable.

From Table 2, it was observed that the phenol content of the cultivar BCDA-5 recorded the highest (77.2 mg/ 100 g) while BCDA-9 the least (52.3 mg/ 100 g) and falls within the range of the findings of Ezeocha and Ojimelukwe (2012) [9] i.e.191 mg/100g and 68 mg/100g (Shajeela *et al.*, 2011) [33] for *D. alata*. The phenolic contents of yam are the substrate responsible for the browning reaction, which occurs when the tubers are cut or damaged. So, high level of phenolics showed fast and strong browning.

Tannin content was highest in BCDA-6 and least in I-212 which are 13.1 and 4.2 mg/ 100 g respectively and correlates the finding of Polycarp *et al.* (2012) [30] were tannin content ranges from 4.3-6.9 and 10.75-13.2 mg/ 100 g for *D. alata*, but lower than the values as reported by Ezeocha and Ojimelukwe (2012) [9] and Shajeela *et al.* (2011) [33] in *D. alata* which is 21 mg/ 100 g and 41 mg/ 100 g respectively; Alamu *et al.* (2014) [1] reported the tannin content for *D. rotundata* varieties of Nigeria ranging from 62-118mg/ 100g while Shanthakumari *et al.* (2008) [34] reported range between 20.00 ± 0.50 mg/ 100 g DM in *D. rotundata* and75 ± 5 mg/ 100 g DM 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 (Liener, 1980) [24].

The result showed that Trypsin inhibitor activity (TIA) among the cultivars was highest in BCDA-6 and least in I-212 which are 3.2 and 1.1 mg/g respectively. The observed values were lower than the findings of Megh and Kawabata (2006) [26] who worked on wild yam tubers of Nepal with values ranging from 4.1 to 20.9 mg pure trypsin inhibited per gram dry matter. So, it can be stated that wild yam tubers content more TIA than the edible ones. However, low in TIA is desirable and is expected to enhance protein digestibility.

The total oxalate content among the cultivars expressed in mg/100 g was highest in BCDA-7 (1.18) and least in BCDA-3 (0.48), water-soluble oxalate highest in BCDA-2 (0.75) and least in BCDA-9 (0.29) and calcium oxalate, highest in BCDA-6 (0.51) and least in BCDA-3(0.13). These values correlate to the findings of Popoola *et al.* (2014) who reported total oxalate content ranging from 0.46-0.68 mg/100 g and 1.16-1.2 mg/100g for *D. alata* and Polycarp *et al.* (2012) [30] 0.58-0.59 mg/100 g for *D. rotundata* and 0.45-0.50 mg/100 g for *D. alata*. The occurrence of oxalates in root and tubers has been considered as the cause of contributing acridity, which causes irritation and swelling of mouth and throat (Holloway *et al.*, 1989) [16]. The water extraction gave soluble oxalates, and extraction with acid gave total oxalates. The difference between them equated the amount of calcium oxalate. Oxalic acid and its salts can have deleterious effects on human nutrition and health, particularly by decreasing calcium absorption and aiding the formation of kidney stones (Noonan and Savage, 1999) [27]. So, lower oxalate content is preferable

Table 1: Nutritional parameters of the twelve yam cultivars

Cultivars	Moist (%)	Dm (%)	Cho (%)	Starch (%)	T.Sugar (%)	Protein (%)	Fat (%)	Vit C (Mg/100g)	B-Caro. (Mg/100g)	Ao (%)
I-212	63.9	36.1	82.3	27.5	2.5	1.3	0.22	7.4	0.32	78.9
I-146	67.5	32.5	81.9	25.3	2.2	1.2	0.23	6.8	0.41	80.4
T-3(1)	65.3	34.7	81.4	26.4	2.8	1.4	0.28	6.5	0.51	79.1
BCDA-1	81.1	18.9	73.3	13.5	4.1	1.8	0.41	8.9	0.23	81.8
BCDA-2	78.3	21.7	71.2	14.4	3.2	2.2	0.39	9.3	0.24	82.6
BCDA-3	70.1	29.9	78.3	19.5	2.1	2.5	0.33	8.6	0.31	78.8
BCDA-4	69.8	30.2	80.3	20.1	1.8	2.1	0.35	9.4	0.22	79.3
BCDA-5	83.5	16.5	74.4	11.2	3.1	2.4	0.45	8.5	0.52	85.7
BCDA-6	72.3	27.7	75.2	17.5	3.9	2.7	0.46	9.2	0.42	84.1
BCDA-7	82.7	17.3	72.5	12.3	4.6	1.6	0.42	8.8	0.24	79.8
BCDA-8	68.7	31.3	81.2	21.6	4.8	1.5	0.37	7.6	0.35	83.2
BCDA-9	76.1	23.9	76.3	16.4	1.9	2.3	0.36	8.4	0.35	78.6
SEm (±)	1.145	0.369	1.150	0.270	0.053	0.029	0.006	0.125	0.006	1.233
CD (5%)	3.342	1.076	3.356	0.787	0.154	0.084	0.018	0.366	0.016	3.598

Note: Cultivars I-212, I-146 and T3 (1) belongs to *Dioscorearotundata*and BCDA-1, BCDA-2, BCDA-3, BCDA-4, BCDA-5, BCDA-6, BCDA-7, BCDA-8 and BCDA-9 belongs to *Dioscoreaalata.* MOIST = Moisture; DM = Dry matter; CHO = Carbohydrate; T. SUGAR = Total sugar; β-Caro. = Beta carotene and AO = Antioxidant

Table 2: Anti-nutritional parameters for twelve yam cultivars

Cultivars	Phenol (Mg/100g)	Tannin (Mg/100g)	Ti Mg/G)	Oxalate (Mg/100g)		
				TO	WSO	CaO
I-212	53.2	4.2	1.1	0.53	0.38	0.15
I-146	58.3	5.6	1.4	0.61	0.39	0.22
T-3(1)	55.5	6.8	1.3	0.57	0.36	0.21
BCDA-1	64.6	12.7	2.8	0.98	0.53	0.45
BCDA-2	66.3	12.2	3.1	1.16	0.75	0.41
BCDA-3	54.7	11.1	2.3	0.48	0.35	0.13
BCDA-4	56.5	9.8	2.5	1.03	0.54	0.49
BCDA-5	77.2	10.2	1.8	0.51	0.32	0.19
BCDA-6	72.5	13.1	3.2	1.12	0.61	0.51
BCDA-7	57.4	11.8	2.6	1.18	0.73	0.45
BCDA-8	66.8	9.6	2.1	1.06	0.58	0.48
BCDA-9	52.3	8.8	1.6	0.55	0.29	0.26
SEm (±)	0.981	0.155	0.033	0.012	0.008	0.005
CD (5%)	2.864	0.454	0.097	0.036	0.023	0.016

Where, TI = Trypsin inhibitor, TO = Total oxalate, WSO = Water soluble oxalate and CaO = Calcium oxalate

Conclusion

Therefore, from the above parameters studied it can be concluded that cultivars with high dry matter and carbohydrate i.e. *D. rotundata* cv. I-212 could be used for processing and as a reliable food and energy security. Comparing at species level *D. rotundata* cultivars was high in dry matter, carbohydrate and starch while *D. alata* cultivars were high in moisture, protein, fat, vitamin C, tannin and TIA. Also, regarding health benefits cultivars rich in antioxidant i.e. BCDA-5, BCDA-6 and BCDA-8 can be commercialized for consumption of tubers. All the studied cultivars 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 yams, negative effects on mineral bioavailability and their pharmacological effect.

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References

1. 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.
2. AOAC. Official Methods of Analysis of the Association of Official Analytical Chemists. 18th Ed., *Association of Official Analytical Chemists*, Gaithersburg, MD, 2005.
3. Araghinkinam M, Chung S, White TN, Eskelson C, Watson RR. Antioxidant activity of dioscorea and dehydroepiandrosterone (DHEA) in older humans. *Life Sciences.* 1996; 59(11):147-157.
4. Bhandari MJ, Kawabata J. Organic acid, phenolic content and antioxidant activity of wild yam (*Dioscorea* spp.) tubers of Nepal. *Food Chem.* 2004; 88:163-168.
5. Bolanle, Otegbayo O, Robert A, Mpoko B. Effect of storage on the chemical composition and food quality of yam. *J Food Process and Preserv.* 2012; 36:438-445.
6. Coursey DG. Cassava as Food: Toxicity and Technology. In: Nestel, B. and R. MacIntyre, (Eds.), *Chronic Cassava Toxicity*, Ottawa, Canada, IDRC, IDRC-10e, 1973, 27-36.
7. Dipak HD, Mukherjee KD Functional properties of rapeseed protein products with varying phytic acid contents. J Agric Food Chem. 1986; 34:775-780.
8. Ekpeyong TE. Composition of some Tropical Tuberous Foods. *Food Chem.* 1984; 15:31-36.
9. Ezeocha VC, Ojimelukwe PC. The impact of cooking on the proximate composition and anti-nutritional factors of water yam (*Dioscoreaalata*). J Stored Products and Postharvest Res., 2012; 3(13):172-176.
10. FAO. Food and Agriculture organization of the United Nations: Production, Rome, Italy, 2001.
11. FAO. FAOSTAT database, 2013. Available at:http://faostat.fao.org/
12. Farombi EO, Britton G, Emerole G. Evaluation of antioxidant activity and partial characterisation of extracts from browned yam flour diet. Food Research International. 2000; 33:493-499.
13. 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.
14. 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.
15. Heldt HW. Plant biochemistry and molecular biology. Oxford University press New York, 1997.
16. 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.
17. Hsu CL, Chen W, Weng YM, Tseng CY. Chemical composition, physical properties, and antioxidant activities of yam flours as affected by different drying methods. *Food Chem.* 2003; 83(1):85-92.
18. 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.
19. Kahkonen MP, Hopia AI, Vuorela HJ, Rauha JP, Pihlaja, K, Kujala TS *et al*. Antioxidant activity of plant extracts containing phenolic compounds. J Agric and Food Chem. 1999; 47:3954-3962.

20. Kaur C, Kapoor HC. Antioxidant activity and total phenolic content of some Asian vegetables. Int J Food Sci Technol. 2002; 37:153-161.
21. Kelmanson JE, Jager AK, Van SJ. Zulu medicinal plants with antibacterial activity. Journal of Ethnoparmacology, 2000; 69:241–246.
22. Knoth J. Traditional storage of yams and cassava and its improvement. *Deutsche Gesellschaft für Technische Zusammenarbit (GTZ)* post-harvest project. Hamburg Germany, 1993.
23. 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.
24. Liener IE. Miscellaneous toxic factor: In Toxic Constituents of Plant Food stuff(Ed), Academic press, London, 1980, 430-469.
25. Martin FW. Composition, nutritional value and toxic substances of the tropical yams. In Tropical Foods: Chemistry and Nutrition. 1979; 1:249-264.
26. Megh RB, Kawabata J. Cooking effects on oxalate, phytate, trypsin and α-amylase inhibitors of wild yam tubers of Nepal. J Food Comp Anal. 2006; 19:524-530.
27. Noonam SC, Savage GP. Oxalic acid and its effects on humans. Asia Pacific Journal of Clinical Nutrition. 1999; 8:64-74.
28. Opara LU. Yam Storage: Handbook of agricultural engineering agro processing. The American society of agricultural Engineers. 1999; 4:182-214.
29. Osagie AU. The yam tuber in storage. Post-Harvest Research Unit, University of Benin, Nigeria. 1992, 107-173.
30. 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.
31. Popoola OE, Doherty VF, Odusami JO, Durowoju OS. Oxalate content of some Nigerian tubers using titrimetric and UV-spectrophotometric methods. Academic Journal of Agricultural Research. 2014; 2(2):54-57.
32. Sadasivam, Manickam. Biochemical Methods. New age International publishers. 3rd edition, 2011.
33. 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.
34. 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.
35. Sumathi S, Pattabiraman TN. Natural plant enzyme inhibitors. Part I. Protease inhibitors of tubers and bulbs. *Ind J Biochem Biophys.* 1975; 12:383-385.
36. 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.
37. Undie AS, Akubue PI. Pharmacological evaluation of *Dioscorea dumetorum* tuber used in traditional antidiabetic therapy. Journal of Ethnopharmacology. 1986; 15:133-144.
38. Yi TC, Wen TK, WL, Kuo. Effects of pH on the total phenolic compound, antioxidant ability and the stability of dioscorin of various yam cultivars. Food Chem. 2008; 107:250-257.