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Proximate composition, Vitamin C and Beta-Carotene Contents of Fifteen Selected Leafy Wild and Semi-Wild Food Plants (WSWFPs) from Bunyoro-Kitara Kingdom, Uganda

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ABSTRACT

This paper presents the proximate composition, vitamin C and beta-carotene contents of 15 selected leafy wild and semi-wild food plants (WSWFPs) from Bunyoro-Kitara Kingdom, Uganda. Proximate analysis using standard procedures included determination of: moisture, energy (caloric value), ash, protein, fat, total carbohydrates and dietary fibre. Results of the analyses were compared those of the conventionally well known and widely cultivated *Brassica oleracea* var *capitata*. L. (Alef.) - the common cabbage plant. Compared to the conventionally planted cabbage, most WSWFPs were generally richer sources of macro-nutrients, vitamin C and beta-carotene, and therefore they can help improve household nutrition especially during the months preceding the harvest of cultivated crops and also during periods of social unrests, droughts, famine, and other natural catastrophes. *Senna obtusifolia*, *Vernonia amygdalina*, *Acalypha bipartita*, *Asystasia gangetica* and *Physalis peruviana* were the richest sources of calories (50.45–544.31 kcal/100g). Ash content was highest (3.69–6.54 g/100g) in *Vernonia amygdalina*, *Solanum nigrum*, *Senna obtusifolia*, *Hyptis spicigera*, while protein was more abundant (5.20–12.11 g/100g) in *Vernonia amygdalina*, *Crotalaria ochroleuca*, *Senna obtusifolia*, *Acalypha bipartita*, *Corchorus trilocularis* and in *Solanum nigrum*. Total fat content was highest in *Senna obtusifolia* (2.05 ± 0.07 g), and *Acalypha bipartita* (1.32 ± 0.10 g) while the tender leaves of *Vernonia amygdalina*, *Asystasia gangetica*, *Corchorus trilocularis*, *Senna obtusifolia*, *Asystasia mysorensis* and *Hibiscus acetosella* were highest (7.49–38.62g/100g) in carbohydrates contents. Good sources (3.50–7.76 g/100g) of dietary fibres were *Vernonia amygdalina*, *Crotalaria ochroleuca* and *Sonchus oleraceus*. Vitamin C was highest (98.03–337.05 mg/100g) in *Cleome hirta*, *Vernonia amygdalina*, *Acalypha bipartita*, *Solanum nigrum*, *Crotalaria ochroleuca*, and *Corchorus trilocularis* more than RDA for an adult (65–90 mg). While β -Carotene contents beyond the RDA were found in *Sonchus oleraceus*, *Cleome hirta*, *Solanum nigrum*, *Senna obtusifolia*, *Crotalaria ochroleuca*, *Vernonia amygdalina*, *Asystasia gangetica*, *Vigna unguiculata*, *Asystasia mysorensis*, *Corchorus trilocularis* and *Amaranthus spinosus*. These findings therefore create a justification that the wild leafy WSWFPs are important food items that needs popularization.

Keywords: Proximate composition, Vitamin C, Beta-Carotene Contents, Wild Food Plants.

INTRODUCTION

According to the United Nation Development Program's quality of life index [1] (Human Development Report, 2013), most developing countries especially those in Africa are ranked the lowest. Uganda for example was ranked 161 (HDI of 0.456) same as Haiti out of 187 countries with data. The Human Development Index (HDI) provides a composite measure of three dimensions of human development: living a long and healthy life (measured by life expectancy), being educated (measured by adult literacy and enrolment at the primary, secondary and tertiary level) and having a decent standard of living (measured by purchasing power parity (PPP) and income) [1]. These rankings, therefore, reflect the enormous challenges (e.g. food insecurity and illiteracy) of developing countries. Millions of people in the developing countries do not have enough food to meet their daily food requirements and a further more people are deficient in one or more micronutrients [2].

Globally, Food and Agricultural Organisation reports that at least one billion people are thought to use wild foods in their diet [3]. The diversity in wild species offers variety in family diet and contributes to household food security. Most of them are nutritionally rich and can supplement nutritional requirements, especially vitamins and micronutrients [4]. Numerous publications provide detailed knowledge of edible wild plants in specific locations in Africa [5, 6, 7, 8, 9]. These publications show that wild plants are essential components of many Africans' diets, especially in periods of seasonal food shortages. In Ghana alone, the leaves of over 300 species of wild plants and fruits are consumed [8]. In Zimbabwe, poor households rely on wild fruits as an alternative to cultivated food for a quarter of all dry season's meals [10]. Similarly, in Northern Nigeria, leafy vegetables and other bush foods are collected as daily supplements to relishes and soups [11]. In Swaziland, wild food plants are still of great importance and contribute a greater share to the annual diet than domestic cultivars [12, 8]. Various reports also noted that many wild edibles are nutritionally rich [13, 12, 14, 15] and can supplement nutritional requirements, especially vitamins and micronutrients.

Whenever inadequate amounts of essential nutrients are provided, nutritional deficiency or inadequacy results and affects all developmental growth, efficiency of labour and the span of working life, which eventually influences the economic potential of a country [16]. Nutritional studies have shown that nutritional deficiency may also lead to very low haemoglobin levels in infants and pregnant women, the elderly and sick people in addition to increasing the prevalence of night blindness. The diet of average rural dwellers in Uganda is known to be deficient in most nutrients that could largely and cheaply be obtain from locally available indigenous vegetables [16]. Nutritional analysis of some wild food plants demonstrates that in many cases the nutritional quality of wild plants is comparable and in some cases even superior to domesticated varieties [17]. Wild food plants can have even higher fat, protein and vitamin contents than cultivated species [18, 12].

This paper therefore, presents the results of the study that was aimed at assessing the nutritional values of selected fifteen leafy wild and semi-wild food plants (WSWFPs) consumed in Bunyoro-Kitara Kingdom, Uganda. We specifically present the moisture, energy (calories), ash, protein, fat, total carbohydrates, dietary fibre and vitamins-ascorbic acid (Vitamin C) and β -carotene (provitamin A) contents of selected leafy WSWFPs from Bunyoro-Kitara Kingdom. We hypothesised that there was no differences in moisture, energy (calories), ash, protein, fat, total carbohydrates, dietary fibre and vitamins-ascorbic acid (Vitamin C) and β -carotene (provitamin A) contents of the selected leafy WSWFPs compared to the conventionally well known and widely cultivated *Brassica oleracea var capitata*. L. (Alef.) - the common cabbage plant.

MATERIALS AND METHODS

Sample collection

Field samples of the selected leafy WSWFPs for nutritional analyses were collected from Mutunda and Kiryandongo sub-counties of Kibanda County in Bunyoro-Kitara Kingdom. The validity and usefulness of plant nutritional analysis depends largely on obtaining a reliable sample. If the samples taken are not representative, then all the careful and costly work put into subsequent analysis would be a wasted effort because the result would be less valid [19]. A minimum of 15-25 plants should be sampled in order to obtain a statistically significant number of plant tissues needed for analysis [20]. Field inventory (field walk) with key informants was undertaken to collect plant samples 15 samples of the leafy WSWFPs for laboratory analysis. The selection of these species for nutrient content analysis were undertaken on the basis of SWOT (Strength, Weakness, Opportunities and Threats) analysis

considering occurrence of the plant in natural habitats, market value, scanty information available on nutrient content, and the extent of anthropogenic pressure on species.

In addition to the 15 selected leafy WSWFPs, samples of the common cabbage plant- *Brassica oleracea var capitata*. L. (Alef.) was also collected from the same region and analysed for comparison purposes. Each plant sample was taken from a minimum of 15 plants found within a radius of about 1 km, with the exception of *Hibiscus acetosella* where samples were collected from 13 plants. Only the frequently harvested edible plant parts were collected in plastic bags labelled with sample numbers, date, code of locations, plant part, and analysis to be conducted. About 500 grams of each plant material were collected in order to have an adequate amount of plant material for the analysis.

Laboratory and analytical procedures

The laboratory and analytical procedures for nutritional analysis was limited to the portion of the plant normally consumed as prepared by local communities. Where appropriate, analyses included determination of moisture content, energy (calories), ash, protein, fat, total carbohydrates, dietary fibre, ascorbic acid (Vitamin C) and β -carotene. All plant materials with exception of those used for determination of vitamin C and β -carotene, were dried in an oven with a fan at 65 °C for 24 hours using the AOAC [21] (1980) air oven method No. 14.003 and then ground for chemical analysis. All samples were analysed in triplicate.

Moisture content

Determination of moisture content (MC) of the samples was carried out following procedures described in Kirk and Sawyer [22] and AOAC [23]. Aluminium dishes were washed, dried in the oven, removed and allowed to cool in a desiccator. About 3–4 g of the samples (in triplicates) were weighed into the dishes using analytical weight balance. The dishes containing the samples were placed in the oven (Gallenkamp hotbox oven fan size 2) and the oven temperature adjusted to 65 °C, and the samples dried to constant weights. The samples were then removed, placed in a desiccator to cool and weighed and the MC of the sample was calculated as follows: $MC (g) = (B - C)/A$; where A is the weight of dry sample (C – weight of the dish) in grams (g); B is Wt. of dish and sample prior to drying in g; C is Wt. (g) of the dish and sample after drying; and B – C is the loss in Wt. (g) of sample after drying.

Total ash

Total ash content of the samples (in triplicates) were determined using the AOAC standard methods [23]. Five (5) g of the samples were weighed into a weighed porcelain dishes and dried for 3–4 hours in a Gallenkamp hotbox oven fan size 2 at 105 °C, until a constant weight was reached. The dishes and the contents were then weighed before being transferred to a muffle furnace and ignited at 550 °C for about 5 to 6 hours until the residues appeared greyish-white. The samples were then removed from the muffle furnace and placed in the desiccator to cool for 1 hour, after which time they were removed from the desiccator and weighed. Ash content of the samples were calculated as follows: $Ash\ content (g) = (B - C)/A$; where A is the Wt. of initial sample (g) after drying at 105 °C; B is Wt. (g) of dish and contents after the ignition process; C is Wt. of the empty dish.

Energy (caloric value)

Total energy (caloric value) of the plant samples were determined using a Gallenkamp Autobomb calorimeter (SG 96/02/536, Gallenkamp and Company Ltd, England UK). The method is based on combustion in a 'bomb' chamber, and when the sample is burned, the resulting heat is measured by the increase in temperature of water surrounding the bomb. One (1) gram of sample (in triplicate) was pelleted with a briquette press and weighed in a crucible. The pelleted sample was connected to the firing wire, which was fitted between the electrodes, by a cotton thread. The electrode assembly was placed into the bomb and the bomb was tightened. The circuit was tested and the bomb was filled with oxygen to a pressure of 3000 Pa (30 bar). The calorimeter vessel was filled with water (total weight 3 Kg) at 21- 23 °C, the prepared bomb was placed inside the calorimeter vessel, and then the calorimeter vessel was placed into the water jacket. The machine was switched on and left for a while (10-15 minutes) to warm up. Prior to firing, the initial temperature of the water was checked and recorded and 10-15 minutes after firing the final temperature was recorded. Benzoic acid was used as a standard. The energy value determined from such a standard of known energy was used to calibrate the system. Finally, the sample energy content was calculated according to the formula: $Gross\ energy (kJ/g) = \{[(Final\ temperature - Initial\ temperature) \times 10.82] - 0.0896\}/Wt.\ of\ the\ sample$. Where, 10.82 = Heat capacity of the calorimeter in kJ/K; 0.0896 = Combined energy value of nickel wire and cotton in kJ.g⁻¹.

Protein

Protein contents of the samples were determined by the Kjeldahl method using Kjeltec Auto 1030 Analyzer (Tecator, Sweden), the most widely used method employed for the determination of protein in organic substances. This is because on digestion with concentrated sulphuric acid and catalysts, organic compounds are oxidized and the nitrogen is converted to ammonium sulphate. Upon making the reaction mixture alkaline, ammonia is liberated, removed by steam distillation, collected and titrated. Two hundred (200) mg samples were placed in a Kjeltec digestion tube. Two mercury Kjeltabs (Fisher K/0130/80) and 5 ml concentrate sulphuric acid (BDH 45006) were added to the samples. The samples were digested at 400°C (Digestion system 40 Tecator 1006 heating unit) for one hour. Twenty (20) ml of deionised water and 5 ml of 1.33N sodium thiosulphate were added to the sample after allowing it to cool. The samples were then distilled and the ammonia liberated, after adding of 25ml of 40% NaOH collected in standard boric acid and titrated against 0.2M hydrochloric acid. Both distillation and titration were automated. Blanks were prepared and treated in the same manner except that the tubes were free of sample. The titre values were read and later used to determine the protein content of the plant samples. Protein content were calculated according to the formula: Protein (g) = [(Sample titre – Blank titre) x 0.21 x 14.0072 x 6.25]/Wt. of the sample. Where, 0.21 is the normality of hydrochloric acid; 14.0072 is the molecular weight of nitrogen; and 6.25 is the nitrogen factor; since protein is assumed to be 16% nitrogen [24].

Total fat

Total fat content of the plant samples were determined using Tecator Soxtec System (HT 1043 Extraction Unit, Tecator Co USA). Metal receiving vessels of the unit, with three glass beads in each, were fired for 15 minutes, cooled and weighed. Five (5) g of sample was weighed into extraction thimble, which was plugged with cotton wool. Thimble was then fixed into the extraction unit and the fan switched on. Fifty (50) ml of petroleum ether (solvent) was put in each receiving vessel and placed under the thimbles. Cooling water was set at a flow rate of 1.5 litres per minute and extraction temperature was set at 80 °C. Initial heating to boiling was set at 10 minutes; refluxing time was set for 1 hour. Rinsing was also done for 1 hour after refluxing. Receiving vessels were removed after petroleum ether had stopped condensing, oven dried for 15 minutes at 100 °C, cooled for another 15 minutes in a desiccator, and weighed. Ether was drained off from all condensers before turning off the water and fan. Total fat content was calculated as follows: Total (g) = (Wt. of fat and the receiving vessel – Wt. of receiving vessel)/Wt. of the sample.

Total carbohydrates

The AOAC method [25] was adopted for the analysis of total carbohydrate using the Manual Clegg Anthrone Method [26]. This method determines the total amount of carbohydrates, based on hydrolysable starch and soluble sugar content. One (1.0) g of grounded sample was weighed and transfer quantitatively to a stoppered 100 ml graduated cylinder, followed by addition of 10 ml of water and the mixture stirred with glass rod to disperse the sample. 13 ml of the perchloric acid solution was then added and the mixture stirred constantly with glass rod for 20 min. The glass rods were rinsed with distilled water and the volume of the mixture brought to 100 ml. The contents were mixed and filtered into a 250 ml volumetric flask. The graduated cylinders were rinsed with distilled water and added to the volumetric flask, after which the flasks were calibrated with distilled water and shaken.

Ten (10) ml of the extract were diluted to 100 ml with distilled water. Using a pipette, 1 ml of diluted filtrates was transferred in to test-tubes. Two 1 ml samples of distilled water for duplicate blanks were also pipetted and each one put in a separate test-tube. Two 1 ml duplicate standards were pipetted out using the dilute glucose solution. Rapidly 5 ml of freshly prepared anthrone reagent was pipetted to all the tubes, capped and mixed thoroughly. The tube were later placed in a water-bath and heated for 12 min, after which they were cooled rapidly to room temperature. The solutions were transferred to 1 cm spectrophotometer cells. The green colour was stable for about 2 hours. The absorbance of the samples and the standards were read at 630 nm against the reagent blanks. Total available carbohydrates (TAC) were calculated as follows: TAC (as grams of glucose) = [(25 x b)/(a x W)] x 10⁻². Where W is the Wt. of the sample; a is the absorbance of the diluted standard (the graphs were straight lines in the range of 0.0 – 0.15 mg glucose); b is absorbance of diluted samples.

Dietary fibre

Dietary fibre was determined using Acid Detergent Fibre (ADF) solution following procedures described by Goering and Van Soest [27]. The solution was prepared as follows: Twenty-eight (28 ml) of 98% H₂SO₄ were carefully added to and mixed with 600 ml of distilled water. Twenty (20 g) of Cetyl trimethyl ammonium bromide (CTAB), a detergent, were added and stirred until it dissolved. The acid detergent was made up to 1 litre with

distilled water and mixed thoroughly. Into a clean one litre conical flask, was added 1.0 g of the sample; 100 ml of the acid detergent solution were added to the beaker followed by 2.0 ml of dekalin (decahydronaphthlene). The mixture was heated to boiling under reflux for 1 hour. Heating was controlled to minimise foaming by adjusting the control knob. The sample digest was filtered with a crucible previously dried in the oven at 100 °C. The beaker was washed with boiling distilled water filtering the content through the same crucible 3 times. The final washing was done with acetone and the residue was collected into a clean crucible dried at 100 °C for 8 hours in the oven. Dietary fibre (DF) of the sample was calculated as follows: $DF (g) = [(Wt. \text{ of crucible and DF}) - (Wt. \text{ of crucible})]/Wt. \text{ of the sample}$.

Vitamins (Ascorbic acid and beta-carotene)

Ascorbic acid (Vitamin C) contents of the plant samples were determined according to the procedures given in Kirk and Sawyer [22]. Five (5) g of the fresh samples were weighed into a clean mortar. The sample were macerated in a mortar using a pestle with 5 ml portions of 5% trichloro acetic acid (TCA) being added at a time. The extracts were quantitatively transferred into a clean 50 ml volumetric flask and made up to volume with TCA. The flask was stoppered, shaken to ensure thorough mixing and the mixture was filtered using a filter paper (Watman no.1). The 2,6-dichlorophenolindophenol (DCPIP) solution was standardised using ascorbic acid standard solution of concentration 1.08 mg/ml. Five (5) ml of standardised ascorbic acid were titrated with DCPIP until a pink colour that persisted for 3-8 seconds was seen (blank). An equivalent five (5) ml of the extracts were pipetted into a clean conical flask and carefully titrated against the DCPIP solution until a pink colour that persisted for 3-8 seconds was observed. The volumes of DCPIP solution used were read from the burette and used to calculate the vitamin C content of the samples. The ascorbic acid content of the sample was calculated using the formula: Vitamin C content (mg/100g DM) = $(\text{Titre} \times VE \times V_1 \times 100 \times 100)/(V_2 \times S \times 1000 \times Y)$. Where VE = vitamin C equivalent of 1 ml of DCPIP (mg/ml); V_1 = total extract volume (ml); V_2 = titrated extract volume (ml); S = sample weight; Y = sample dry matter (%).

β -carotene was determined following procedures outlined by De Ritter and Purcell [28]. Samples were separately weighed out and placed in a mortar; 5-7 mls of hexane-acetone mixture in a ratio of 1:1 were added. A pestle was used to stir the sample-solvent mixture to facilitate extraction. The extract was transferred to a 50 ml volumetric flask and extraction was repeated 5 times with 5-7 ml portions of solvent mixture adding the extract of volumetric flask each time to the flask contents. When the sample was free of beta-carotene, the volume of the extract was made up to 50 mls with the solvent mixture. The volumetric flask was kept away from light by wrapping it with aluminium foil to prevent photo degradation of beta-carotene.

The extract was placed in a clean, dry 100 ml beaker and the beaker was heated gently on a hot plate in the fume cupboard with the fan on until all the solvent evaporated. The beaker was then removed and allowed to cool after which 2.0 ml of pure solvent mixture were added to dissolve the residue; 1.0 ml of the dissolved extract was pipetted and transferred to a packed column of magnesium oxide. A fresh solvent mixture was used to elute the extract from the column. The deep coloured band of beta-carotene was collected in a 50 ml volumetric flask until the eluate was colourless, the extract was made up to volume, with the extracting mixture, shaken to dissolve and put in the dark ready for absorbance reading. 15mg capsules of beta-carotene were dissolved in 100mls of hexane to make stock solutions. Using a spectrophotometer (SP20), the absorbencies of the stock solutions and the samples were read at 450 nm. Standard curves of absorbance Vs concentration (microgram/ml) were plotted. By using their absorbencies, the β -carotene concentrations of the samples were read off the previously prepared standard curves. The calculation of β -carotene was as follows: β -carotene content ($\mu\text{g}/100\text{g DM}$) = $(\text{observed } \beta\text{-carotene content } (\mu\text{g/ml}) \times V \times D \times 100 \times 100)/(W \times Y)$. Where V = total extract volume; D = dilution factor; W = sample weight; Y = dry matter content of the sample (%).

Statistical data analysis

The proximate composition, Vitamin C and Beta-Carotene contents of the analysed 15 leafy WSWFPs were compared to those of the common cabbage (*Brassica oleracea var capitata*) using ANOVA [29] at 5% level of significance in MINITAB statistical software.

RESULTS

Proximate composition

Table 1 summarises the levels of moisture, calories, ash, protein, fat, total carbohydrates and dietary fibres contents present in the 15 selected leafy WSWFPs per 100 grams of edible portions compared to the commonly cultivated and consumed cabbage (*Brassica oleracea var capitata*). With the exception of *Basella alba* (19.98 ± 0.83 Kcal), all of the leafy WSWFPs analysed had significantly ($P < 0.05$) higher calories compared to the common cabbage (25.32 ± 0.59 Kcal). *Senna obtusifolia* was the richest ($71.56 + 1.15$ Kcal) in calories, followed by *Vernonia amygdalina* and *Acalypha bipartita* respectively.

The moisture contents of the leafy WSWFPs ranged from 33.43 ± 0.99 g to 92.06 ± 0.25 g. Apart from *Basella alba* (92.06 ± 0.25 g), cabbage was significantly ($P < 0.05$) higher in moisture content (90.47 ± 0.52 g) compared to other leafy WSWFPs. Protein values ranged from as low as 1.94 ± 0.15 g in *Basella alba* to as high as 12.11 ± 0.61 g in *Vernonia amygdalina*. Compared with common cabbage, all the mean protein values of WSWFPs analysed were significantly ($P < 0.05$) higher than that of the cabbage. *Vernonia amygdalina* (7.76 ± 0.20 g), *Crotalaria ochroleuca* (4.78 ± 0.16 g), *Sonchus oleraceus* (3.57 ± 0.15), *Corchorus trilocularis* (3.50 ± 0.27 g), and *Bidens pilosa* (3.52 ± 0.13 g) had significantly ($P < 0.05$) higher contents of dietary fibre compared to the cabbage (2.04 ± 0.04 g). However, there were no significant differences in the mean dietary fibre contents of *Acalypha bipartita*, *Amaranthus spinosus*, *Cleome hirta*, and *Senna obtusifolia* from that of the cabbage.

Table 1 Moisture, calories, ash, protein, fat, total carbohydrates and dietary fibre contents of the selected leafy WSWFPs compared to cabbage.

Species	Nutrients (Mean composition per 100 gram edible portion \pm SEM)						
	Energy (Kcal)	Moisture (g)	Protein (g)	Dietary fibre (g)	Ash (g)	Fat (g)	CHO (g)
<i>Acalypha bipartita</i> Müll. Arg.	52.36 (0.80)	75.26 (0.19)	6.19 (0.14)	1.93 (0.04) ^a	2.12 (0.11)	1.32 (0.10)	6.51 (0.30)
<i>Amaranthus spinosus</i> L.	30.73 (0.81)	84.67 (0.18)	3.57 (0.24)	2.29 (0.09) ^a	3.06 (0.10)	0.52 (0.04)	6.66 (0.25)
<i>Asystasia gangetica</i> (L.) T.Anders.	50.74 (0.53)	86.54 (0.82)	3.11 (0.37)	1.50 (0.07)	2.97 (0.10)	0.92 (0.06)	9.11 (0.42)
<i>Asystasia mysorensis</i> (Roth) T.Anders.	44.67 (0.99)	84.49 (0.51)	2.78 (0.16)	1.33 (0.12)	2.64 (0.21)	0.57 (0.04)	7.72 (0.16)
<i>Basella alba</i> L.	19.98 (0.83)	92.06 (0.25)	1.94 (0.15)	1.11 (0.07)	1.59 (0.16)	0.32 (0.02)	3.62 (0.25)
<i>Bidens pilosa</i> L.	45.18 (0.62)	85.48 (0.42)	4.29 (0.17)	3.52 (0.13)	3.52 (0.12)	0.66 (0.05)	7.31 (0.11)
<i>Cleome hirta</i> (Klotzsch) Oliv.	40.28 (0.84)	85.18 (0.18)	4.84 (0.42)	2.27 (0.11) ^a	2.93 (0.27)	0.64 (0.06)	4.52 (0.22) ^b
<i>Corchorus trilocularis</i> L.	48.49 (0.89)	81.61 (0.47)	5.77 (0.11)	3.50 (0.27)	1.92 (0.11)	0.26 (0.03)	8.51 (0.26)
<i>Crotalaria ochroleuca</i> G.Don	49.62 (0.68)	76.68 (0.36)	7.46 (0.33)	4.78 (0.16)	2.13 (0.11)	0.69 (0.06)	5.29 (0.18) ^b
<i>Hibiscus acetosella</i> Welw. ex Hiern	42.10 (0.89)	80.95 (0.93)	2.88 (0.12)	1.45 (0.06)	1.54 (0.10)	0.46 (0.04)	7.49 (0.18)
<i>Senna obtusifolia</i> (L.) Irwin & Barneby	71.56 (1.15)	79.47 (0.48)	6.72 (0.16)	2.33 (0.19) ^a	4.12 (0.15)	2.05 (0.07)	8.50 (0.26)
<i>Solanum nigrum</i> L.	41.13 (0.69)	85.66 (0.37)	5.20 (0.19)	1.25 (0.12)	5.58 (0.25)	0.66 (0.05)	5.44 (0.14) ^b
<i>Sonchus oleraceus</i> L.	28.81 (0.08)	86.32 (0.92)	3.45 (0.07)	3.57 (0.15)	3.26 (0.26)	0.72 (0.01)	2.09 (0.12)
<i>Vernonia amygdalina</i> Del.	54.38 (1.11)	33.43 (0.99)	12.11 (0.61)	7.76 (0.20)	3.69 (0.14)	0.56 (0.04)	38.62 (1.10)
<i>Vigna unguiculata</i> (L.) Walp.	31.22 (0.70)	83.66 (0.93)	4.54 (0.27)	1.60 (0.14)	2.42 (0.11)	0.43 (0.01)	4.40 (0.25)
<i>Brassica oleracea var capitata</i> . L. (Alef.) (Common cabbage)	25.32 (0.59)	90.47 (0.52)	1.45 (0.04)	2.04 (0.04) ^a	0.67 (0.02)	0.12 (0.01)	5.25 (0.18) ^b

Means are of three measurements. Bracketed are the standard errors of the mean. Means in the same column followed by the same superscript letter are not significantly different from those of the corresponding cabbage ($P > 0.05$).

Table 2 Vitamin C and β -carotene contents of the selected leafy WSWFPs compared to cabbage.

Species	Nutrients (Mean composition per 100 gram edible portion \pm SEM)	
	Vit. C (mg)	β -carotene (μ g)
<i>Acalypha bipartita</i> Müll. Arg.	138.89 (1.05)	1100.13 (1.60)
<i>Amaranthus spinosus</i> L.	35.01 (0.57)	5387.30 (2.60)
<i>Asystasia gangetica</i> (L.) T.Anders.	48.51 (0.91)	5937.21 (1.50)
<i>Asystasia mysorensis</i> (Roth) T.Anders.	45.75 (1.17)	5783.50 (2.40)
<i>Basella alba</i> L.	81.39 (0.69)	3319.90 (2.80)
<i>Bidens pilosa</i> L.	74.00 (0.91)	1908.90 (4.00)
<i>Cleome hirta</i> (Klotzsch) Oliv.	337.05 (1.50)	13170.05 (2.00)
<i>Corchorus trilocularis</i> L.	98.03 (0.88)	5443.10 (2.10)
<i>Crotalaria ochroleuca</i> G.Don	126.00 (1.06)	6900.70 (3.10)
<i>Hibiscus acetosella</i> Welw. ex Hiern	67.01 (1.23)	3409.04 (1.70)
<i>Senna obtusifolia</i> (L.) Irwin & Barneby	78.02 (1.03)	7856.20 (3.70)
<i>Solanum nigrum</i> L.	141.01 (0.81)	9047.31 (2.40)
<i>Sonchus oleraceus</i> L.	69.81 (1.01)	13411.63 (2.00)
<i>Vernonia amygdalina</i> Del.	318.12 (1.00)	6115.40 (2.10)
<i>Vigna unguiculata</i> (L.) Walp.	47.00 (1.28)	5880.80 (2.50)
<i>Brassica oleracea var capitata</i> . L. (Alef.) (Common cabbage)	57.41 (0.47)	111.82 (1.26)

Means are of three measurements. Bracketed are the standard errors of the mean. All means in the columns are significantly different from those of the corresponding cabbage in that column ($P < 0.05$).

Ash contents ranged from 1.54 ± 0.10 g as in *Hibiscus acetosella* to 5.58 ± 0.25 g as in *Solanum nigrum*. In all cases, the ash contents were significantly higher than those of cabbage. All the leafy WSWFPs had significantly ($P < 0.05$) higher fat contents compared to that of the cabbage (0.12 ± 0.01 g), with *Senna obtusifolia* (2.05 ± 0.07 g), and *Acalypha bipartita* (1.32 ± 0.10 g) being the richest in fat contents. Total carbohydrate contents of the leafy WSWFPs ranged from as low as 2.09 ± 0.12 g in *Sonchus oleraceus* to as high as 38.62 ± 1.10 g recorded in *Vernonia amygdalina*. Means values of *Cleome hirta*, *Crotalaria ochroleuca*, and *Solanum nigrum* were not significantly different ($P < 0.05$) from that of cabbage (5.25 ± 0.18 g). The rest of the leafy WSWFPs except *Sonchus oleraceus*, *Basella alba*, and *Vigna unguiculata*, had significantly higher total carbohydrate contents compared to cabbage.

Vitamins (Ascorbic acid and β -carotene)

Table 2 presents vitamin C and β -carotene (provitamin A) contents present in 15 leafy WSWFPs per 100 grams of edible portions compared to the commonly cultivated and consumed cabbage (*Brassica oleracea var capitata*). Vitamin C content of the leafy WSWFPs ranged from 35.01 ± 0.57 mg to 337.05 ± 1.50 mg per 100 grams of edible portions. With the exception of *Amaranthus spinosus*, *Asystasia gangetica*, *Asystasia mysorensis* and *Vigna unguiculata*, the rest of the leafy WSWFPs had significantly higher Vitamin C contents compared to that of the cabbage (57.41 ± 0.47 mg). *Cleome hirta* (337.05 ± 1.50 mg), *Vernonia amygdalina* (318.12 ± 1.00 mg), *Solanum nigrum* (141.01 ± 0.81 mg), *Acalypha bipartita* (138.89 ± 1.05 mg), and *Crotalaria ochroleuca* (126.00 ± 1.06 mg) were the richest in Vitamin C contents among the leafy WSWFPs. The β -carotene contents of the leafy WSWFPs ranged from 1100.13 ± 1.60 μ g to 13411.63 ± 2.00 μ g, and all were significantly ($P < 0.05$) higher than that of the cabbage (111.82 ± 1.26 μ g). *Sonchus oleraceus* (13411.63 ± 2.00 μ g), *Cleome hirta* (13170.05 ± 2.00 μ g), *Solanum nigrum* (9047.31 ± 2.40 μ g), *Senna obtusifolia* (7856.20 ± 3.70 μ g); *Crotalaria ochroleuca* (6900.70 ± 3.10 μ g) and *Vernonia amygdalina* (6115.40 ± 2.10 μ g) were the richest in β -carotene contents.

DISCUSSION

Proximate composition

Moisture

Moisture is one of the most commonly measured properties of food materials. It is important to know because there are legal limits of the maximum or minimum amount of water that must be present in certain types of food. Besides, the propensity of microorganisms to grow in foods depends on their water content [30]. In the present study, the moisture content of most WSWFPs except *Acalypha bipartita*, *Crotalaria ochroleuca*, *Corchorus trilocularis*, *Senna obtusifolia*, *Physalis peruviana* and *Vernonia amygdalina* were found to be higher than the usual range (60-83g/100g) of moisture content for fruits and vegetables [31]. However, compared to the conventionally cultivated cabbage (*Brassica oleracea var capitata*), all the leafy WSWFPs analysed in the present study except *Basella alba*

had significantly lower moisture contents. The fruits of *Aframomum angustifolium* had higher moisture content than that *Mangifera indica*. The high moisture contents of WSWFPs often above normal range will encourage microbial growth, increase the rate of enzymatic reaction and hence deterioration. The implication of this is that the harvested food plant cannot be stored fresh for more than 24 hours before it starts to deteriorate. The low moisture contents as in *Vernonia amygdalina* and the seeds of *Hyptis spicigera* are indicative of their high dry matter content and possible long shelf-life.

Food energy (calories)

Energy obtained from food is used to support physical activities and to maintain life supporting metabolic processes such as regulation of body temperature, maintenance of breathing, control of heartbeat, breaking up molecules and building muscle tissues [32]. Analyses from present study show that most leafy WSWFPs like *Senna obtusifolia*, *Vernonia amygdalina* and *Acalypha bipartita* are rich sources of food energy compared to conventionally cultivated cabbage (*Brassica oleracea var capitata*). Furthermore, the calorie content of most of the WSWFPs were within the range of other conventional food crops reported in literature [31, 33].

Ash

Ash is the inorganic residue that remained after the water and organic matter have been removed after heating the food plant. It is a measure of the total amount of minerals within a food [34]. The findings from the present study show that ash contents were significantly high in most WSWFPs compared to the conventional food crops. In fact, all leafy WSWFPs had significantly higher ash contents compared to the common cabbage. Notably high in ash contents were leaves of *Solanum nigrum* (5.58 ± 0.25 g/100g) and *Senna obtusifolia* (4.12 ± 0.15 g/100g), all indicating their richness with mineral elements. Elsewhere, Handique [36] reported that most non-conventional cultivated food plants like the tender shoot of wild banana (*Musa bulbisiana*) and *Paederia foetida* have remarkably higher ash contents often in the range of 8.3-20.4% compared to some conventional food crops.

Protein

Protein is the building material for all body parts, such as muscle, brain, blood, skin, hair, nails, bones and body fluids. It is essential for growth, repair of worn-out tissues, replacement of used-up blood and resistance against infections. One gram of protein is known to supply the body with about 4 Kcal [32]. Findings from the present study indicated that most WSWFPs were rich sources of protein compared to the three conventional food plants (*Brassica oleracea var capitata*, sesame and *mangifera indica*) that were analysed in this study. In fact, the tender leaves of *Vernonia amygdalina*, *Crotalaria ochroleuca*, *Senna obtusifolia*, *Acalypha bipartita*, *Corchorus trilocularis*, *Solanum nigrum* were significantly richer in protein contents compared to the common cabbage. In deed Handique [35] opined that many non-conventional leafy vegetables are either at par or even superior to many conventional and cultivated leafy vegetables as far as protein content is concerned. Species such as Diplazium (Fern), wild Amaranths like *A. viridis* that occur as garden weed, *Momordica*, and *Moringa* which are of limited occurrence as backyard crop have protein content in the range of 12-27% as against about 23% protein in case of well known cultivated and conventional leafy vegetables like Spinach [35].

Fats

Fats perform life-supporting functions in every human cell, including cell membrane structure, enzyme reactions, blood and tissue structure, in memory and nervous system operations, and in the manufacture and utilization of the sterol hormones and the hormone-like prostaglandins [30]. Fats are also required for healthy skin, the transport and absorption of the fat-soluble vitamins A, D, E and K, and the regulation of cholesterol metabolism. Besides, they are concentrated sources of energy needed by the body- 1 g of fat provides 9 kcal, more than double the energy given by carbohydrate or protein per unit weight [32]. Although vegetables naturally have low fat contents, most of the leafy WSWFPs analysed in the present study had higher fat contents compared to the commonly grown cabbage. For instance, tender leaves of *Senna obtusifolia* (2.05 ± 0.07 g/100g) and *Acalypha bipartita* (1.32 ± 0.10 g) were notably richer in fat contents compared to the cabbage plant (0.12 ± 0.01 g/100g). However, these values are still very low compared to the fat contents of edible oil seeds such as *Hyptis spicigera* [9] implying that leafy WSWFPs presented in paper should not be relied upon as the primary sources of fats.

Total carbohydrates

Carbohydrates are the primary source of energy for the body and are often referred to as 'fuel of life' [36]. Each gram of carbohydrate yields 4 calories in the process of its metabolism. They help to provide energy for muscular work and nutritive processes, maintenance of body temperature, besides their role in oxidation of fats, and as spare

protein for growth and repair [36]. Most WSWFPs analysed in this study were found to contain significantly higher total carbohydrate contents compared to the conventional food crops used for comparison. For instance, the tender leaves of *Vernonia amygdalina*, *Asystasia gangetica*, *Corchorus trilocularis*, *Senna obtusifolia*, *Asystasia mysorensis*, and *Hibiscus acetosella* were found to be good sources of carbohydrates. Therefore, daily consumption of such WSWFPs can significantly contribute to the recommended daily intake of total carbohydrate, which is about 130 g [37].

Dietary fibre

Dietary fibre plays an important role in decreasing the risks of many disorders such as constipation, colon cancer, cardiovascular diseases (CVD), diverticulosis and obesity [38]. Besides, they inhibit absorption of glucose and cholesterol from the gastrointestinal tract, thus are helpful in diabetes and heart disease control [39]. In the present study, apart from *Acalypha bipartita*, *Asystasia gangetica*, *Asystasia mysorensis*, *Basella alba*, *Hibiscus acetosella*, *Solanum nigrum*, and *Vigna unguiculata*, all other WSWFPs analysed were rich in dietary fibre contents often ranging from 2.27–7.76 g/100g. In most cases, their dietary contents were significantly higher than the corresponding conventional cultivated food crops that were analysed for comparison. Elsewhere Tukan *et al.* [40] reported large numbers of wild edible plants in Jordanian diet also being richer in fibre contents compared to cultivated food crops. In the present study, therefore, daily consumption of some WSWFPs such as *Vernonia amygdalina*, *Crotalaria ochroleuca*, and *Sonchus oleraceus* could contribute to the much-needed daily dietary fibre (30 g) for our normal wellbeing [37].

Vitamins (Ascorbic acid and β -carotene)

Vitamin C

Vitamin C also known as ascorbic acid helps in the formation of protein, collagen, bone, teeth, gums, cartilage, blood vessels, skin and scar tissue [41]; facilitates the absorption of iron and calcium from the gastrointestinal tract, involved in fats and amino acid metabolisms, increases resistance to infection and contributes to brain functioning [42]. Findings from the present study show that a number of leafy WSWFPs are rich sources of Vitamin C compared to the conventionally cultivated cabbage plant. The recommended daily allowance (RDA) of vitamin C for a normal adult is 65 to 90 mg [43], implying that consumption of most leafy WSWFPs such as such as *Cleome hirta* (337.05 ± 1.50 mg/100g), *Vernonia amygdalina* (318.12 ± 1.00 mg/100g), *Acalypha bipartita* (138.89 ± 1.05 mg/100g), *Solanum nigrum* (141.01 ± 0.81 mg/100g), *Crotalaria ochroleuca* (126.00 ± 1.06 mg), and *Corchorus trilocularis* (98.03 ± 0.88 mg/100g) could more than meet the RDA for an adult compared to the consumption of the cabbage (57.41 ± 0.47 mg/100g).

β -carotene contents

β -Carotene is the major precursor of vitamin A (retinol). Its cleavage yields retinal - the first and requisite step to produce retinoids, which are involved in many essential biological functions, including vision, reproduction, cell differentiation, gene expression, and general body maintenance [44]. Compared to the cultivated cabbage plant, leafy WSWFPs analysed in this study are much superior sources of β -Carotenes. Similarly, β -Carotene contents of *Hyptis spicigera* seeds of are comparable to that of sesame. The recommended daily allowance (RDA) of β -carotene for a normal adult is in the range of 6000 μ g for men, 4800 μ g for women and between 2400 and 4200 μ g for children [45, 46]. This implies consumption of 100 grams of WSWFPs such as *Sonchus oleraceus*, *Cleome hirta*, *Solanum nigrum*, *Senna obtusifolia*, *Crotalaria ochroleuca*, *Vernonia amygdalina*, *Asystasia gangetica*, *Vigna unguiculata*, *Asystasia mysorensis*, *Corchorus trilocularis* and *Amaranthus spinosus* would supply all the RDA for adult men, women and children. Mean while the consumption of about 100 g of *Basella alba* and *Hibiscus acetosella* would meet RDA of β -Carotene for children.

CONCLUSION

This research provides an overview of the proximate composition, vitamin C and beta-carotene contents of fifteen selected leafy wild and semi-wild food plants (WSWFPs) from Bunyoro-Kitara Kingdom, Uganda. It confirmed the empirical knowledge of local people in a scientific way. Compared to the conventionally planted cabbage, most leafy WSWFPs were generally richer sources of nutrients, right from protein, vitamin C, beta-carotene, calories, carbohydrates, dietary fibres, ash, and moisture, and therefore they can help improve household nutrition especially during the months preceding the harvest of cultivated crops and also during periods of social unrests, military

conflicts, droughts, famine, and other natural catastrophes. A diet of comprising of WSWFPs can definitely assure a relief from some of the major and minor nutrient deficiencies often faced by the poor people in Uganda.

Senna obtusifolia, *Vernonia amygdalina*, *Acalypha bipartita*, *Asystasia gangetica* and *Physalis peruviana* were the richest sources of calories (50.45–544.31 kcal/100g). Ash content was highest (3.69–6.54 g/100g) in *Vernonia amygdalina*, *Solanum nigrum*, *Senna obtusifolia*, *Hyptis spicigera*, while protein was more abundant (5.20–12.11 g/100g) in *Vernonia amygdalina*, *Crotalaria ochroleuca*, *Senna obtusifolia*, *Acalypha bipartita*, *Corchorus trilocularis* and in *Solanum nigrum*. Total fat content was highest in *Senna obtusifolia* (2.05 ± 0.07 g), and *Acalypha bipartita* (1.32 ± 0.10 g) while the tender leaves of *Vernonia amygdalina*, *Asystasia gangetica*, *Corchorus trilocularis*, *Senna obtusifolia*, *Asystasia mysorensis* and *Hibiscus acetosella* were highest (7.49–38.62g/100g) in carbohydrates contents. Good sources (3.50–7.76 g/100g) of dietary fibres were *Vernonia amygdalina*, *Crotalaria ochroleuca* and *Sonchus oleraceus*.

Vitamin C was highest (98.03–337.05 mg/100g) in *Cleome hirta*, *Vernonia amygdalina*, *Acalypha bipartita*, *Solanum nigrum*, *Crotalaria ochroleuca*, and *Corchorus trilocularis* more than RDA for an adult (65–90 mg). While β -Carotene contents beyond the RDA were found in *Sonchus oleraceus*, *Cleome hirta*, *Solanum nigrum*, *Senna obtusifolia*, *Crotalaria ochroleuca*, *Vernonia amygdalina*, *Asystasia gangetica*, *Vigna unguiculata*, *Asystasia mysorensis*, *Corchorus trilocularis* and *Amaranthus spinosus*. This knowledge therefore creates a justification that the wild leafy WSWFPs are important food items that needs popularization.

Recommendations

There is a need for policy-makers and technocrats both at the local (counties, sub-counties, parishes, villages) and national levels (e.g. Ministry of Agriculture, Animal Industry, and Fisheries) to create policies, by-laws or any other avenues for mainstreaming the management of some of the nutrient-rich WSWFPs into existing the farming systems and any the programs (e.g. Plan for Modernisation of Agriculture) aimed at addressing household poverty and food insecurity. There is an urgent need for research on the possibility of adapting, growing and intentionally managing some of the nutrient-rich leafy WSWFPs (e.g. *Hibiscus acetosella*). A Large proportion of these plants were reportedly gathered from the forests, bush lands (woodlands), grasslands and other out-of-farm niches such as wetlands and along village footpaths. There is a need for an investigation of anti-nutrient factors or toxic compounds that could be present in some of the documented WSWFPs. Some of these plants may contain lethal levels of toxic principles, and must therefore, be correctly processed before consumption. So far in Uganda, little attempt has been made in this direction. Therefore, attempts to research in this aspect of WSWFPs would be quite rewarding.

REFERENCES

- [1] Human Development Report. The Rise of the South: Human Progress in a Diverse World. HDRO (Human Development Report Office) United Nations Development Programme, 2013, pp. 144–147. Retrieved 25 March 2014.
- [2] FAO. The State of food insecurity in the world. Monitoring the progress towards the world food summit and millennium development goals. Annual Report. Rome, 2004.
- [3] B Burlingame. *Journal of Food Composition and Analysis*, 2000, 13: 99-100.
- [4] MS Ali-Shtayeh, RM Jamous, JH Al-Shafie, WA Elgharabah, FA Kherfan, KH Qarariah, IS Khair, IM Soos, AA Musleh, BA Isa, HM Herzallah, RB Khlaif, SM Aiash, GM Swaiti, MA Abuzahra, MM Haj-Ali, NA Saifi, HK Azem, Nasrallah HA. *Journal of Ethnobiology and Ethnomedicine*, 2008, 4: 13 doi:10.1186/1746-4269-4-13.
- [5] B Becker. *Journal of Arid Environments*, 1986, 11: 61-64
- [6] BM Campbell. *Food and Nutrition*, 1986, 12 (1): 38-44.
- [7] A Zemed. Indigenous African food crops and useful plants: survey of indigenous food crops, their preparations and home gardens. Nairobi: The United Nation University, Institute for Natural Resources in Africa, 1997.
- [8] A Aberoumand. *Food Analytical Methods*, 2009, 2:204-207.
- [9] JG Azea. *Use and potential of wild and semi-wild food plants in alleviating household poverty and food insecurity: A case study of Bunyoro-Kitara Kingdom, Uganda*. PhD Thesis. School of Environment, Natural Resources & Geography, Bangor University, Bangor, U K. 2010, 360 pp (including 15 preliminary pages, i – xiv).
- [10] KB Wilson. Ecological dynamics and human welfare: a case study of population, health and nutrition in southern Zimbabwe. PhD Thesis, Department of Anthropology, University of London, London, 1990.
- [11] R Loghurst. *IDS Bulletin*, 1986, 17: 27-35.
- [12] BM Ogle, Grivetti LE. *Ecology of Food and Nutrition*, 1985, 17: 41-64.

- [13]FAO. Food composition table for use in Africa: calculations to derive nutrients. FAO, Rome: <http://www.fao.org/docrep/003/x6877e/X6877E20.htm>., **1985**.
- [14]International Institute for Environment and Development (IIED). The value of wild resources in agricultural systems. The hidden harvest. London, UK, **1995**.
- [15]PM Maundu, GW Ngugi, Kabuye CHS. Traditional food plants of Kenya Nairobi: National Museums of Kenya, **1999**.
- [16]EB Rubaihayo, T Hart, E Kakonge, A Kaaya, J Kawongolo, F Kabeere, J Mugisha, J Tumwiine, Rubaihayo P. Development of mechanisms for sustainable production and utilisation of indigenous vegetables and management of their genetic diversity in Uganda. Unpublished report. Faculty of Agriculture, Makerere University Kampala, **2003**.
- [17]CHS Kabuye. Potential wild food plants of Kenya. *In: Conservation and utilization of indigenous medicinal plants and wild relatives of food crops* (eds.): Kinyua AM, Kofi-Tsekpo WM and Dangana LB. Nairobi, UNESCO, **1997**, pp 107-112.
- [18]JC Brand, Cherikoff V. Nutrients in native plant seeds. *In: G.P. Jones (Ed.) The food potential of seeds from Australian native plants*, Deakin University Press, Victoria, **1985**, pp. 31-45.
- [19]EJM Temminghoff, Houba VJG (Eds.). *Plant analysis procedures* (2nd ed.). Kluwer Academic Publishers, Dordrecht, Netherlands, **2004**.
- [20]A and L Eastern Labs. Sampling for Plant Analysis: how to collect plant samples for nutrient analysis. A&L Eastern Laboratories, Inc. Accessed on 13th November 2007, http://al-labs-eastern.com/taking_plant_sample.html. **2006**.
- [21]AOAC. Official methods of analysis of the Association of Official Analytical Chemists. 13th edition. Washington, DC, **1980**
- [22]RS Kirk, Sawyer R. Pearson's composition and analysis of foods (9th ed.). Longman Group Limited, UK, **1991**.
- [23]AOAC. Official methods of analysis of the Association of Official Analytical Chemists, 14th edition. Arlington, VA, **1984**.
- [24]AL Frank. Basic food chemistry. Westport: The Avi Publishing Company Inc. **1975**.
- [25]AOAC. Official Methods of Analysis, 15th edition, Food Composition, Additives, Natural Contaminants, volume two. AOAC, Inc. USA, **1990**.
- [26]KM Clegg. *J. Sci. Food Agric.*, **1956**, 7: 40-44.
- [27]HK Goering, PJ Van Soest. Forage fiber analyses- Apparatus, reagents, procedures and some applications. Agricultural Handbook No. 379, ARS, USDA., Washington, D.C, **1970**.
- [28]E De Ritter, AE Purcell. Carotenoids analytical methods. *In: Carotenoids as colourants and vitamin A precursors*. Bauernfeind, J. C. (ed.), Academic Inc. London, **1981**.
- [29]RG Steel, JH Torrie. Principles and procedures of statistics: biometrical approach, (2nd ed.), McGraw-Hill, New York, **1980**.
- [30]MLL Nollet. Handbook of food analysis: physical characterization and nutrient analysis. Volume 1, Second Edition. ISBN13: 9780824750367, Taylor & Francis Inc., London, **2004**.
- [31]FAO. Food composition table for use in Africa. Food and Agricultural Organisation, Rome, Italy, **1968**.
- [32]R Garrison, E Somer. The nutrition desk reference (3rd ed.), ISBN13-9780879838263, Keats Pub Inc., New Canaan, CT, **1997**.
- [33]VA Farrell, L Houtkooper. Calcium and calorie content of selected foods. The University of Arizona Cooperative Extension. Tucson, Arizona, **2009**, pp 5.
- [34]SS Nielson. Food analysis (3rd ed.). Kluwer Academic/Plenum Publishers, London, **2003**.
- [35]AK Handique. Collection and evaluation of non-conventional food plants of Assam and Nagaland. ENVIS Bulletin Volume 10 issue 1, Himalayan Ecology & Development, **2002**.
- [36]WHO and FAO. Carbohydrates in human nutrition. FAO food and nutrition paper no. 66. Rome, **1998**.
- [37]Institute of Medicine, Food and Nutrition Board. Dietary reference intakes for energy, carbohydrate, fibre, fat, fatty acids, cholesterol, protein, and amino acids. National Academy Press, Washington, DC, **2005**.
- [38]GA Spiller. Dietary fibre in prevention and treatment of disease. *In: Handbook of dietary fibre in human nutrition*. Spiller, GA (ed.). CRC Press, Washington, DC, **2001**, pp 363-431.
- [39]AH Ensminger, ME Ensminger, JE Konlande, JRK Robson. Foods and nutrition encyclopedia (2nd ed.). ISBN: 9780849389801, Taylor & Francis Ltd, Boca Raton, USA, **1993**.
- [40]SK Tukan, HR Takruri, DM Al-Eisawi. *International Journal of Food Sciences and Nutrition*, **1998**, 49: 225-235.
- [41]SK Gaby, VN Singh. *Vitamin C, – Vitamin intake and health: a scientific review*, SK Gaby, A Bendich, V Singh and L Machlin (eds.) Marcel Dekker, N.Y., **1991**, pp. 103-143.
- [42]G Schectman, JC Byrd, R Hoffmann. *American Journal of Clinical Nutrition*, **1991**, 53 (1) 1466-1470.

[43]Institute of Medicine, Food and Nutrition Board (2000). Dietary reference intakes for vitamin C, vitamin E, selenium, and carotenoids: a report of the panel on dietary antioxidants and related compounds. National Academy of Sciences, Washington D.C.

[44]JL Napoli. *Clin Immunol Immunopathol*, 1996, 80: 52-62.

[45]National Research Council of USA. Recommended Dietary Allowances- Report of the Subcommittee on the Tenth Edition of the RDAs. National Academy Press, Washington D.C, 1989.

[46] J Ndawula, JD Kabasa, YB Byaruhanga. *African Health Sciences*, 2004, 4 (2): 125-130.