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**Research Article**

# Nutritional Profile and Radical Scavenging Capacity of Tubers of Two *Dioscorea* Species

[1, 2]Ibtisam G. Doka, [1]Sayadat El Tigani and [1]Sakina Yagi
[1]Department of Botany, Faculty of Science, University of Khartoum, P.O. Box 321, Khartoum,
[2]Department of Botany, Faculty of Science, University of Kordofan, Sudan

**Abstract:** This study was aimed at evaluating the nutritional and antioxidant properties of raw and boiled tubers of *Dioscorea dumetorum* and *D. hirtiflora*. Tubers of *D. hirtiflora* were characterized by higher total essential amino acids (9576 mg/100 g dry weight (dw)) than those of *D. dumetorum* (1085 mg/100 g dw). Boiling decreased the total amino acid content of both tubers. Monounsaturated Fatty Acids (MUSFAs) and Polyunsaturated Fatty Acids (PUFAs) accounted for 15.92 and 26.64% in *D. dumetorum* tubers respectively whereas, MUSFAs and PUFAs accounted for 29.62 and 24.11% in *D. hirtiflora* tubers respectively. Boiling increased the total unsaturated fatty acids from 42.56 to 56.81% in *D. dumetorum* tubers and decreased it from 53.73 to 49.08% in *D. hirtiflora* tubers. The total phenolic content of boiled *D. hirtiflora* tubers showed 4.5-fold gain which might explain partly the increase in their antioxidant capacity ($IC_{50}$ 22.35 mg/L in DPPH assay). Boiling did not change significantly the antioxidant activity of *D. dumetorum* tubers ($IC_{50}$ 74.13 mg/L in DPPH assay) although a significant decrease in total phenolic (60%) and vitamin C contents (56.7%) was observed. These results suggest that boiled tubers of *D. dumetorum* and *D. hirtiflora* can contribute significantly to human nutrition and health.

**Keywords:** Antioxidant activity, essential amino acids, polyunsaturated fatty acids, total phenolics, vitamin C, yam

## INTRODUCTION

In many developing countries people utilize wild edible plants to meet their food needs especially in periods of food shortage (Bussmann *et al*., 2006; Grivetti and Ogle, 2000; Medley and Kalibo, 2007).

A balanced diet fully meets all the nutritional needs of a person. One of the most common causes of dietary deficiencies and food insecurity appears to be the decreasing diversity of traditional diets (Batal and Hunter, 2007). Several studies suggest that consumption of many different wild edible plants as food provides favorable nutritional effects (Vanderjagt *et al*., 2000; Cook *et al*., 2000; Doka *et al*., 2014).

There are a number of clinical studies suggesting that the antioxidants in fruits, vegetables, tea and red wine have protective effect against many human neurologic disorders, heart disease and some cancers (Miller *et al*., 2000). Antioxidants present in edible plants involve mainly vitamin antioxidants (vitamin E, vitamin C, carotenoids) and polyphenols (Bouayed and Bohn, 2013).

Local people of Kordofan (Western Sudan) know about the importance and the contribution of wild plants such as yam to their daily diet. Moreover, during the famine of 1988 wild edible plants contributed more than any other food sources in saving the lives of a large number of famine victims. Two species of yam (family Dioscoraceae) were commonly eaten; *Dioscorea dumetorum* (Kunth) Pax. and *D. hirtiflora* Benth. People remove the bitter taste of yam by soaking the sliced tubers in water and a meal is prepared by either being cooked with meat or ground into fine flours and cooked with milk or boiled and eaten as chips.

No detailed reports evaluating the nutritional content and beneficial effect of boiled *D. dumetorum* and *D. hirtiflora* tubers were presented in the literature. Therefore, the present study aims to analyze the amino acid content, fatty acid profile, vitamin C, total phenolics and radical scavenging capacities of raw and boiled tubers of *D. dumetorum* and *D. hirtiflora.*

## MATERIALS AND METHODS

**Plant materials:** Plants were collected from Southern-West Kordofan in July 2009, were identified and voucher specimens (voucher No. of *D. dumetorum* 1109 KD3 and of *D. hirtiflora* 1109 KD4) were deposited in the Herbarium of Botany Department, Faculty of Science, University of Khartoum.

**Preparation of samples and extracts:** Tubers were washed with tap water after removing manually inedible parts, peeled and sliced. Leaching of the bitter taste of tubers was accomplished by steeping in water for three days using fresh water each day. Each sample

**Corresponding Author:** Sakina Yagi, Department of Botany, Faculty of Science, University of Khartoum, P.O. Box 321, Khartoum, Sudan, Tel.: 00 249 915030004

was divided into two portions. One portion was retained raw, the other was cooked by boiling. Samples (100 g) were added to 150 mL of water that had just reached the boil in a stainless steel pan and cooked for 10 min. The samples were drained off and air dried. Dry raw and processed samples were pounded and were kept at -20°C until analyses. All calculations were made according to dry matter basis.

Ethanolic extracts of raw and processed samples were also prepared for total phenolic and antioxidant capacity determination. The ethanol extract was prepared by soaking 20 g of sample in 200 mL ethanol at ambient temperature for 6 h. The extract was decanted, filtered and concentrated in a rotary evaporator to yield 0.8 and 1.2 g from raw and boiled tubers of *D. dumetorum* respectively and 1.3 and 1.9 g from raw and boiled *D. hirtiflora* tubers respectively.

**Chemicals:** Ninhydrin, boron trifluoride, metaphosphoric acid, dichloroindophenol sodium salt, Folin-Ciacalteu reagent, L-ascorbic acid, gallic acid, 1, 1-diphenyl-2- picrylhydrazyl (DPPH), 2, 2'-azino-bis (3-ethylbenzthiazoline-6-sulphonic acid) (ABTS), potassium persulfate were purchased from Sigma-Aldrich (France). Other chemicals used were all analytical grade.

**Amino acids analysis:** Amino acids composition of samples was measured as hydrolysate using an amino Acid Analyzer (Sykam-S7130) based on high performance liquid chromatography technique. Sample hydrolysis was prepared following the method of Moore and Stein (1963). Two hundred mg of sample were taken into a hydrolysis tube. Five mL 6 N HCl were added to the sample. The tube was tightly closed and incubated at 110°C for 24 h. After incubation period, the solution was filtered and 200 µL of the filtrate were evaporated to dryness at 140°C for an hour. The hydrolysate was diluted with one mL of buffer (citrate buffer pH 2.2). Aliquot of 150 µL of sample hydrolysate was injected in cation separation column at 130°C. Ninhydrin solution and an eluent buffer (the buffer system composed of solvent A of pH 3.45 and solvent B of pH 10.85) were delivered simultaneously into a high temperature reactor coil (16 m length) at a flow rate of 0.7 mL/min. The buffer/ninhydrin mixture was heated at 130°C for 2 min to accelerate chemical reaction of amino acid with ninhydrin. The products of the reaction mixture were detected at wavelength of 570 nm (440 nm for proline) on a dual channel photometer. The amino acids were identified by their retention time and wavelength ratio calculated from the areas of standards obtained from the integrator and expressed as mg/100 g.

**Fatty acids:** Fatty acid profiles of total lipids were determined after transesterification with 14% boron trifluoride in methanol (1:1 v/v). Fatty acid methyl esters were analyzed by GC-MS (QP 2010 Shimadzu GC-MS equipment). Supelco equity 1 column with a film thickness of 30 m×0.25 microns was used. The total flow rate was 24 mL/min and column flow rate was 1 mL/min. Ultra high purity Helium was used as the carrier gas with injector split ratio of 20: 1. The ion source and inter-phase temperatures were 200 and 250°C, respectively. The solvent cut time of 4 min and detector gain was 0.70 kv. A Wiley 229 library search was conducted on major peaks of the sample in order to identify the components of the sample. The relative percentage of each compound was determined.

**Determination of vitamin C:** The modified method of Bahorun *et al*. (2004) was used to determine the vitamin C content of *Dioscora* spp tubers. A 10 g of sample was blended with 40 mL of a solution of 3% metaphosphoric acid in 8% glacial acetic acid, pH 1.5, for 1 min. The extract was then mechanically shaken for 15 min in darkness filtered through glass wool. After filtration the clear extract was stored at -40°C prior to analysis by the 2, 6-dichloroindophenol titrimetric method (AOAC, 1995). Triplicate titration was conducted for all samples.

**Determination of total phenolics:** Total phenol contents in the extracts of raw and boiled *Dioscora* spp tubers were determined using modified Folin-Ciocalteu method (Wolfe *et al*., 2003). Ethanol extracts were resuspended in ethanol to make 50 mg/mL stock solutions. An aliquot of the extract was mixed with 5 mL Folin-Ciocalteu reagent (previously diluted with water at 1:10 v/v) and 4 mL (75 g/L) of sodium carbonate. The tubes were vortexed for 15 s and allowed to stand for 30 min at 40°C for color development. Absorbance was then measured at 765 nm using the SHIMADZU UV-2550 UV-VS spectrophotometer. Total phenolic contents were expressed as gallic acid equivalents (mg/100 g) using the following equation based on the calibration curve: $y = 0.0057x$, R2 = 0.9315, where x was the absorbance.

**DPPH radical-scavenging test:** Antioxidant activity of the extracts of raw and boiled *Dioscora* spp tubers was estimated using DPPH *in vitro* method (Mensor *et al*., 2001). Test samples were dissolved separately in methanol to get test solution of 1 mg/mL. Series of extract solutions of different concentrations (1, 5, 10, 20, 40, 60, 80 and 100 µg/mL) were prepared by diluting with methanol. Assays were performed in 96-well, microtiter plates. 140 µL of 0.6×10-6 mol/L DPPH was added to each well containing 70 µL of sample. The mixture was shaken gently and left to stand for 30 min in dark at room temperature. The absorbance was measured spectrophotometrically at 517 nm using a microtiter plate reader (Synergy HT Biotek, logiciel GEN5). Blank was done in the same way using methanol and sample without DPPH and control was done in the same way but using DPPH and methanol without sample. Ascorbic acid was used as reference antioxidant compound. Every analysis is done in triplicate.

The ability to scavenge DPPH radical was calculated by the following equation:

$$\text{DPPH radical scavenging activity (\%)} = 1-[(Abs_{sample}-Abs_{blank})]/(Abs_{control})] \times 100$$

where,
$Abs_{sample}$ = The absorbance of DPPH radical+sample
$Abs_{blank}$ = The absorbance of sample+methanol
$Abs_{control}$ = The absorbance of DPPH radical+methanol

The $IC_{50}$ value was calculated from the linear regression of plots of concentration of the test sample against the mean percentage of the antioxidant activity. The $IC_{50}$ values obtained from the regression plots (Sigma PlotsR 2001, SPSS Science) had a good coefficient of correlation, (R2 = 0.998).

**ABTS radical-scavenging test:** A second *in vitro* method was performed to estimate antioxidant potential of the extracts: ABTS assay, based on the method of Re *et al.* (1999). Test samples were dissolved separately in methanol to get test solution of 1 mg/mL. Series of extract solutions of different concentrations (1, 5, 10, 20, 40, 60, 80 and 100 μg/mL) were prepared by diluting with methanol. The ABTS radical cation ($ABTS^{*+}$) was produced by reacting 7 mM stock solution of ABTS with 2.45 mM potassium persulfate and allowing the mixture to stand in the dark at room temperature for 12 h before use. The obtained $ABTS^{*+}$ solution was diluted with methanol to an absorbance of 0.700±0.02 at 734 nm. 190 μL of $ABTS^{*+}$ solution was added to each well containing 10 μL of sample. The mixture was shaken gently and left to stand for 15 min in dark at room temperature. The absorbance was measured spectrophotometrically at 734 nm using a microtiter plate reader (Synergy HT Biotek®, logiciel GEN5). The $ABTS^{*+}$ scavenging capacity of the extract was compared with that of ascorbic acid and the percentage inhibition calculated as:

$$\text{ABTS radical scavenging activity (\%)} = [(Abs_{control}-Abs_{sample})]/(Abs_{control})] \times 100$$

where,
$Abs_{control}$ = The absorbance of $ABTS^{*+}$ (= 0.700±0.02)
$Abs_{sample}$ = The absorbance of sample + $ABTS^{*}$

The $IC_{50}$ value was calculated from the linear regression of plots of concentration of the test sample against the mean percentage of the antioxidant activity obtained from three replicate assays. The $IC_{50}$ values obtained from the regression plots (Sigma PlotsR 2001, SPSS Science) had a good coefficient of correlation, (R2 = 0.9926).

**Statistical analysis:** All analyses were performed in triplicate and data reported as mean±standard deviation (SD). Differentiation between data sets was determined by Student's t-test and significant differences were considered when means of compared sets differed at p<0.05.

## RESULTS AND DISCUSSION

**Amino acids content:** The composition and amount of amino acids in D. dumetorum and D. hirtiflora raw and boiled tubers are presented in Table 1. Comparing the total amounts of amino acids in the two Dioscorea species, the amount of the essential and non-essential amino acids in D. hirtiflora was higher. The total amount of essential amino acids was 9576 mg/100 g in raw D. hirtiflora tubers and 1085 mg/100 g in raw D. dumetorum tubers whereas the total amount of non-essential amino acids was 13869 mg/100 g in raw D. hirtiflora tubers and 3075 mg/100 g in raw D. dumetorum tubers. The contents of all amino acids varied significantly (p<0.05) within both Dioscorea species. Boiling decreased the total amino acids of both species. A decrease (23.29%) in total essential amino acids content in D. dumetorum was observed after processing. However, boiling increased significantly (p<0.05) isoleucine from 43 mg/100 g to 265 mg/100 g (13.2% of RDA) and methionine from 18 mg/100 g to 57 mg/100 g (5.7% of RDA) whereas phenylalanine was reduced significantly (p<0.05) from 106 mg/100 g to 67 mg/100 g. Comparison of these data of D. dumetorum tubers from Sudan with previous works on amino acid composition of wild and edible D. dumetorum varieties from Nigeria showed that the Nigerien species contained higher level of amino acids with remarkable high amount of leucine ranged from 2280 to 4900 mg/100 g and lysine ranged from 1140 to 490 mg/100 g (Alozie *et al*., 2009; Lape and Treche, 1994). Variations in levels of nutrients between Sudanese and Nigerian D. dumetorum tubers could be explained partly by variation in nature of the soil, seasonality, genetic diversity and stage of maturity (Guthrie and Picciano, 1995; Greenfield and Southgate, 2003).

Boiling also affected the amino acids content of *D. hirtiflora* tubers where, a decrease (10.66%) in total essential amino acids content was observed. The most abundant components of essential amino acids in boiled *D. hirtiflora* tubers, in decreasing order, were leucine (3135 mg/100 g) representing 80.4% of RDA, isoleucine (1782 mg/100 g) representing 89.1% of RDA and tyrosine+phenylalanine (2015 mg/100 g) representing 80.6% of RDA. Methionine was only detected in boiled tubers (258 mg/100 g) representing 25.8% of RDA. The major components of non-essential amino acids were alanine (3866 mg/100 g) and arginine (2065 mg/100 g). Although, methionine and lysine

Table 1: Amino acids profile of *Dioscorea dumetorum* and *D. hirtiflora* tubers (dry weight basis, mg/100 g)

| Amino acids | | *D. dumetorum* Raw | *D. dumetorum* Boiled | *D. hitriflora* Raw | *D. hitriflora* Boiled |
|---|---|---|---|---|---|
| Essential | | | | | |
| | Thr | 72±4[aA] | 84±15[a] | 832±8[bB] | 697±17[b] |
| | Met | 18±4[a] | 57±8[b] | ND | 258±2 |
| | Ile | 43±2[aA] | 265±5[b] | 1888±9[cB] | 1782±5[c] |
| | Leu | 278±9[aA] | 166±16[a] | 3533±97[bB] | 3135±86[c] |
| | Tyr | 73±7[aA] | 49±9[a] | 558±2[bB] | 483±3[b] |
| | Phe | 106±5[aA] | 67±9[b] | 1740±10[cB] | 1532±124[d] |
| | Lys | 39±2[aA] | 71±3[a] | 514±14[bB] | 361±1[b] |
| | His | 69±2[aA] | 62±3[a] | 511±19[bB] | 385±22[b] |
| Total | | 1085 | 821 | 9576 | 8.633 |
| Non-essential | | | | | |
| | Asx | 398±1[aA] | 436±7[a] | 1973±22[bB] | 1842±14[b] |
| | Ser | 144±6[aA] | 152±4[a] | 615±5[bB] | 557±7[b] |
| | Glx | 133±2[aA] | 211±12[a] | 1456±16[bB] | 1834±15[b] |
| | Gly | 78±9[aA] | 86±1[aA] | 251±2[bB] | 158±19[b] |
| | Ala | 751±4[aA] | 264±6[b] | 4377±9[cB] | 3866±29[c] |
| | Arg | 259±8[aA] | 151±1[a] | 2915±11[bB] | 2065±22[b] |
| | Pro | 1312±12[aA] | 107±11[b] | 2282±17[cB] | 1991±6[c] |
| Total | | 3075 | 2902 | 13869 | 12313 |
| Total amino acids | | 4160 | 3191 | 23445 | 20946 |

ND: not detected; Each value represents mean±S. D. of triplicate (n = 3); Different lowercase letters for in the same row correspond to significant differences by Student's t test (p<0.05) between raw and boiled samples; Different capital letters in the same row correspond to significant differences by Student's t test (p<0.05) between raw samples

Table 2: Composition of fatty acids (dry weight basis, %) of *Dioscorea dumetorum* and *D. hirtiflora* tubers

| Fatty acids | | *D. dumetorum* Raw | *D. dumetorum* Treated and boiled | *D. hitriflora* Raw | *D. hitriflora* Treated and boiled |
|---|---|---|---|---|---|
| Caproic | C6:0 | 0.32±0.01[a] | 0.25±0.02[b] | ND | 0.83±0.03 |
| Undecanoic | C11:0 | 0.38±0.02 | ND | ND | ND |
| Lauric | C12:0 | 0.28±0.01[aA] | 1.29±0.01[b] | 0.53±0.01[cB] | 0.45±0.01[d] |
| Tridecanoic | C13:0 | 0.33±0.01 | ND | 0.45±0.01 | ND |
| Myristic | C14:0 | 1.63±0.06[aA] | 1.80±0.01[b] | 2.27±0.01[cB] | 2.71±0.01[d] |
| Pentadecanoic | C15:0 | 1.71±0.01[aA] | 1.06±0.01[b] | 1.60±0.01[cA] | 1.58±0.01[c] |
| Palmatic | C16:0 | 42.71±1.2[aA] | 31.58±0.6[b] | 33.54±0.7[cB] | 37.28±0.5[d] |
| Heptadecanoic | C17:0 | ND | ND | ND | 0.47±0.01 |
| Stearic | C18:0 | 7.17±0.06[aA] | 5.55±0.05[b] | 6.33±0.02[cB] | 6.73±0.01[d] |
| Heneicosanoic | C21:0 | 0.15±0.01 | 0.36±0.02 | ND | ND |
| Behenic | C22:0 | 2.49±0.01[aA] | 1.21±0.02[b] | 0.88±0.02[cB] | 0.59±0.02[d] |
| Tricosanoic | C23:0 | ND | ND | ND | ND |
| Llignoceric | C24:0 | 0.20±0.028 | ND | ND | 0.20±0.08 |
| Myristoleic | C14:1 | ND | 0.10±0.01 | ND | ND |
| Pentadecenoic | C15:1 | 0.55±0.01[aA] | 0.65±0.01[b] | 0.67±0.01[cB] | 0.73±0.03[d] |
| Palmitoleic | C16:1 | 0.63±0.03[aA] | 0.90±0.01[b] | 1.38±0.04[cB] | 1.26±0.02[d] |
| Oleic | C18:1 | 13.71±0.02[aA] | 29.13±0.8[b] | 27.19±0.2[cB] | 21.73±1.18[d] |
| Elaidic | C18:1 | ND | ND | ND | 0.59±0.01 |
| Eicosenoic | C20:1 | ND | ND | ND | 0.16±0.01 |
| Erucic | C21:1 | ND | 0.14±0.03 | ND | ND |
| Nervonic | C24:1 | 1.03±0.06[aA] | 0.78±0.02[b] | 0.38±0.02[cB] | 0.88±0.01[d] |
| Linoleic | C18:2 | 1.34±0.17[aA] | 0.93±0.02[b] | 0.80±0.02[cB] | 1.34±0.01[d] |
| Linolelaidic | C18:2 | 10.83±0.62[aA] | 15.74±0.12[b] | 13.93±0.03[cB] | 12.14±0.7[d] |
| Linolenic | C18:3 | 11.62±0.17[aA] | 6.80±0.26[b] | 8.59±0.24[cB] | 9.67±0.01[d] |
| Arachidonic | C20:4 | 2.85±0.04[aA] | 1.64±0.02[b] | 0.79±0.02[cB] | 1.18±0.09[d] |
| Total Saturated Fatty Acids (TSFAs) | | 57.30 | 43.1 | 44.72 | 50.84 |
| Total Unsaturated Fatty Acids (TUSFAs) | | 42.56 | 56.81 | 53.73 | 49.08 |
| Monounsaturated fatty acids (MUSFAs) | | 15.92 | 31.70 | 29.62 | 26.13 |
| Polyunsaturated fatty acids (PUSFAs) | | 26.64 | 25.11 | 24.11 | 22.95 |

ND: Not Detected; Each value represents mean±S.D. of triplicate (n = 3); Different lowercase letters for in the same row correspond to significant differences by Student's t test (p<0.05) between raw and boiled samples; Different capital letters in the same row correspond to significant differences by Student's t test (p<0.05) between raw samples

contents were higher in *D. hirtiflora* boiled tubers, they represented only 17 and 12% of RDA respectively. These results agreed well with earlier report (Guerrero-Beltran *et al*., 2009) showing that the sulfur-containing amino acids, methionine, cystein and lysine, turned out to be the most limiting essential amino acids in yam tubers.

**Fatty acids composition:** The composition of fatty acids in *D. dumetorum* and *D. hirtiflora* tubers is shown in Table 2. Total saturated fatty acids ranged from 44.72% in *D. hirtiflora* tubers to 57.30% in *D. dumetorum* tubers. These values were higher than the values reported for Nigerian edible (36.7%) and wild (36.5%) *D. dumetorum* (Alozie and Akpanabsatu,

Table 3: Vitamin C and total phenolic content of Dioscorea dumetorum and D. hirtiflora tubers

| | Food state | Vitamin C (mg/kg) | Total phenolic content (mg GAE/100 g) |
|---|---|---|---|
| *D. dumetorum* | Raw | $127 \pm 1^{aA}$ | $602 \pm 10^{aA}$ |
| | Treated and boiled | $55 \pm 1^{b}$ | $242 \pm 7^{b}$ |
| *D. hirtiflora* | Raw | $60.5 \pm 8^{cB}$ | $131 \pm 2^{cB}$ |
| | Treated and boiled | $28.8 \pm 8^{d}$ | $585 \pm 5^{d}$ |

Each value represents mean±S.D. of triplicate (n = 3); Different lowercase letters for in the same column correspond to significant differences by Student's t test ($p<0.05$) between raw and boiled samples; Different capital letters in the same column correspond to significant differences by Student's t test ($p<0.05$) between raw samples

2010). Monounsaturated fatty acids (MUSFAs) and polyunsaturated fatty acids (PUFAs) accounted for 15.92 and 26.64% in *D. dumetorum* tubers respectively whereas, MUSFAs and PUFAs accounted for 29.62 and 24.11% in *D. hirtiflora* tubers respectively. Ratio of unsaturated fatty acid: saturated fatty acid (U:S) was 0.74 in *D. dumetorum* tubers and 1.20 in *D. hirtiflora* oness. The contents of most fatty acids varied significantly ($p<0.05$) within the two *Dioscorea* species. Palmitic acid and oleic acid were the most abundant saturated and unsaturated fatty acids respectively in both species. Palmitic acid content of *D. dumetorum* tubers (42.71%) and that of *D. hirtiflora* tubers (33.54%) was higher than the value of Nigerian *D. dumetorum* (22-29%) reported by Alozie and Akpanabsatu (2010).

Boiling of *D. dumetorum* tubers increased the Total Unsaturated Fatty Acids (TUSFTs) from 42.56 to 56.81% whereas, the total saturated fatty acids was decreased from 57.30 to 43.1%. However, *D. hirtiflora* tubers showed an increase in TSFAs from 44.72 to 50.84% and decrease in TUSFTs from 53.73 to 49.08% upon boiling. MUSFT was increased from 15.92 to 31.70% and PUSFAs showed a slight decrease from 26.64 to 25.11% in boiled *D. dumetorum* tubers. A slight decrease in both MUSFTs and PUSFAs was observed in boiled *D. hirtiflora* tubers. As in raw materials, palmitic acid and oleic acid were the most abundant saturated and unsaturated fatty acids respectively in both species. The palmitic acid content was significantly ($p<0.05$) decreased from 42.71 to 31.58% in *D. dumetorum* tubers and increased from 33.54 to 37.28% in *D. hirtiflora* tubers, whereas, a significant ($p<0.05$) increase in oleic acid content in boiled *D. dumetorum* tubers from 13.71% to 29.13% and a decrease from 27.19 to 21.73% was observed in *D. hirtiflora* tubers. Linolelaidic acid was the most abundant PUSFA in raw and boiled tubers of the both *Dioscorea* species. Shajeela *et al*. (2013) found that the predominant PUSFA of others *Dioscorea* species from India was its isomer linoleic acid.

**Vitamin C:** The content of vitamin C in *Dioscorea* tubers varied significantly ($p< 0.05$) within the two species (Table 3). Vitamin C content was twofold higher in *D. dumetorum* tubers (127 ± 0.01 mg/kg) content than *D. hirtiflora* tubers (60.5 ± 0.06 mg/kg). This variation might be related to the differences in genotypes. However, boiling caused a significant decrease ($p<0.05$) in the vitamin C content of the two *Dioscorea* tubers. Boiling led to a decrease of 56.7 and 52.4% in *D. dumetorum* and *D. hirtiflora* tubers respectively. It is well established that vitamin C and thiamine are the nutrient most susceptible to the thermal degradation and leaching from food (Nagy and Smooth, 1977; Bognár, 1998).

**Phenols:** The total phenolic contents were expressed as mg Gallic Acid Equivalent (GAE) per 100 g dry sample and are listed in Table 3. The raw *D. dumetorum* tubers showed higher the total phenol content (602 mg GAE/g) than that of raw *D. hirtiflora* tubers (131 mg GAE/g). Interestingly, after boiling *D. hirtiflora* tubers showed 4.5-fold gain in their total phenolic content whereas, *D. dumetorum* tubers showed 60% loss in their total phenolic content after boiling. Contradicted results on the effect of different cooking process on the total phenolic content were obtained. This difference might depend on type of vegetable used. Blessington *et al*. (2010) and Burgos *et al*. (2013) showed that cooked potato samples had greater levels of total phenolic than in uncooked ones. On the other hand, some studies (Ismail *et al*., 2004; Zhang and Hamauzu, 2004; Turkmen *et al*., 2005) showed that cooking process like boiling, baking and microwaving reduced both the polyphenol content in selected vegetables. The percent gain in the total phenol content during cooking may be due to the breakdown of tough cell walls and increased extractability of compounds (Adefegha and Oboh, 2011). Dewanto *et al*. (2002a) found that ferulic acid found in the cell wall of grains such as corn, wheat and oats, doubled after 10 min of cooking and increased by as much as 900% after 50 min of cooking.

**Antioxidant activity:** In this study, DPPH radical and ABTS radical cation assays were used for evaluation of free radical-scavenging properties of the ethanolic extracts of raw and processed *Dioscorea* spp. tubers. The results of investigation are shown in Fig. 1 and 2. Raw *D. dumetorum* tubers showed higher radical-scavenging activity ($IC_{50}$ 72.351 mg/L) than that of *D. hirtiflora* ($IC_{50}$ 307.958 mg/L). Boiling caused a sharp increase, comparable to the control, in the radical-scavenging properties of *D. hirtiflora* tubers ($IC_{50}$ 22.35 mg/L). This increase in antioxidant activity could be correlated to the increase in total phenolic content (4.5-fold gain) after boiling. It is worth noting that this increase in antioxidant activity with cooking, agrees with earlier reports on the effect of cooking on the antioxidant properties of maize (Dewanto *et al*., 2002a), carrots (Talcott *et al*., 2000) and tomatoes (Dewanto

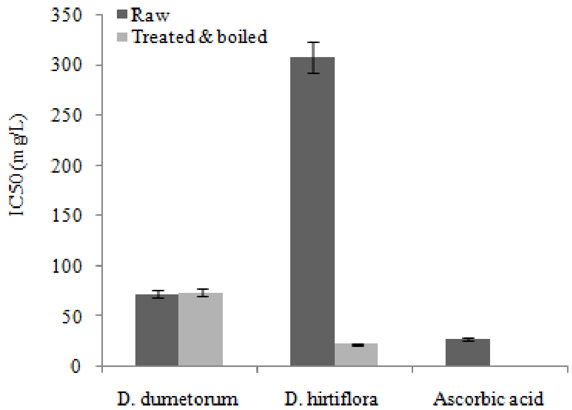


Fig. 1: DPPH radical scavenging activities of *Dioscorea dumetorum* and *D. hirtiflora* tubers

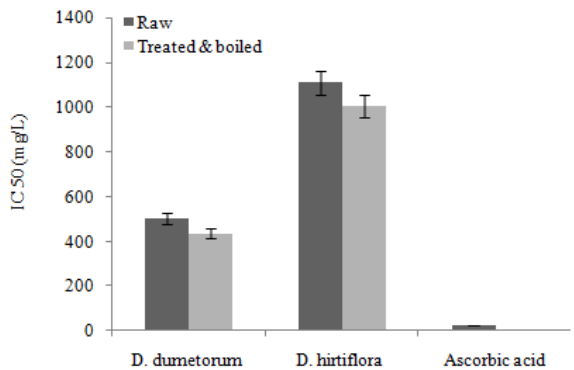


Fig. 2: ABTS radical scavenging activities of *Dioscorea dumetorum* and *D. hirtiflora* tubers

*et al*., 2002b). However, boiling did not change significantly the antioxidant activity of *D. dumetorum* tubers although a significant decrease in total phenolic and vitamin C contents was observed.

The antioxidant capacity of the two *Dioscorea* spp. tubers using the ABTS method was lower than that obtained from the DPPH method and very weak when compared with that of ascorbic acid (Fig. 2). The antioxidant capacity using the ABTS method was 6.4 and 3.6 fold lower for raw *D. dumetorum* and *D. hirtiflora* tubers than those determined by the DPPH method. Boiling did not also change the scavenging capacity of the two *Dioscorea* spp. tubers. The ABTS and DPPH assays are both associated with electron and radical scavenging but have been reported to give different results (Burgos *et al*., 2013). Gramza *et al*. (2005) found that Yunan tea extracts showed also different scavenging capacity on using the two different methods of scavenging the stable free radicals $ABTS^{+\bullet}$ and $DPPH^{\bullet}$. They suggested that variation might be attributed to different action mechanisms of oxidative factors, including free radicals and in addition, they proposed that possible antiradical activity of plant extracts was conditioned by antioxidant structures as well as other component interactions.

## CONCLUSION

Boiling decreased the amino acids content of both tubers studied whereas, the total unsaturated fatty acids increased in *D. dumetorum* tubers and decrease in *D. hirtiflora* tubers. Boiling enhanced the antioxidant capacity of *D. hirtiflora* tubers and did not significantly affect that of *D. dumetorum* tubers. The high phenolic content present in the tubers in raw and boiled state might be the main contributors of this antioxidant activity. Therefore, boiled *D. dumetorum* and *D. hirtiflora* tubers could contribute positively for human diets and health.

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## REFERENCES

Adefegha, S.A. and G. Oboh, 2011. Cooking enhances the antioxidant properties of some tropical green leafy vegetables. Afr. J. Biotechnol., 10(4): 632-639.

Alozie, Y., M.I. Akpanabiatu, I.B. Umoh, E.U. Eyong and G.A.O. Alozie, 2009. Amino acid composition of *Dioscorea dumetorurm* varieties. Pak. J. Nutr., 8(2): 103-105.

Alozie, Y.E., O.O. Lawal, I.B. Umoh and M.I. Akpanabiatu, 2010. Fatty acid composition of *Dioscorea Dumetorum* (pax) varieties. Afr. J. Food Agric. Nutr. Dev., 10(8): 2956-2966.

AOAC (Association of Official Analytical Chemists), 1995. Official Methods of Analysis. Association of Official Analytical Chemists, Washington, D.C.

Bahorun, T., A. Luximon-Ramma, A. Crozier and O.I. Aruoma, 2004. Total phenol, flavonoid, proanthocyanidin and vitamin C levels and antioxidant activities of Mauritian vegetables. J. Sci. Food Agr., 84: 1553-1561.

Batal, M. and E. Hunter, 2007. Traditional Lebanese recipes based on wild plants: An answerer to diet simplification? Food Nutr. Bull., 28(suppl. 2): S303-S311.

Blessington, T., M.N. Nzaramba, D.C. Scheuring, A.L. Hale, L. Reddivari and J.C. Miller Jr., 2010. Cooking methods and storage treatments of potato: Effects on carotenoids, antioxidant activity, and phenolics. Am. J. Potato. Res., 87(6): 479- 491.

Bognár, A., 1998. Comparative study of frying to other cooking techniques influence on the nutritive value. Grasas Aceites, 49(3-4): 250-260.

Bouayed, J. and T. Bohn, 2013. Dietary Derived Antioxidants: Implications on Health. Nutrition, Well-Being and Health. Retrieved form: http://www.intechopen.com/books/nutrition-well-being-and-health/dietary–derived-antioxidants-implication-on-health.

Burgos, G., W. Amoros, L. Munoa, P. Sosa, E. Cayhualla, C. Sanchez, C. Diaz and M. Bonierbale, 2013. Total phenolic, total anthocyanin and phenolic acid concentrations and antioxidant activity of purple-fleshed potatoes as affected by boiling. J. Food. Compos. Anal., 30: 6-12.

Bussmann, R.W., G.G. Gilbreath, J. Solio, M. Lutura, R. Lutuluo, K, Kunguru, N. Wood and S.G. Mathenge, 2006. Plant use of the Maasai of Sekenani Valley, Maasai Mara, Kenya. J. Ethnobiol. Ethnomed., 2: 22.

Doka, I.G., S. El Tigani and S. Yagi, 2014. Amino acid content, fatty acid profile and radical scavenging capacities of *Coccinia grandis* (L.) Voigt. Fruits. Adv. J. Food Sci. Technol., 6(12): 1307-1312.

Cook, J.A., D.J. VanderJagt, A. Pastuszyn, G. Mounkaila, R.S. Glew, M. Millson and R.H. Glew, 2000. Nutrient and chemical composition of 13 wild plant foods of Niger. J. Food. Compos. Anal., 13: 83-92.

Dewanto, V., X. Wu and R.H. Liu, 2002a. Processed sweet corn has higher antioxidant activity. J. Agr. Food Chem., 50 (17): 4959-4964.

Dewanto, V., X. Wu, K.K. Adom and R.H. Liu, 2002b. Thermal processing enhances the nutritional value of tomatoes by increasing total antioxidant activity. J. Agr. Food Chem., 50(10): 3010-3014.

Gramza, A., K., Pawlak-Lemañska, J. Korczak, E. Wąsowicz and M. Rudzinska, 2005. Tea extracts as free radical scavengers. Pol. J. Environ. Stud., 14(6): 861-867.

Greenfield, H. and D.A.T. Southgate, 2003. Food Composition Data. Production, Management and Use. 2nd Edn., FAO, Rome.

Grivetti, L.E. and B.M. Ogle, 2000. Value of traditional foods in meeting macro-and micronutrient needs: The wild plant connection. Nutr. Res. Rev., 13: 31-46.

Guerrero-Beltrán, J.A., Y. Estrada-Giron, B.G. Swanson and G.V. Barbosa-Canovas, 2009. Pressure and temperature combination for inactivation of soymilk protease inhibitors. Food Chem., 116: 676-679.

Guthrie, H.A. and M.F. Picciano, 1995. Micronutrients. Human Nutrition: With Assistance of Andrew Scott. Published by Mosby-Yearbook, Healthing. 2nd Edn., Avery Publishing Group. Garden City Park. New York, pp: 333-350.

Ismail, A., Z.M. Marjan and C.W. Foong, 2004. Total antioxidant activity and phenolic content in selected vegetables. Food Chem., 87: 581-586.

Lape, I.M. and S. Treche, 1994. Nutritional quality of yam (*Dioscorea dumetorum* and *D. rotundata*) flours for growing rats. J. Sci. Food Agr., 66: 447-455.

Medley, K.E. and H.W. Kalibo, 2007. Ethnobotanical survey of 'wild' woody plant resources at mount Kasigau, Kenya. J. East Afr. Nat. Hist., 96(2): 149-186.

Mensor, L.L., F.S. Menezes, G.G. Leitão, A.S. Reis, T.C. dos Santos, C.S. Coube and S.G. Leitão, 2001. Screening of Brazilian plant extracts for antioxidant activity by the use of DPPH free radical method. Phytother. Res., 15:127-130.

Miller, H.E., F. Rigeihof, L. Marquart, A. Prakash and M. Kanter, 2000. Whole-grain products and antioxidants. Cereal Food. World, 45(2): 59-63.

Moore, S. and W.H. Stein, 1963. Methods in Enzymology. In: Colowick, S.P. and N.O. Kaplan (Eds.), Academic Press, New York, Vol. 6.

Nagy, S. and J.M. Smooth, 1977. Temperature and storage effects on percent retention and percent U.S. recommended dietary allowances of vitamin C in canned single-strength orange juice. J. Agr. Food Chem., 25: 135-138.

Re, R., N. Pellegrini, A. Proteggente, A. Pannala, M. Yang and C. Rice-Evans, 1999. Antioxidant activity applying an improved ABTS radical cation decolorization assay. Free Radical Bio. Med., 26: 1231-1237.

Shajeela, P.S., P.S. Tresina and V.R. Mohan, 2013. Fatty acid composition of wild yam (*Dioscorea* spp.). Trop. subtrop. Agroecosyst., 16: 35-38.

Talcott, S.T., L.R. Howard and C.H. Brenes, 2000. Contribution of periderm material and blanching time to the quality of pasteurized peach puree. J. Agr. Food Chem., 48(10): 4590-4596.

Turkmen, N., F. Sari and Y.S. Velioglu, 2005. The effect of cooking methods on total phenols and antioxidant activity of selected green vegetables. Food Chem., 93: 713-718.

Vanderjagt, D.J., C. Freiberger, H.T. Vu, G. Mounkaila, R.S. Glew and R.H. Glew, 2000. The trypsin inhibitor content of 61 wild edible plant foods of Niger. Plant Food Hum. Nutr., 55(4): 335-46.

Wolfe, K., X. Wu and R.H. Liu, 2003. Antioxidant activity of apple peels. J. Agr. Food Chem., 51: 609-614.

Zhang, D. and Y. Hamauzu, 2004. Phenolics, ascorbic acid, carotenoids and antioxidant activity of broccoli and their changes during conventional and microwave cooking. Food Chem., 88: 503-509.