

THE IMPORTANCE OF INDIGENOUS CROPS IN MALAWI – A CASE OF NYMPHAEA PETERSIANA (NYIKA)

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ABSTRACT

Researchers have during the last 20 years documented declining interest among younger people for traditional food sources. This change has led to substantial loss in knowledge for traditional foods, since knowledge of wild gathered foods and technology and on how to preserve these foods have been orally passed on from previous generations. When this occurs, lost is both the knowledge and skills of recognition and identification of climatically adapted food resources that have previously sustained societies.

As migration from rural to urban areas increases it has become common knowledge that more and more people tend to look down on our own indigenous foods. Wild fruit, vegetables and tubers are looked upon as food for the rural poor and tinned foods and exotic vegetables are perceived as a sign of affluence. Furthermore, loss of indigenous food resources that have previously sustained societies has contributed to the inadequate amounts of food and inadequate basis nutrients in the diet leading to undernutrition in most developing countries, including Malawi.

INTRODUCTION

The genus *Nymphaea* is the largest genus of the waterlily family and occurs worldwide with more than 50 species in tropical and temperate climates. The genus is represented by four species in Malawi – *N. Caerulea*, *N. Capensis*, *N. Lotus* and *N. Petersiana*. *Nymphaea petersiana* (Nyika) is an important water tuber in Chikwawa and Nsanje districts, where the tubers are commonly sold in markets as snack foods. They can also be peeled, cut in small pieces, dried and ground into powder (ufa), which can be used for cooking nsima. Although these tubers have been eaten as food from as early as the 1940's (in certain parts of the country), there is to our knowledge, no available data concerning their nutrient composition or potential for toxicity. This study was there undertaken to determine the tuber's content of selected nutrients and antinutrients in order to assess how it might best be utilized in the Malawian diet, especially in the rural areas; and secondly to begin establishing a nutrient data base for the tuber, and hopefully, lay the foundation for a nutrient data base for edible wild tubers eaten in Malawi. The research involved laboratory analysis of the tuber for some selected nutrients and antinutrients. Results

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in a wet weight basis indicated that the tuber is well balanced in essential amino acids except lysine. It also has a higher iron content. A comparison of the mineral content of *N. petersiana* with other African root tubers showed that the tuber contains more calcium (**1300µg/g**) than cassava (wild and domesticated), potatoes, sweet potatoes and yams (**520µg/g**) (wild and domesticated). Phosphorus content (**2600µg/g**) was also higher than the literature values for most African root tubers. The antinutrients tannin, phytate, trypsin and chymotrypsin inhibitors were low and considered not to be of nutritional concern, Hydrogen cyanide levels were below detection limits.

Data from this study indicated that this tuber is of nutritional significance, hence efforts need to be made to utilize it as a weaning food for use in the rural areas where people cannot afford to buy the commercial weaning foods currently on the market.

MATERIALS AND METHODS

Sampling and Processing of Nyika Tubers

Tubers were collected from the Kademera and Chigumukire swamps of the Chikwawa and Nsanje districts, respectively, of southern Malawi, where the tuber is habitually eaten. Tubers were collected in September 1995 and again in September 1997. Harvested tubers were put into cooler boxes with blue ice and transported to a University of Malawi laboratory, Blantyre, Malawi. The tubers were frozen at -60°C for one week, then shipped in the frozen state to Blacksburg, Virginia. The tubers were again kept frozen at -60°C prior to analysis.

Three-digit random numbers were used to randomly assign collected tubers to one of two processing methods. In one method the tubers had their outer coats removed, were cut into small pieces, and dried in the sun for 24 to 48 hours. A cyclotec 1093 sample mill (Tecator, Hoganas, Sweden) was used to grind sun-dried tuber pieces into powder, which was placed in plastic bottles and stored at -4°C for further analysis (uncooked/sundried (UCSD) tubers). In the other processing method, the tubers were boiled in tap water for 45 minutes, peeled, and freeze-dried. The freeze-dried tubers were ground into a powder and stored at -4°C (boiled/freeze-dried (BFD) tubers).

Analysis

Proximate Composition

The moisture content of BFD and UCSD tubers was determined by drying in a Brabender Moisture Tester oven (Brabender Instruments Inc., South Hackensack, NJ) at 135°C for 2 hours according to AOAC approved method 7.007 (AOAC, 1984). Nitrogen content was determined by the Kjeldahl method 2.057 (AOAC, 1984), and crude protein was estimated by multiplying % N by a factor of 6.25. Crude fat was determined by the chloroform-methanol extraction method of Phillips et al. (1997), which is a modification of AOAC method 983.23 (AOAC, 1990). Dietary fiber content was determined

using a total dietary fiber assay kit (Sigma, 1991). Ash content was determined by decomposition in a muffle furnace at 450-620°C for 12 hours according to AOAC method 7.009 (AOAC, 1984). The percentage of total crude carbohydrate was obtained by difference {100 – (% crude protein + % crude fat + % moisture + % ash)} (Muller and Tobin, 1980). A standard reference material (SRM) 1544, a frozen diet composite, purchased from the National Institute of Standards & Technology (NIST), was run simultaneously with the tuber samples for method validation.

Mineral Analysis

Tuber samples were wet-ashed according to AOAC method 7.099 (b) (AOAC, 1984). The wet-ashed samples were analyzed for calcium, zinc, phosphorus and iron. Calcium and zinc content were determined by atomic absorption spectrophotometry (AAS) according to AOAC method 7.100 (AOAC, 1984), using a Perkin-Elmer, Model 2100 atomic absorption spectrophotometer. Phosphorus was determined colorimetrically using AOAC method 7.126 (AOAC, 1984). Iron was determined by AAS using a Perkin-Elmer ICP Emission Spectrometer Plasma 400 (Norwalk, Connecticut). A standard reference material (SRM, 1515 Apple Leaves, purchased from NIST) was run simultaneously with the samples from method validation.

Amino Acid Analysis

The ACSD and BFD tuber samples were subjected to amino acid analysis using AOAC method 982.30E (a,b,c) and F (AOAC, 1990). The amino acids were separated and quantified using a Beckman 6600 automated amino acid analyzer, with a Beckman exchange column. Norleucine was used as an internal standard.

Fatty Acid Analysis

The gravimetric method of Phillips et al. (1997) was used for extraction of total fat from the tuber samples. Fatty acids were analyzed by gas chromatography using a Shimadzu GC14A gas chromatograph with model AOC-14 Autoinjector and a Chromatopac C-R4AX processor (Shimadzu, Columbia, MD). Fatty acid methyl esters (FAMES) were separated on a SP 2330 capillary Columbia (Supelco, Bellefonte, PA) using temperature programming (from 60-100°C at 10°C/min, hold for 2 min at 100°C, then 10°C per min to 220°C). A set of short-chained C₄-C₁₂ and long-chained C₁₆-C₂₀ FAME standards were used to compare retention times of these standards to retention times of sample peaks eluted from the column as a means of tentatively identifying fatty acids in the tubers. FAMES were qualified using the internal standard technique, with heptadecanoic acid (17:0) as the internal standard.

Analysis of Mono and Disaccharides and Ascorbic Acid

The mono and disaccharide content of tuber samples was determined by high performance liquid chromatography (HPLC) following the method of Conrad and Palmer (1976) as modified by Johnson

and Harris (1987). The samples were analyzed for ascorbic acid content by HPLC using the method of Wimalasiri Wills (1983).

Analysis of Antinutritional Factors

Tuber samples were also assayed for the possible presence of trypsin and chymotrypsin inhibitors, cyanogenic glucosides, tannins, and phytates. The colorimetric procedures of Bradbury et al. (1986) was used to estimate the quantities of cyanogenic glucosides in the tuber samples. The UV-absorbance method of Killipara and Hymowitz (1992) was used to determine trypsin and chymotrypsin inhibitor activity. The colorimetric procedure of Wheeler and Ferrel (1971) was used to estimate the phytate content of the samples. Tannins were analyzed using the method of Burns (1971).

Statistical Analysis

Analysis of variance (ANOVA) was used to determine if there were significant differences in the content of nutrients and antinutrients in the two Nyika samples, due to processing method. A randomized complete block design model was chosen for statistical design of this study. Location and time factors were completely blocked and the only variable tested for was the processing method. Significant differences were tested at $p \leq 0.05$. The analysis was done using the SAS statistical package (SAS Inc., Copyright, 1989-1995, Cary, NC).

RESULTS AND DISCUSSION

Proximate Composition

The proximate composition of UCSD and BFD tubers is presented on both a wet and dry-weight basis in Table 1. UCSD tubers were found, on a dry weight basis, to be significantly higher in crude protein and ash content than BFD tubers. The results suggest that some of the tuber's proteins and minerals leached into the cooking water, when the tubers were boiled. There was no significant difference in the dietary fiber content of UCSD and BFD tubers, which implies the majority of the dietary fiber is composed of water-insoluble fiber components such as cellulose, hemicelluloses and lignin.

A comparison of the proximate compositions of Nyika tubers and some cereals eaten in Africa (Table 2) indicated that except for sorghum (10.7%), the protein content of the tubers (8.0 and 8.1%, on a wet-weight basis, for BFD and UCSD tubers, respectively) was comparable to that of the other cereals including that of the Malawian staple maize (7.9%), and that of milled and polished rice (7.0%). Since the tuber contains approximately 8% protein, it can under famine conditions, be substituted for the Malawian staple maize without compromising the protein content of the diet.

A comparison of the proximate composition of Nyika tubers and other tubers eaten in Africa (see Table 3) indicates that the tuber has a higher protein content than cassava (1.2 and 1.3% protein for bitter and sweet varieties, respectively), potato (1.7%), sweet potato (1.6%), yams (3.2 and 1.5%, wild and domesticated, respectively), and the Egyptian *Nymphaea lotus* (5.2%). Staple foods with protein contents below 3% (like those of most of the root tubers cited in Table 3) do not meet the protein requirements of humans even when ingested in amounts supplying more than the caloric requirements. On the contrary, a diet with an 8-10% protein content meets the protein requirements of adults, provided enough is eaten to supply caloric requirements (Cheftel et.al., 1985). This means that when eaten in sufficient quantities, *Nymphaea petersiana* tubers can meet the protein requirements of an adult.

Amino Acid Composition

The nutritional quality of a food protein depends on the kinds and amounts of amino acids it contains, and represents a measure of the efficiency with which the body can utilize the protein. A balanced or high quality protein contains essential amino acids in ratios that are sufficient to meet human needs. This can be determined by comparing the amino acid content of a protein to a FAO/WHO reference pattern (Cheftel et al., 1985). The essential amino acid profiles of UCSD and BFD are shown in Table 4. The profiles indicate that the tuber is well balanced in essential amino acids except for lysine. Based on their lysine content, UCSD and BFD tubers had amino acid scores of 91 and 84, respectively. Knowledge of amino acid scores helped in estimating the complementary value of different proteins in a food mixture. In this case, the amino acid scores would help in deciding what cereals or legumes would complement the tuber if it had to be used as a weaning food, or what side dishes should be eaten with the tuber to complement the limiting amino acid lysine. Two possible choices available to Malawians are groundnuts (peanuts) and bambarra nuts. Both are high in lysine and deficient in the sulfur amino acids (FAO, 1970) complementing Nyika proteins which are low in lysine but more than the FAO/WHO requirements of cysteine and methionine (see Table 4).

Minerals

Statistical analysis revealed that there were significant differences in the calcium, phosphorus, and iron content of UCSD and BFD tuber samples (see Table 5). Approximately 20% of the phosphorus and 80% of the iron in the tubers presumably leached into the cooking water during boiling of BFD tubers. UCSD tubers appear to be an excellent source of iron. According to our calculations, a one hundred gram serving (about 3 1/2 ounces) of the UCSD tubers would, on a wet-weight basis, supply approximately 88% of the USRDA for iron for children six month to 10 years of age and 59% of the USRDA for iron for woman 11 to 50 years of age (NRC, 1989).

$$\frac{8.8 \times 10^{-5} \text{ g of } \frac{\text{iron}}{\text{g}} \text{ of tuber} \times 100 \text{ g of tuber}}{1.0 \times 10^{-2} \text{ g of iron}} = 0.88 \times 100 = 88\%$$

And

$$\frac{8.8 \times 10^{-5} \text{ g of } \frac{\text{iron}}{\text{g}} \text{ of tuber} \times 100 \text{ g of tuber}}{1.5 \times 10^{-2} \text{ g of iron}} = 0.585 \times 100 = 58.6\%$$

UCSD tubers had a higher iron content on a wet-weight basis (88.0 ug/g) than literature values for cassava (78.0 $\mu\text{g/g}$). A comparison of the mineral content of *N. petersiana* with other African root tubers (which are also eaten in Malawi) indicated that BFD tubers contain more calcium (1300 $\mu\text{g/g}$) than cassava (480 $\mu\text{g/g}$ wild and 1210 $\mu\text{g/g}$ domesticated), potatoes (110 $\mu\text{g/g}$), sweet potatoes (330 $\mu\text{g/g}$) and yams (520 $\mu\text{g/g}$ wild and 690 $\mu\text{g/g}$ domesticated). Phosphorus content (2200 $\mu\text{g/g}$ and 2600 $\mu\text{g/g}$ for BFD and UCSD, respectively, on a wet-weight basis) was also higher than the literature values for the root tubers listed in Table 3 (Leung, 1968).

Other Nutrients

Nyika tuber samples were found to contain a preponderance of polyunsaturated (approximately 31% linoleic and 7% linolenic acid) and monosaturated (45% oleic acid) fatty acids. Presence of high levels of unsaturated fatty acids is nutritionally desirable. However, unsaturated fatty acids are much more susceptible to oxidation than their saturated counterparts, therefore exposure of tuber material to oxygen, light and high temperatures should be minimized during processing and storage to prevent autoxidation of tuber lipids.

The phytate content of *N. petersiana* was 3.9 $\mu\text{g/g}$ and 5.4 $\mu\text{g/g}$ of tuber (BFD and UCSD, respectively, on a wet-weight basis.) These values were very low compared to those found by Ferguson et al. (1988) for the Malawian staple white maize flour (in mg/100g) (211); cooked maize flour (55); unrefined maize flour (792); cassava (59); and sweet potato (12). This indicates that the phytate content of *N. petersiana* tubers is also low as to be of little concern nutritionally when compared with the phytate content of other foods commonly eaten in Malawi.

Nyika flour samples were also analyzed for hydrogen cyanide, a compound released from cyanogenic compounds during heating. Some varieties of cassava contain cyanogenic glucosides. Boiled *N. petersiana* tubers have slightly bitter taste (like that of some cassava varieties) and this prompted us to analyze the tubers for cyanogenic glucosides. Hydrogen cyanide levels in both UCSD and BFD samples were below the limit of detection for the assay (LOD <16 nmoles/L), an indication that cyanogenic glucosides, if present at all in the tuber are in negligible quantities and of little toxicological concern

CONCLUSIONS

Results from the study that the tuber is well balanced in essential amino acids (except lysine). It is also high in iron content. A comparison of the mineral content of *Nymphaea Petersiana* with other African root tubers shows that the tuber has more calcium and phosphorus than most domesticated tubers (cassava, potatoes, sweet potatoes and yams). There is therefore great need to utilize this tuber more and to sensitise more people to explore the potential of this locally found but under exploited wild tuber. There is need to assess how best this tuber might best be utilized in the Malawian diet, especially in the rural areas.

Secondly, there is need to establish a nutrient data base for this tuber, in particular, and hopefully lay a foundation for a nutrient data base for more edible wild tubers in Malawi.

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Table 1

Proximate Composition of Boiled/Freeze-Dried BFD and Uncooked/Sun-Dried (UCSD) *Nymphaea petersiana* (Nyika) Tubers⁴

Tuber Sample	% Moisture	% Protein	% Fat	% Ash	% Total CHO	% Dietary Fiber
BFD Tubers (wet-weight basis)	0.7 ^b	8.0 ^b	1.0 ^d	1.9 ^c	88.4	13.0 ^a
UCSD Tubers (wet-weight basis)	10.8 ^a	8.1 ^b	0.8 ^b	2.2 ^b	78.1	12.0 ^a
BFD Tubers (dry-weight basis)	0	8.1 ^b	1.0 ^a	1.9 ^c	89.0	13.1 ^a
UCSD Tubers (dry-weight basis)	0	9.1 ^a	0.9 ^b	2.5 ^a	87.5	13.4 ^a

Table 2

Comparison of the Proximate Composition of Nyika Tubers With Some African Cereals

Crop	Protein (%)	Ash (%)	Total CHO	Fat (%)	Fiber (%)
Nyika ^b (BFD)	8.0	1.9	88.4	1.0	13.0
Nyika ^b (UCSD)	8.1	2.2	78.1	0.8	12.0
Maize ^a , soaked, sun dried	7.9	0.4	73.1	1.5	0.6
African millets ^a , red	7.5	3.3	73.1	1.47	3.4
Rice ^a , milled, polished	7.0	0.6	79.5	0.5	0.4
Sorghum ^a	10.7	1.9	71.1	3.2	2.4

⁴ Reported values are means of eight determinations

^{a,b,c} Means in the same column with different superscripts are significantly at the p = 0.05 level.

Source: Food Composition Table for Use in Africa (Leung, 1968)

All Nyika values are on a wet-weight basis

Table 3

Comparison of the Proximate Composition of Nyika with Other African Root Tubers

Crop	Protein (%)	Fat (%)	Total CHO (%)	Fiber (%)	Ash (%)
Nyika (BFD)	8.0	1.0	88.4	13.0	1.9
Nyika (UCSD)	8.1	0.8	78.1	12.0	2.2
Cassava bitter (raw)	1.2	0.2	35.7	1.1	0.9
Cassava sweet (dried)	1.3	.05	86.6	1.8	2.9
Potato (raw)	1.7	0.1	18.9	0.6	1.6
Sweet Potato (raw)	1.6	0.2	28.5	1.0	0.9
Yam wild tuber	3.2	0.1	26.5	1.0	0.9
Yam (African) tuber	1.5	0.1	26.5	0.9	0.9
Nymphaea lotus root (Egyptian)	5.2	0.2	29.5	1.0	1.1

Source: Food Composition Tables for Use in Africa (Leung, 1968)

All Nyika values are on a wet-weight basis

Table 4

Comparison of Essential Amino Acid Content of Nymphaea petersiana (Nyika) Tubers to a FAO Reference Pattern

Amino Acid	BFD Tubers	UCSD Tubers	FAO/WHO (1990) Reference Pattern
Threonine	39	39	34
Cys. & Met	45	46	25
Valine	52	52	35
Leucine	86	84	66
Isoleucine	46	45	28
Phe. & Tyr.	101	99	63
Lysine	49	53	58
Tryptophan	26	28	11

Reported values are in mg of amino acid/g of crude protein and are means of two determinations.

Based on preschool child data from FAO/WHO/UNU (1985).

Sources: FAO/WHO/UNU

Table 5

Mineral Composition of Boiled/Freeze-Dried (BFD) and Uncooked/Sun-Dried (UCSD) *Nymphaea petersiana* (Nyika) Tubers

Tuber Sample	Calcium (in $\mu\text{g/g}$ to tuber)	Phosphorus (in $\mu\text{g/g}$ of tuber)	Zinc (in $\mu\text{g/g}$ of tuber)	Iron (in $\mu\text{g/g}$ of tuber)
BFD Tubers (wet-weight basis)	1300	2200	20	20
UCSD Tubers (wet-weight basis)	928	2600	22	88
BFD Tubers (dry-weight basis)	1309	2215	20	20
UCSD Tubers (dry-weight basis)	1040	2914	25	99

Reported values are means of eight determinations

Means in the same column with different superscripts are significantly at the $p = 0.05$ level

Table 6

Antinutrient Content of Boiled/Freeze-Dried (BFD) and Uncooked/Sun-Dried (UCSD) *Nymphaea petersiana* (Nyika) Tubers

Tuber Sample	% Tannin	Phytate (in $\mu\text{g/g}$ of tuber)	Trypsin Inhibitor (UTIU/g of tuber)	Chymotrypsin Inhibitor (CIU/g of tuber)	Hydrogen Cyanide
BFD Tubers (wet-weight basis)	1.0	3.9	55	50	<LOD
UCSD Tubers (wet-weight basis)	1.5	5.4	400	240	<LOD

Reported values are means of eight determinations

Means in the same column with different superscripts are significantly different at the $p = 0.05$ level

Limit of detection (LOD) = 16 nmoles/L