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Compositional Characteristics of Young Shoots of Selected Bamboo Species Growing in Kenya and Their Potential as Food Source

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Abstract Bamboo shoots have been used for many years as food particularly in Asian countries. In Kenya however utilization of bamboo for food is largely unknown despite the frequent food shortages, high poverty level and widespread nutritional disorders. The objective of this study was to determine some compositional characteristics of three bamboo species namely, *Bambusa vulgaris*, *Dendrocalamus giganteus* and *Yushania alpina* growing in Kenya and show their potential as important food source. Proximate and mineral composition were determined using standard AOAC methods. Total polyphenol, flavonoids, antioxidant activity and anti-nutrient factors were also determined using established protocols. Results were expressed on fresh weight basis. The shoots were found to contain 1.9-3.6% of carbohydrates, 2.3-2.6% of protein, 91.2-92.3% of moisture, 1.6-2.6% of fiber, 0.14-0.17% of fat and 0.98-1.17% of ash. Mineral content in mg/100g were 20.2-31.8 of Ca, 53.4-103.0 of Mg, 51.4-67.4 of P, 288.8-362.6 of K, 0.3-1.3 of Mn and 0.9-1.5 of Zn. 3.0-16.1 mg/100g of total polyphenols and 53.1-288.4mg/100g of flavonoids were observed to be contained. Tannins, oxalates and phytic acid of 0.007-0.030%, 0.7-1.2% and 0.8-2.7%, respectively were found present. These findings provide vital baseline data for exploitation of bamboo shoots in nutritional interventions in Kenya.

Keywords: *bamboo shoots, proximate composition, minerals, polyphenols, flavonoids, anti-nutrients*

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1. Introduction

Bamboo belongs to the family *Poaceae* and is widely distributed in the world [1]. Asia holds about 65% of the world's bamboo resources and contributes about 63% of the world market, whereas Africa has barely 5% of world market share [2]. In Kenya, the native species of *Yushania alpina* is widely distributed on Kenyan highlands and covers about 150,000 hectares [3,4,5]. A number of the exotic species of bamboo have been planted in the central and western regions and these include *Bambusa*, *Dendrocalamus*, *Gogantochloa*, *Oxytenanthera*, *Phyllostachys*, amongst others [3,4,6].

The young shoots of bamboo have been reported rich in protein, fiber, carbohydrates and minerals, low in fat and sugars, and have been eaten as a vegetable for a long time in many Asian countries [7]. The shoots are said to be richer in nutrients than most common vegetables [8,9,10]. On health benefits, bamboo is said to reduce fever and maintain water balance in the body [11] and has been found to possess antioxidant and nutraceutical properties such as lowering blood cholesterol and improving bowel movement [7,12,13].

In Kenya, there are rising cases of cancer and high blood pressure incidences today, compared to the period before 1963, with breast, cervical and lung cancers being on the lead [14,15]. These are lifestyle diseases and are mostly associated with food consumption. The shoots contain high concentration of minerals especially potassium, dietary fiber, antioxidants and low fat which are vital in fighting hypertension and development of cancer [7].

Due to widespread poverty level, most Kenyans especially in the rural areas and town slums rely on leafy vegetables such as kales and cabbages when consuming starchy food. These vegetables are hardly enough for the population and therefore they cannot supply the necessary nutrients required by the body. Similarly, most people cannot afford meat as a source of protein. Bamboo shoots are known to be among the fastest growing plants [16] and because of their nutrient rich constituents such as protein, fiber and micronutrients, they could be ideal for Kenyan case as an alternative vegetable.

The shoots have also been reported to contain varying levels of some anti-nutrient factors such as tannins, phytic acid and oxalates [17], which may bind vital nutrients and prevent their bioavailability [18,19]. This problem is also prevalent in beans and most vegetables [20,21]. However, there is a lot of on-going research about processing aspect of the shoots to reduce the composition of these anti-nutrient factors and therefore bamboo is a promising crop.

Currently, bamboo in Kenya is used for furniture and construction, but little is known about use of its young shoots for food. Although the *Sabaot* community in Mt. Elgon region are reported to consume the shoots of *Yushania alpina* (*Y. alpina*) [4], there is hardly any technical information about this resource [6]. Similarly, compositional data of the most popular exotic species on Kenyan farms, namely *Bambusa vulgaris* (*B. vulgaris*) and *Dendrocalamus giganteus* (*D. giganteus*) are lacking. The growing of these exotic species is also currently not well established probably due to lack of information about their nutritive value. This study reports for the first time some chemical characteristics of these species of bamboo shoots growing in Kenya and indicates their potential as a source of nutrients of health benefit.

2. Materials and Methods

2.1. Sample Acquisition

Three species, one indigenous and two exotic were chosen for this study due toavailability and good adaptability to local conditions. *Y. alpina*, a naturally growing indigenous species was harvested at Mt Elgon in the western Kenya during a peak season in May 2014, whereas exotic species of *B. vulgaris* and *D. giganteus* were harvested from a private farm in Murang'a county in the central Kenya during the same period. The shoots had lengths of 30-60cm and were transported to the laboratory in a cooler box. At the laboratory, the outer leaves were removed and moisture content of the inner fleshy shoot was determined immediately. The rest of the samples were chopped and dried at 70°C for 24 hours in an air-circulating oven [22]. They were then ground into powder and stored in sealed polyethylene bags at 5°C until analysis.

2.2. Reagents and Chemicals

Gallic acid, follin ciocalteau and 1,1-diphenyl-2-picrylhydrazyl (DPPH) were purchased from Sigma-Aldrich in Germany. Sodium phytate (inositol hexaphosphoric acid sodium salt) was sourced from BDH Biochemical Ltd in England, catechin hydrate from Fluka in Switzerland and quercetin was bought from Riedel de Haen in Germany. Ascorbic acid was purchased from Panreac in Spain whereas specific standards of minerals were purchased from Wako chemicals, Japan. All other reagents/chemicals used were of analytical grade. The water that was used had been deionized and distilled.

2.3. Determination of Proximate and Mineral Composition

Proximate composition was determined using standard methods according to AOAC [23] as follows. Moisture content was determined by drying 5 g of sample at 105°C to constant weight. Protein content was determined by semi-micro Kjeldahl method and protein content calculated by multiplying percentage nitrogen by 6.25. Fat was extracted by Soxhlet's method using petroleum spirit (b.p. 40-60°C) and determined gravimetrically after drying the extract in an oven. Ash content was determined by incinerating 5 g of the sample at 550°C until the ash turned grayish. Fiber was determined by consecutively boiling under reflux 2 g of sample in 1.25% H_2SO_4 and 1.25% NaOH. The residual after filtering was washed with alcohol and ether before drying and then incinerating at 500°C for 1 h. The difference in weight before and after incineration was calculated as a percentage fiber content. Carbohydrates content was determined by subtracting the sum of moisture, fat, ash, fiber and protein content from 100.

Minerals were determined by digesting ground samples with H_2SO_4-H_2O_2 using a block heater and the resulting digest was diluted to 50 ml with de-ionized water. Specific minerals were determined by an inductively coupled plasma spectrometer (ICPS 8100, Shimadzu Ltd, Japan).

2.4. Determination of Total Polyphenols, Total Flavonoids and Antioxidant Activity

2.4.1. Determination of Total Polyphenols

Total polyphenol content was determined by the method of Waterman and Mole [24]. Ten milligrams of dry and ground sample wereextracted using aqueous 50% methanol at 80°C for one hour. One milliliter of the extract was reacted with follin ciocalteau reagent and the absorbance was read at 760nm against gallic acid as the standard.

2.4.2. Sample Extraction for Flavonoids and Antioxidants

Sample extraction for analysis of flavonoids and antioxidant activity was done as described by Harbone [25]. Five grams of the dry sample powder were weighed into 250ml flasks and 100ml of methanol added. The flasks were tightly closed with parafilm, covered with aluminium foil and shaken for 3 hours. They were then kept in the dark to extract for 72 hours after which they were filtered and concentrated to 20ml, and kept in tightly covered vials. Working concentrations were prepared from these solutions.

2.4.3. Quantitative Determination of Flavonoids

Aluminum chloride colorimetric method was used for determination of flavonoids by the method of Jagadish et al. [26]. In a 10 ml volumetric flask, 4 ml of distilled water and 1 ml of plant extract were added. After 3 min, 0.3 ml of 5% sodium nitrite solution were added and left to stand for 3 min, after which 0.3 ml of 10% aluminum chloride was added and held for 5 min. Two milliliters of 1 M sodium hydroxide were added and the volume was made up to 10 ml with distilled water. Absorbance was measured at 415 nm using a spectrophotometer and the amount of total flavonoids was calculated from a calibration curve of standards prepared from quercetin.

2.4.4.Determination of Free Radical Scavenging Activity

The radical scavenging activity of the extracts against 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical was

determined at 517nm [27]. Concentration of the extract were prepared in volumes of 0.01, 0.1, 1.0, 2.0, 5.0 and 10.0 mg/ml in methanol and the results were expressed on dry matter basis. Vitamin C was used as the standard at the same concentrations as the extracts. One milliliter of the extract was put in a test tube and 3.0 ml of methanol added, followed by 0.5ml of 1mM DPPH in methanol. A blank solution was prepared using methanol and DPPH only. The mixture was kept in the dark for 30 min and absorbances were measured. The DPPH radical scavenging activity was calculated using Equation 1 below.

$$\text{DPPH radical scavenging activity} = \frac{(Ab - Aa)}{Ab} \times 100 \quad (1)$$

Where Ab is the absorbance of the reference (blank) and Aa is the absorbance of the sample.

2.5. Determination of Anti-nutrients

Phytates were determined as phytic acid according to the method of Camire et al. [18] using HPLC fitted with a reverse phase C-18 column and a refractive index detector. The mobile phase was 0.025M KH_2PO_4at a flow rate of 1ml per min and sodium phytate was used as a standard. Oxalates were determined according to the method by Libert [28] with modifications by Yu et al. [29]. Half a gram of the ground samplewasextracted by mixing with 0.5M HCl and heated at 80°C for 10min, and quantified by HPLC with a reverse phase C-18 column and a photodiode array detector. Condensed tannins were assayed according to vanillin-hydrochloric acid method [30, 31]. Quarter a gram of ground sample was extracted with HCl-methanol mixture by centrifuging at 4500 rpm for 10 min and extract was diluted to 25 ml. The sample extracts were reacted with vanillin-HCl reagent and absorbance read at 500 nm after 20 min, using catechin hydrate as the standard.

2.6. Statistical Analysis

All samples were analyzed at least in triplicates and data presented as mean ± standard deviation (n≥3). The means were subjected to Duncan's multiple range test for significance test ($p<0.05$) using SPSS version 17.0.

3. Results and Discussion

3.1.Proximate Composition

The results of proximate composition in the three species of bamboo shoots analyzed are shown in Table 1 below.

Table 1. Proximate Composition of Bamboo Varieties Expressed as % Fresh Weight

Parameter	*B. vulgaris*	*D. giganteus*	*Y. alpina*
Moisture	91.4±0.4^b	91.2±0.3^b	92.3±0.2^a
Protein	2.3±0.1^b	2.3±0.1^b	2.6±0.1^a
Fat	0.14±0.01^b	0.17±0.01^a	0.16±0.02^a
Ash	1.15±0.02^a	1.17±0.07^a	0.98±0.03^a
Fiber	2.6±0.1^a	1.6±0.1^c	2.1±0.2^b
Carbohydrates	2.43±0.06^b	3.6±0.13^a	1.9±0.2^c

Data are presented as mean ± SD (n=6). Mean values within each row followed by different letters differ significantly at p<0.05

There was a significant difference in moisture content between *Y. alpina* and the two exotic species of*B. vulgaris* and *D. giganteus* ($p<0.05$). Protein content was significantly higher in *Y. alpina* than in the other two species($p<0.05$). The fat content was generally low in all the samples with *B. vulgaris* containing the lowest amount. There was no significant difference in ash content between different species($p<0.05$). Carbohydrates and fiber content differed significantly between all samples analyzed($p<0.05$). In his review paper, Nirmala et al. [7] reported moisture content of 89.4-90.7%, protein of 1.49-4.04%, carbohydrate of 4.9-6.5%, fat content of 0.39-0.50%, ash content of 0.89-1.01%, and fiber content of 2.65-4.24%. Santosh et al. [22] also reviewed nutrients in bamboo species of *B. nutans*, *B. vulgaris*, *D. strictus*, *D. asper* and *D. giganteus*, and reported moisture content of 77.0-94.7%, carbohydrates of 2.6-5.1%, ash of 0.8-1.0% and crude fiber of 0.71-0.98%. Bhatt et al. [32] reported protein content of 1.98-3.29%, carbohydrate content of 3.83-9.94% and fat content of 1.0% in some *Bambusa* and *Dendrocalamus* species in India. When the results of the present study are compared with the findings of other researchers elsewhere in the world on edible shoots, the potential of the Kenyan bamboo shoots for nutritional interventions seems to be high. The slight variations may be due to varying maturity at harvest and different agro-ecological conditions.

3.2.Mineral Composition

Table 2 shows the results for the mineral composition for the species.

Table 2. Composition of Minerals in the Fresh Shoots of Bamboo (mg/100g)

Type of Mineral	*B. vulgaris*	*D. giganteus*	*Y. alpina*
Calcium	31.8±0.8^a	27.0±1.7^b	20.2±0.5^c
Magnesium	91.0±0.7^b	103.0±6.2^a	53.4±1.7^c
Potassium	351.2±4.4^a	362.6±24.1^a	288.8±5.3^b
Phosphorus	51.4±3.0^b	67.4±4.3^a	64.8±0.6^a
Zinc	1.3±0.1^b	1.5±0.1^a	o.9±0.1^c
Manganese	1.3±0.0^a	0.9±0.1^b	0.3±0.0^c
Iron	trace	0.2±0.0	trace
Copper	0.3±0.0	trace	trace

Data are presented as mean ± SD (n=3). Mean values within each row followed by different letters differ significantly at p<0.05

The samples analyzed contained considerable amount of major minerals. Potassium level ranged 288.8-362.6 mg/100g and this was comparable with reported results [7]. The content in *Y. alpina* was significantly lower than*B. Vulgaris* and *D. giganteus* ($p<0.05$). Nongdam and Tikendra [33] reported values of 20-1400 mg/100g in some *Bambusa* and *Dendrocalamus* species inNorth East India. Potassium is an essential mineral particularly for people prone to high blood pressure and consumption of the shoots can help in boosting the amount needed by the body.A report on a slum in Nairobi noted 12.3% cases of hypertension among the population sampled [34].

Calcium content varied significantly between 20.2mg/100g and 31.8 mg/100g among the species. However, the content can vary between 21.17mg/100g and 180.69mg/100g as has been reported [36]. Magnesium was also found to vary significantly among the three species with *D. giganteus* containing the highest and *Y. alpina* the lowest ($p<0.05$). The content of phosphorus was significantly lower in *B. vulgaris* ($p<0.05$) and similar

quantities were observed in *Y. alpina* and *D. giganteus*. These values were much higher than 6.1-8.7mg/100g and 19.3-28.1 mg/100g for magnesium and phosphorus, respectively, as reported by other authors [7,36]. The amount of zinc was similar to other leafy vegetables, which were reported to contain 0.6-1.67mg/100g fresh weight [37]. Other micronutrients such as iron, copper and manganese were also detected though some in trace amounts and compared well with reported values [7]. High calcium and magnesium intake is highly beneficial in maintaining strong bones and teeth in the body. Magnesium and dietary fiber intake has been associated with lower risk of diabetes mellitus [38]. Comparatively the bamboo species were found to contain more minerals than most common vegetables [7]. This fact makes bamboo shoots an ideal vegetable for providing the much needed micronutrients in Kenya.

3.3. Composition of Total Polyphenol, Flavonoids and Antioxidant Activity

Plant polyphenols are secondary metabolites that are believed to offer protection against development of cancer, heart diseases, diabetes, osteoporosis and neurodegenerative diseases [39]. Flavonoids are also secondary metabolites found in plants and are known to possess anti-bacterial, anti-inflammatory, anti-allergic and vasodilatory activities [40]. The concentration of total polyphenol and flavonoid content are shown in Table 3 below.

Table 3. Total Polyphenol and Flavonoid Content (mg/100g fresh weight)

Bamboo species	Total polyphenol (as gallic acid Eq.)	Total flavanoids (as quercetin Eq.)
B. vulgaris	16.1±1.4[a]	284.7±5.2[a]
D. giganteus	14.5±1.5[a]	288.4±3.5[a]
Y. alpina	3.0±0.3[b]	53.1±1.6[b]

Data are presented as mean ± SD (n=3). Mean values within each column followed by different letters differ significantly at p<0.05.

In this study, a significant difference was noted between the exotic and the indigenous species for both polyphenols and flavonoids (p<0.05). Sarita et al. [12] reported levels of polyphenols of about 1.0 mg/100g in bamboo growing in reserves in Sichuan, China. Ayoola et al. [41] has shown that there is a good correlation between the flavonoids content and the antioxidant activity. Antioxidant activity of the extracts of the shoots was measured against vitamin C as the standard. Figure 1 below shows the antioxidant activity of the three species of bamboo shoots.

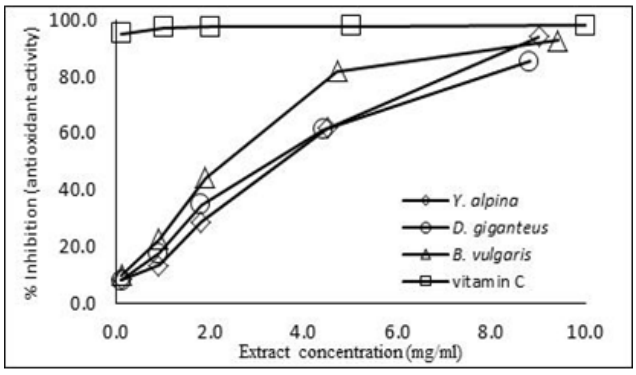

Figure 1. Antioxidant activity of bamboo shoots extract expressed on dry weight basis

Strong inhibition activity against oxidation of DPPH radical was found among the species. The inhibition concentration of 50% (IC_{50}) was obtained from a linear plot of concentration against percentage inhibition (antioxidant activity). It was noted that *B. vulgaris* had the highest IC_{50} value of 2.0mg/ml, *D. giganteus*at 3.0mg/ml and *Y. alpina*at 3.8 mg/ml. The lower the concentration of the extract at 50% (IC_{50}) value, the higher the radical scavenging activity. Thus, *B. vulgaris* has better antioxidant activity than the other two. This high activity may be due to high polyphenolic and flavonoid content as indicated in Table 3. Strong antioxidant property of bamboo powder has been reported [13] and it has also shown that bamboo shoots contain anti-carcinogens, thus helping to reduce production of free radicals in the body and therefore decreasing the chance of cancer development [7]. The results from this study suggest thatbamboo shoots growing in Kenya possess high potential for health benefits.

3.4. Anti-nutrients Content

Anti-nutrients which were considered in this study are tannins, phytic acid and oxalates. This factors have the effect of reducing nutrients availability in the body and can be harmful beyond certain thresholds. The results are summarized in Table 4 below.

Table 4. Concentration of Tannins, Phytic Acid and Oxalates in Fresh Bamboo Shoots

Bamboo species	Tannin content (% CE)	Phytic acid (%)	Oxalates (%)
B. vulgaris	0.024±0.001[a]	2.70±0.10[a]	1.2±0.1[a]
D. giganteus	0.030±0.001[a]	2.40±0.30[a]	1.0±0.1[b]
Y. alpina	0.007±0.001[a]	0.83±0.07[b]	0.7±0.0[c]

Data are presented as mean ± SD (n=3). Mean values within each column followed by different letters differ significantly at p<0.05, CE=Catechin equivalent.

3.4.1. Tannin Content

Tannins in plants are compounds exhibiting polyphenol-like properties and are found in vegetables, fruits and seeds. Theyare known to bind proteins and therefore reducing their availability to the body. Wang et al. [42] has reported up to 1.71% of tannins in bamboo species known as *Fargesia yunnanensis* growing in China. The species tested in this study showed values lower than 0.03% in raw shoots as shown in Table 4. Omobolanle [20] reported 0.88% in fresh amaranthus, whereas 0.1% has been reported by other authors in the same vegetable [21]. Since tannins are water soluble [43], their levels are likely to reduce further during boiling and therefore may haveno adverse health effect after cooking.

3.4.2. Phytates Content

Phytates occur in plants as inositol hexa-phosphates and are known to complex strongly with certain dietary minerals such as zinc, iron and proteins,thus decreasing their bioavailability in the body and causing health problems [15,44]. As shown in Table 4, there was a significant difference inphytate content between the exotic and the indigenous species (p<0.05). *B. vulgaris* showed the highest concentration of 2.7% followed by *D. giganteus* at 2.4% and 0.8% in *Y. alpina*. Dongmeza et al. [17] found 1.8-3.4% of phytates in dried leaves of bamboo.

It is important to reduce the levels particularly during processing so as to improve mineral bioavailability and prevent nutritional disorders.

3.4.3. Oxalates Content

Oxalic acid is considered as an anti-nutrient and is a common constituent of most plants. It occurs as a free acid, as soluble salts of potassium and sodium, and as insoluble salts of calcium, magnesium and iron [19]. The type of oxalate salts present in food may be important because soluble oxalates appear to be more bio-available than insoluble oxalates [45]. Oxalates have been reported to exhibit a lethal minimum dosage of 4-5% [46].

The bamboo species tested showed a significant difference between the species with values ranging 0.7-1.2%, where*B. vulgaris* had the highest as shown in Table 4 ($p<0.05$). Mukda et al. [35] reported about 0.3%, whereas other authors found 0.1-0.69% content in fresh shoots [47]. Gupta [21] found 0.69% in fresh amaranthus. Raw spinach, rhubarbs and amaranth are reported to be the highest in oxalates containing 0.32-1.26%, 0.28-1.34 and 1.59%, respectively [19].

4. Conclusion

The results of this study show that the shoots of the species of bamboo growing in Kenya are as rich in important macro-nutrients as found in similar species that are edible in countries such as Indian and China. The cultivated ones are richer particularly in calcium, magnesium and zinc content compared to others reported from other parts of the world. The shoots were found to possess high levels of polyphenols and flavonoids and indicated strongcontribution to human health as important antioxidants. Kenyan bamboo can therefore be exploited in fighting food insecurity, malnutrition as well as maintaining proper body health.

The anti-nutrients which were found in the shoots were generally lower than those found in most common vegetables and thus the bamboo shoots could provide nutrients of higher quality to the body.

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