Makerere University Journal of Agricultural and Environmental Sciences
Vol. 13. pp. 54 - 72, 2024

pISSN 1563-3721
eISSN: 2958-4795

The potential of underutilized crops in providing required macro and micro nutrients in diets of persons living with HIV/AIDS: A case study of Hoima district in Uganda

Nabubuya, A.[1]*, Asiimwe, A.[3], Nakalembe, I.[2], Mugabi, R.[1], Mukisa, M. I.[1] and Mwakha, A.[2]

[1]Department of Food Technology and Nutrition, Makerere University P.O Box 7062, Kampala, Uganda
[2]Department of Biomolecular Resources and Biolab Sciences, Makerere University, P.O Box 7062, Kampala, Uganda
[3]National Agricultural Research Laboratories, Kampala, Uganda

*Correspondent author: agnesnabubuya@yahoo.co.uk

Abstract

Malnutrition is one of the major challenges faced by persons living with HIV/AIDS (PLWHA) especially in rural areas of Uganda. Underutilized crops present an unexploited alternative with potential to affordably improve micro and macro nutrients in the diets for different age groups of PLWHA. In this study, it was hypothesized that *Dioscorea alata* (white yam) tubers and leaves, *Vigna unguiculata* (cowpea seeds & leaves), *Telfairia pedata* (oyster nut), and *Cucurbita pepo* (pumpkin) leaves are high in nutrients and could individually significantly contribute to the improvement of the diets of PLWHA. The underutilized crops were processed into flours and analyses were carried out using standard procedures. It was observed that oyster nut could provide 20.8% and 26.0% of the RDA of energy for asymptomatic male and female adults, respectively, and 19.07%, 23.84% for symptomatic males and female adults, respectively. Cowpea seeds could provide > 25% of the RDA for zinc in all cohorts of PLWHA, and 10.75% and 12.29% of the RDA for iron for male adults & children of 9 to 13 years, and those of 1 to 3 years of age, respectively. Leaf samples of cowpea, pumpkin and white yam though rich in micronutrients were associated with tannins and phenols that may need culinary processing to ensure safety. The crops are good candidates to include in diets of PLWHA to alleviate malnutrition and optimize nutritional benefits.

Key words: Anti-nutritional components, cowpea, macronutrients, micronutrients, oyster nut, pumpkin, white yam

Introduction

Malnutrition continues to be on the rise in Sub-Saharan Africa (WHO, 2019). The vicious cycle of poverty, disease and illnesses aggravates this situation (Bain *et al*., 2013). Sub-Saharan Africa is the most hit by HIV/AIDS globally. Indeed, 70% of the over 40 million people living with HIV/AIDS (PLWHA) globally, are found in Sub-Saharan Africa (Farhoudi e*t al*., 2022). The prevalence of HIV in Uganda is at 7%, of which 25% are malnourished (WHO, 2019). Malnutrition in PLWHA depresses immunity (Sashindran and Thakur, 2020) further predisposing affected persons to optimistic infections.

Many interventions to address malnutrition have left out PLWHA due to challenges such as associated stigma, costs, and misconceptions (Jadgal *et al*., 2022). The domestic funding of HIV related programmes remains minimal with donors carrying the greatest load (Barr *et al*., 2021). This leads to controls in resource allocation, with donors prioritizing supplementary and therapeutic feeding among undernourished children.

Reports show that underutilized food crops such as millets, pseudo cereals, root and tuber crops, leafy vegetables, and fruits have potential to improve dietary diversity (Yadav *et al*., 2020), and to affordably complement diets (Bandula *et al*., 2016). However, their utilization remains low. Underutilized crops are domesticated plant species that, despite their nutritional benefits and adaptability to specific agroecological niches, are perceived to be used to a small degree relative to their potential. These crops are characterized by low production levels compared to staple crops, limited market availability, and cultural significance (Mabhaudhi *et al*., 2016). Underutilized crops have been reported to provide adequate amounts of micro and macro nutrients (Migliozi *et al*., 2015; Willett *et al*., 2019). Besides, these crops present tremendous opportunity for fighting not only hunger and malnutrition, but also poverty, and making agricultural production systems more resilient to climate change (Padulosi *et al*., 2013). There are numerous underutilized crops in Uganda that can be useful in lessening the burden of malnutrition among PLWHA, however, little has been done to establish their potential in terms of nutrient and anti-nutritional composition/density, and their ability to cater for the dietary needs of these populations. This paper presents a case study of selected underutilized crops from Hoima, a district in Western Uganda.

Materials and methods

Selection of underutilized crops

The underutilized crops were identified based on low production levels relative to staple crops, limited market availability, and cultural significance according to the people in Hoima. White Yam *(Dioscorea alata*: Dioscoreaceae; leaves and tubers), Cowpea (*Vigna unguiculata:* Fabaceae; cowpeas, leaves and seeds), Oyster nut (*Telfairia pedata:* Cucurbitaceae; nut), and Pumpkin (*Cucurbita pepo*: Cucurbitaceae; pumpkin leaves) were the underutilized crops (parts) selected for the study. The selection of underutilized crops was informed by focus group discussions with local communities in Hoima District, who highlighted these crops based on their perceived nutritional benefits, cultural significance, and adaptability to local agroecological conditions. The crops were selected after a preliminary survey on preference. The choice of Hoima for this study is justified by the region's socio-economic context, particularly the impending oil mining activities in the nearby Bunyoro area, which are expected to attract a significant influx of workers and businesses, potentially increasing demand for commercial sex services and exacerbating vulnerabilities among local populations, including PLWHA (Dietler *et al.*, 2022).

Preparation of crop samples for analysis

The study crops were bought from local famers in Kigorobya Sub County, Hoima district, Uganda. Standard techniques were used to prepare the underutilized crops. White yam tubers were washed under running water, peeled, chopped to 1cm thick pieces and dried at 90^{O}C for 24 hours. The cowpea seeds were manually cleaned and sorted to remove the chaff and stones. The shells of oyster nuts were mechanically broken to obtain the nuts. They were dried in an electric drier as were the cowpea leaves, pumpkin leaves and white yam leaves at 70 ^{O}C for 24 hours (Barroca *et al*., 2020). All the dry materials were milled using an electric mill and sieved using a 600 micron sieve to obtain fine powders (Deli *et al*., 2020) that were used in analyses in the Biochemistry Laboratory at the School of Food Technology, Nutrition and Bioengineering of Makerere University.

Analyses

Proximate analysis

Moisture content, protein, ash, and crude fat contents were determined using standard AOAC methods (AOAC, 2015). Moisture content of the underutilized crops was determined using the Air Oven Method, with an air-forced laboratory oven (MRC

Model: DFO-150). Total ash content was determined using a laboratory chamber furnace (Carbolite™ CWF 1300). Crude fat was determined using the soxhlet method; percentage nitrogen was determined by the macro-Kjeldahl method and converted to crude protein content by multiplying with a factor of 6.25. Crude fiber was determined gravimetrically using acid detergent fibre reagent and the carbohydrate content was determined by the difference method.

The energy content was calculated using the Atwater general factors (Merrill & Watt, 1955), where the crude protein, crude fat, and crude carbohydrate percentages were multiplied by 4, 9, and 4, respectively, to accurately estimate the total energy content of the food based on the established caloric values of each macronutrient. Thus, energy values were calculated as: (Crude protein x 4 kcal) + (Crude fat x 9 kcal) + (Total carbohydrate x 4 kcal) = kcal

Micronutrient determination

Determination of Vitamin A content

Total carotenoids (Provitamin A) were determined according to the method of Rodriguez and Kimura (2004). Exactly 2 g of sample was extracted by mixing with 50 ml cold acetone in the dark and transferred into a separating funnel containing 30 ml of petroleum ether. The acetone was removed through the slow addition of 250 ml double distilled water with the separating funnel at an angle of 45^o to prevent the formation of emulsions. The aqueous phase was discarded and this procedure was repeated four times until there was no residual acetone. The extract was then transferred through a funnel into a 50 ml volumetric flask containing glass wool with 15 g of anhydrous sodium sulfate. The final volume was adjusted with petroleum ether. Absorbance was measured at 450 nm (Genesys 10-UV spectrophotometer, Thermo Electron Corporation, Madison, WI) against petroleum ether as a blank. The obtained carotenoids were then converted to vitamin A, retinol equivalent activity (REA).

Determination of vitamin C

Vitamin C was determined according to the method of Kumar *et al.* (2013) with some modifications. One gram of the sample was weighed, extracted using an extracting solvent prepared by mixing 160 ml of glacial acetic acid and 37 ml of orthophosphoric acid and the mixture made to 2 L using distilled water. The extract was then transferred into a 50 ml volumetric flask. Two, 5 ml aliquots of this solution were pipetted into two conical flasks. Each of the aliquots was titrated with indophenol solution until a faint but distinct rose-pink color persisted for at least 5 seconds. Vitamin C content in the samples was calculated as mg ascorbic acid per 100 g of sample

Mineral profile analysis

Determination of iron and zinc content of the underutilized crops was done using atomic absorption spectrometry as described by Ogbemudia (2017). While other minerals are also important for overall health, iron and zinc were prioritized because of their ability to boost the immunity of PLWHA (Sashindran & Thakur, 2020).

One gram of each of the samples was weighed and transferred into a digesting glass tube and mixed with 12 ml of nitric acid. Then 4 ml Perchloric acid were added to the mixture and kept and digested at 250ºC for 85 min under a fume hood. After cooling, the contents of the tubes were transferred to 100 ml volumetric flasks and made to 100 ml by adding distilled water and analyzed for iron and zinc.

The atoms of an element were vaporized and atomized in the flame before getting absorbed to hollow cathode lamp light with a characteristic wavelength. The absorbed energy was measured by a photo-detector read-out system after calibration with standard solutions. The amount of energy absorbed was proportional to the concentration of iron and zinc in the sample. The concentrations of iron and zinc were recorded in "ppm" before being converted to milligrams (mg) of the minerals

Determination of anti-nutrient factors

Quantification of total phenols and tannins

The extraction method described by Makkar (2000) was used with slight modifications. Briefly, about 2 g of sample was weighed into a falcon tube and mixed with 5 ml of extracting solution (80% methanol: 20% water solution, v/v). The falcon tube containing the mixture was suspended in an ultrasonicator (Bransonic series, M 2800- E; Branson Ultrasonics Co, Danbury, CT) containing water and subjected to ultrasonic treatment for 20 min at room temperature. The extract was immediately cooled in a refrigerator at 4°C for 10 min and then centrifuged at 1008 xg (Fischer scientific 225, Fisher Scientific Co. St. Louis, MO) for 10 min. The supernatant was collected into a separate falcon tube and stored at 4°C in a refrigerator. The residue was then further re-extracted as described above, to ensure efficient extraction. The two supernatants were pooled in a falcon tube and stored in a refrigerator at 4°C to be used in the determination of total phenolic content (TPC) and tannins content.

The TPC of the flours from the different crop samples was determined using the Folin- Ciocalteu colorimetric method Makkar (2000) with some modifications. Briefly, 100 μL of sample extract was pipetted into a test tube and covered with aluminum foil. Subsequently 0.25 ml of Folin–Ciocalteu reagent (0.2N) was added, left to stand for 5 min and then 1.25 ml of sodium carbonate (7.5% w/v) added. The mixture in the test tube was homogenized using a vortex and kept in dark at room temperature for 90 min to allow for color development. Absorbance was measured at 765 nm (Genesys 10- UV spectrophotometer, Thermo Electron Corporation) against 80% methanol as the blank. The total phenolic content was determined using the standard gallic acid calibration curve with varying concentrations (0.02- 0.125) mg/ml). The TPC was expressed as mg GAE/100 g of the sample

The tannin content of the flours from the selected underutilized crops was determined according to Broadhurst *et al*. (1978) with slight modifications, using catechin as a reference compound. Four hundred microlitres of extract obtained in the subsection above were added to 3 ml of a solution of vanillin (4% in methanol) and 1.5 ml of concentrated hydrochloric acid. After 15 minutes of incubation, the absorbance was read at 500 nm. The total tannin content was expressed as g E.Catechin.100g-1DM.

Determination of phytic acid content

Phytic acid content was determined using a colorimetric (Wade reagent) method as described by Harland and Oberleas (1986) with modifications. One gram of sample was used to extract phytic acid using 100 ml of 2.4 M hydrochloric acid (HCl) mixed with 0.1M sodium chloride and filtered. The clear supernatant of filtrate of the extract was diluted 10 times into a 100 ml volumetric flask and made to the mark using distilled water. Exactly 3 ml of the diluted sample was mixed with 1 ml of Wade reagent (0.03% $FeCl_3 \cdot 6H_2O$ + 0.3% sulfosalicylic acid), thoroughly vortexed & centrifuged for 10 min. A series of calibration standards containing 0, 1.1, 2.2, 3.3, 5.5, 7.7 and 11.1 mg/ml were prepared from hexa-sodium Phytate salt M.W. 660.04g. Absorbance of colour reaction products for both samples and standards were read at 500 nm on a spectrophotometer (spectroquant Pharo 300M, EU). The phytate content was determined using the standard phytic acid calibration curve.

Determination of oxalates

Oxalate composition in the flours was determined by a method as described by Day and Underwood (1986). About 2.5 g of the sample was mixed with 75 ml of 3 M H2SO4 and stirred for 1 h with a magnetic stirrer. The mixture was filtered and 25 ml of the filtrate was titrated while hot against 0.05 M KMnO4 solution to a faint pink color that persisted for 30 s. The oxalate composition was calculated by assuming that 1 ml of 0.05 M KMnO4 is equivalent to 2.2 mg oxalate.

Computation of percentage contribution of individual underutilized crops to nutrient RDAs for PLHA

The percentage contribution to the Recommended Dietary Allowance (RDA) of nutrients for persons living with HIV/AIDS (PLWHA) by the underutilized crops was calculated based on the consumption of 100g of flour of each crop. The RDA values were derived from WHO guidelines and relevant literature (WHO, 2003; Britten et al., 2012). The nutrient composition of the crops was analyzed, and their contributions to the RDA for energy, protein, iron, and zinc were determined for various cohorts, such as asymptomatic and symptomatic males and females, as a percentage.

Data analysis

The XLSTAT software version 2019 was used to analyse data from triplicate analyses. Data were subjected to one-way analysis of variance (ANOVA) and Fischer's least significance difference test was used to separate means at the 5% significant level.

Results

Proximate composition and energy content of selected underutilized crops

The moisture content varied significantly among study crop elements, ranging from 4.31 to 9.08% (Table 1; P < 0.05). Yam tubers had the highest moisture content while the oyster nut had the lowest. All the underutilized crop flours had moisture content < 10%.

Table 1. Proximate composition and Caloric content of selected underutilized crops (%)

Sample	Moisture content	Carbo-hydrates	Crude proteins	Crude fat	Crude ash	Crude fibre	Energy (kcal/100g)
Oyster nut	$4.3^{c}\pm0.2$	$7.6^{d}\pm0.3$	$24.1^{b}\pm0.1$	$49.1^{a}\pm0.4$	$3.2^{c}\pm0.1$	$11.6^{c}\pm0.3$	572.0^{a}
Cowpea seeds	$8.1^{ab}\pm0.1$	$52.9^{b}\pm0.6$	$23.7^{b}\pm0.7$	$1.9^{c}\pm 0.2$	$3.2^{c}\pm0.1$	$9.3^{c}\pm0.6$	298.7^{c}
Cowpea leaves	$5.2^{c}\pm0.4$	$27.1^{c}\pm1.1$	$29.7^{a}\pm1.4$	$1.8^{c}\pm0.1$	$15.1^{b}\pm0.4$	$20.2^{b}\pm1.9$	176.7^{d}
Pumpkin leaves	$5.3^{c}\pm0.2$	$27.7^{c}\pm1.2$	$9.2^{c}\pm0.5$	$2.57^{c}\pm0.2$	$25.3^{a}\pm0.9$	$28.7^{a}\pm1.2$	163.7^{d}
Yam leaves	$7.5^{b}\pm0.1$	$23.9^{c}\pm 1.1$	$8.9^{c}\pm1.0$	$6.1^{b}\pm0.2$	$24.5^{a}\pm0.6$	$28.5^{a}\pm1.1$	157.3^{d}
Yam tubers	$9.1^{a}\pm0.2$	$80.7^{a}\pm0.4$	$5.4^{d}\pm0.2$	$0.49^{cd}\pm0.0$	$2.4^{c}\pm0.2$	$1.7^{d}\pm0.1$	348.5^{b}
Mean	6.58	36.50	16.83	10.33	12.27	13.50	286.17
Lsd	1.00	5.00	3.00	1.50	2.00	3.00	30.00

Data are presented as means ±SD. Values within the same column with different superscripts are significantly different from each other (P<0.05)

The carbohydrate content of the samples also varied significantly (P < 0.05) among crop elements, ranging from 7.6% (oyster nut) to 80.7% (white yam tubers). Yams were followed by cowpea seeds. However, the carbohydrate content of the leafy forms of the test crops (23.9 to 27.1%) was not significantly different (Table 1).

There was a significant variation (P<0.05) in the crude protein content of the flours of the different test crop elements. The protein content ranged from 5.36 to 29.67%

(Table 1) with cowpea leaves and white yam tubers having the highest and lowest protein content, respectively. The other leafy vegetable flours were generally low in crude protein content (5.36 to 9.2%).

There was significant variation ($P<0.05$) in the fat content of the different underutilized crop elements, in the range of 0.49 to 49.1%. Crude fat content observed was highest in oyster nut and lowest in white yam tubers (Table 1).

Significant differences ($P<0.05$) were also observed in the crude ash content of the different underutilized crops. The crude ash ranged from 3.18 to 25.36% (Table 1) with pumpkin and yam leaves at the high end (25.3% and 24.5 %), outperforming the other underutilized crop elements. The lowest crude ash values were observed in oyster nut.

The crude fibre content of the analyzed crop samples varied significantly ($P < 0.05$) and ranged from 1.71 to 28.74% (Table 1). Crude fibre was highest in pumpkin and white yam leaves, and lowest in white yam tubers.

The energy content of the samples of selected underutilized crops varied significantly ($P<0.05$) and ranged from 157.28 to 572.04 kcal/100g (Table 1). Oyster nut had the highest energy content (572.04 kcal/100g) followed by yam tubers (348.5 kcal/100g) while the leafy samples displayed the lowest energy content (157-176kcal/100g).

Micronutrient content for selected underutilized crops

The zinc content varied significantly ($P < 0.05$) among the underutilized crop samples and ranged from 1.161 to 2.314 mg/100g (Table 2). It was highest in cowpea seeds and lowest in the oyster nut. Iron content also varied significantly ($P < 0.05$) among the flours of the different underutilized crops and ranged from 0.1602 to 0.864 mg/100g. Iron was had the highest concentration in cowpea seeds, and the lowest was in oyster nut.

The vitamin A content, measured as Retinoic Acid Equivalent (RAE) differed significantly ($P < 0.05$) among the crop elements, ranging from 0.015 to 0.437 mg/100g. It was highest in cowpea leaves and lowest in the oyster nut. Vitamin C content on the other hand ranged from 5.22 to 9.20 mg/100g (Table 2). Vitamin C values were significantly highest in white yam leaves (9.20 mg/100g), and lowest in oyster nut.

Table 2. Micronutrient content for selected underutilized crops (mg/100g)

Sample	Zn	Fe	Vitamin A RAE	Vitamin C
Oyster nut	$1.16^{bc} \pm 0.02$	$0.16^{cd} \pm 0.00$	$0.017^{cd} \pm 0.00$	$5.22^{b} \pm 0.03$
Cowpea seeds	$2.31^{a} \pm 0.49$	$0.86^{a} \pm 0.01$	$0.064^{c} \pm 0.00$	$8.32^{a} \pm 0.22$
Cowpea leaves	$1.57^{b} \pm 0.03$	$0.80^{a} \pm 0.03$	$0.437^{a} \pm 0.01$	$5.97^{b} \pm 1.03$
Pumpkin leaves	$2.13^{a} \pm 0.23$	$0.52^{b} \pm 0.00$	$0.020^{c} \pm 0.00$	$6.14^{b} \pm 0.02$
Yam leaves	$1.94^{ab} \pm 0.09$	$0.36^{bc} \pm 0.01$	$0.157^{b} \pm 0.00$	$9.20^{a} \pm 0.23$
Yam tubers	$1.66^{b} \pm 0.06$	$0.38^{bc} \pm 0.07$	$0.062^{c} \pm 0.00$	$8.09^{a} \pm 0.14$
Mean	1.79	0.35	0.126	7.16
Lsd	0.50	0.15	0.05	1.00

Values are means ± standard deviations. Means within the same column with different superscripts are significantly different ($P<0.05$)

Anti- nutritional factors

Significant variations ($P < 0.05$) were observed in the phytate content of the underutilized crops, which ranged from 5.09 to 10.62 mg/100g (Table 3). White yam tubers and pumpkin leaves had the highest and lowest content, respectively. The total phenolic content of the underutilized crops varied significantly ($P < 0.05$) and ranged from 114.1 to 563.86 mg/100g (Table 3). The total phenols were highest in yam leaves (563.86 mg/100g), and least in yam tubers (114.10 mg/100g). Notably, the total phenols were higher in the leafy samples compared to the seeds and nuts. Tannins varied significantly among the study samples and ranged from 22.79 mg/100g to 107.50 mg/100g (Table 3). White yam leaves had the highest tannin content (107.50 mg/100g) and oyster nut the lowest (22.79 mg/100g). It was also observed that the leafy samples contained more tannins than the non-leafy samples. The oxalate content varied significantly among the study samples and ranged from 6.83 to 136.67 mg/100g with cowpea seeds having the highest, and oyster nut having the lowest amounts. The oxalate content was observed to be quite low also among leafy samples.

Contribution of underutilized crops to the recommended daily allowances (RDAs) for selected nutrients for PLWHA

The analyzed underutilized crops could provide substantial energy, with oyster nuts having the highest energy content and being able to contribute 19.07.80% of the RDA for symptomatic males (2750 kcal) and 23.84% for symptomatic females (2200 kcal) in 100g (Table 4). The leafy vegetables contributed minimally to the RDA for energy requirement of the different population cohorts (5.72% to 8.03%). Cowpea seeds and oyster nuts on the other hand emerged as excellent sources of protein, providing 43% and 52% of the RDA (males and females, respectively) and 42% and

Table 3. Antinutrient content of selected underutilized crops (mg/100g)

Sample	Phytates	Total phenolics (mg GAE/100 g)	Tannins	Oxalates
Oyster nut	5.89^{c} ± 1.42	147.21^{d} ± 3.30	22.79^{e} ± 3.26	6.83^{e} ± 1.94
Cowpea seeds	6.85^{bc} ± 1.42	205.68^{c} ± 6.44	28.50^{d} ± 3.60	136.67^{a} ± 2.60
Cowpea leaves	6.70^{bc} ± 2.04	531.85^{b} ± 2.34	98.15^{b} ± 1.11	23.33^{d} ± 2.80
Pumpkin leaves	5.09^{c} ± 2.10	500.37^{b} ± 1.81	83.99^{c} ± 1.68	20.33^{d} ± 2.42
Yam leaves	8.49^{b} ± 1.77	563.86^{a} ± 2.42	107.50^{a} ± 4.38	46.00^{c} ± 1.03
Yam tubers	10.62^{a} ± 0.44	114.10^{e} ± 1.92	23.01^{e} ± 1.03	78.50^{b} ± 1.87
Mean	7.27	343.68	60.66	51.94
Lsd	1.00	30.00	10.00	5.00

Values are means ± standard deviations. Means within the same column with different superscripts are significantly different (P<0.05)

Table 4. Percentage contribution to RDAs for PLWHA upon consumption of 100g of selected underutilized crops

Nutrient	Cohort		Percentage (%) contribution to RDA						
			RDA*	Oyster nut	Cowpea seeds	Cowpea leaves	Pumpkin leaves	Yam leaves	Yam tubers
Energy (Kcal)	Adults & adolescents	Asymptomatic: Males	2750	20.80	10.86	6.43	5.95	5.72	12.67
		Asymptomatic: Female	2200	26.00	13.58	8.03	7.44	7.15	15.84
		Symptomatic: Males	3000	19.07	9.96	5.89	5.46	5.24	11.62
		Symptomatic: Females	2400	23.84	12.44	7.36	6.82	6.55	14.52
Proteins	Adults & adolescents	Male	56	43.09	42.39	35.13	37.93	16.00	10.64
		Female	46	52.46	51.61	42.76	46.17	19.48	12.96
Iron	Adults & adolescents	Male	8	2.00	10.75	10.00	6.50	4.50	4.75
		Female	18	0.89	4.78	4.44	2.89	2.00	2.11
Zinc	Adults & adolescents	Male	11	10.55	21.00	14.27	19.36	17.64	15.09
		Female	8	14.50	28.88	19.63	26.63	24.25	20.75

*as per WHO (2003) and Britten *et al.* (2012)

51 % of the RDA (males and females, respectively), respectively. Cowpea seeds and pumpkin leaves were the highest contributors for zinc, offering 21.00% and 28.88% (males and females, respectively) and 19.3 and 26.6% (males and females, respectively). However, majority of the selected underutilized crops contributed minimally to the RDAs for iron for the different cohorts, with only cowpea seeds and cowpea leaves providing the highest percentages 10.75% and 4.78% (males and females, respectively) and 10.0% and 4.44% (males and females, respectively), respectively.

Discussion

Proximate nutrient composition of selected underutilized crops and their contribution to RDAs for PLWHA

The moisture content of the underutilized crops (4.31 to 9.08%) was low (<10%) as dry milled flours were used. A food's moisture content and water activity are two parameters frequently evaluated with respect to food chemical stability (Bell, 2020). Moisture content below 10%, prolongs the shelf life of the product (Sujeetha, 2014). This implies that these underutilized crops can be harvested during season, dried and ground into flour for storage and utilization off season. These results were in agreement with those reported by Okechukwu *et al*. (2020)

Carbohydrates provide energy for various physiological functions in the body (Ahsan, 2021). The carbohydrate content observed in white yam tubers (80.7%) was higher than the 36.2% reported by Adeniji *et al*. (2020). This could be attributed to the different geographical settings, since both studies also determined carbohydrate content by difference just like the present study. Determination of carbohydrates content in the current study was limited by the inclusion of resistant starches in the analysis. Studies show that white yam tubers contain resistant starch (Chiranthika *et al*., 2022).

Plant-based protein has been reported to be a healthy alternative for PLWHA. Plant-rich diets have been associated with slower decline in kidney function due to low inflammation rates among women leaving with HIV/AIDS (Banerjee et al., 2023). Cowpea (seeds and leaves) and oyster nut were rich in protein (23.7% - 29%). These results are in line with those of Fasoyiro *et al*. (2006) who recorded protein content of 22 to 37% in underutilized grain legumes. Any plant food capable of providing 12% of its calorific value from protein is a good source of protein (Effiong *et al*., 2009). Most of the underutilized crops studied could provide > 25% of the recommended dietary allowance (RDA) for protein for adults upon consumption of 100 g, with exception of white yam leaves and tubers; based on WHO (2003) RDA for PLWHA.

Crude fat content observed was highest in oyster nut (49.08%) and lowest in white yam tubers. The findings on oyster nuts are in line with the report of Mwakasege *et al*. (2021), who showed that oyster nuts can enhance nutritional status of PLWHA due to their high fat content of 49 % that would boost the energy intake of that population. Fat also enhances absorption of fat-soluble vitamins such as A, D, E and K, palatability and satiety (Inobeme *et al*., 2014), making it an important component in formulating balanced diets for vulnerable groups like PLWHA. Vitamins A, D, E, and K are essential for optimizing immune health in persons living with HIV/AIDS, supporting immune function, reducing infection risk, and enhancing overall nutritional status (Obeagu *et al.*, 2024).

Ash is a proxy indicator for mineral content in food and a recognized measure for nutrient quality in food (Temple *et al*., 1991). Pumpkin leaves had the highest ash value of 25.3%. Very low ash values were observed for oyster nut, cowpea seed and yam tubers. These results are comparable to those reported by Oulai *et al.* (2014), Akinwunmi *et al*. (2016), Inobeme *et al*. (2014), Mariam *et al*. (2021), and Ayo (2018) who also noted variations in ash content across different underutilized crops. As a crucial indicator of mineral presence in food, the observed ash values were generally low in individual underutilized crop flours (3.18 to 25.36%) supporting blending different underutilized crops into composites as a means to address mineral deficiencies and enhancing the nutritional status of this vulnerable population living with HIV/AIDS.

Fibre is indigestible plant material capable of lowering cholesterol level in humans, prevents cancer and reduces the risk of developing diabetes, hypertension and hypercholesterolemia (Viuda-Martos et al., 2010). The observed high crude fiber content in pumpkin leaves and white yam leaves implies that these crops if consumed by PLWHA would improve on their body lipid profiles by promoting cholesterol regulation, gut health (Cronin et al., 2021; Li et al., 2020) and also reduce inflammation since PLWHA are at an increased risk of developing the mentioned conditions (Gill et al., 2022; Xie et al., 2023). The crude fiber content observed in this study especially for the cowpeas is in agreement with that reported by Fasoyiro et al., (2006) in his study of underutilized legumes where he observed a range from 1.92–7.2%.

Oyster nut had a significantly higher energy content (572.04 kcal/100g) than the rest of the underutilized crops, especially the leafy samples. This could be attributed to the high fat content of this crop. These findings are in agreement with those reported by Mwakasege et al. (2021) and Mariam et al. (2021). Basing on WHO (2003) RDA for energy intake amongst people living with HIV/AIDS, these nuts can meet 20.80% and 26% energy for asymptomatic male and female adults, respectively, and 19.07%, 23.84% of energy for symptomatic males and female adults, respectively upon consumption of 100g of the crop. This shows the potential of the oyster nut in boosting energy intake amongst these cohorts of people living with HIV/AIDS.

Micronutrient content for selected underutilized crops

Cowpea seeds had the highest zinc content (2.314 mg/100g) providing >20% of the RDA for all age groups and genders of PLWHA. This demonstrates its potential in boosting the zinc intake for PLWHA. Zinc together with vitamin A boost immunity in immune compromised patients (Joachimiak, 2021). These results were lower than the range reported for other types of pulses (5.0-10.9 mg/100g) Vadivel and Janardhanan (2009).

The highest iron content found in cowpea seeds (0.864 mg/100g) was similar to that of cowpea leaves (0.801 mg/100g). These results are in line with those of Fasoyiro et al. (2006) working with underutilized legumes but lower than those reported by Borokini et al., (2017) who reported values ranging (1.4 - 2.0 mg/100g) for certain underutilized vegetables. Cowpea seeds could contribute 10.75% of the iron RDA (in 100g) for adult males and children of 9 to 13 years, 12.29% for children 1 to 3 years but < 10.00% of the RDA for other age cohorts. This implies that consumption of larger amounts of the crop would potentially increase iron intake for PLWHA. Iron is key in preventing anaemia which is endemic among PLWHA in Hoima (Kaudha et al., 2023).

Vitamin A and vitamin C help to keep the lining of the gut and lungs healthy and strong and prevent germs from entering the body (Pustaka, 2002), among other benefits. The leafy underutilized crops were highest in vitamin A and their observed values agreed with those reported by Owade *et al*. (2020). Vitamin C values were highest in white yam leaves, cowpea seeds and yam tubers (>8 mg/100g); however, while these findings align with the general trend observed by Owade *et al*. (2020), the specific values reported for the other leafy underutilized crops differed, highlighting the variability in nutrient content among different studies possibly due to different environmental factors. Vitamin C is an anti-oxidant and immune booster capable of scavenging free radicals from drug metabolism and excretion (Krishnamurthy and Wadhwani, 2012). This makes Vitamin C a valuable nutrient for PLWHA, helping to support immune function, reduce infection risk, and potentially enhance the effectiveness of ART (Colunga Biancatelli *et al*., 2020).

Anti- nutritional factors

Phytates have been reported to be toxic at values beyond 6 mg/100g (Inuwa *et al*., 2011). Majority of the underutilized crops had phytate content above the reported toxic limit with white yams having highest phytates (10.62 mg/100g); higher than the 8.20mg/100g reported by Omoniyi (2022), which may be attributed to different pretreatment and geographical locations. High levels of phytates above the toxic dose could hamper the activity of enzymes necessary for protein digestion (Samtiya *et al*., 2020). Phenolic content of the underutilized crops ranged from 114.1 to 563.86 mg/100g. These were highest in white yam leaves (563.86 mg/100g). Very high phenolic intake may have detrimental effects on health. High levels of phenolics have been known for precipitation of protein and reduction of protein bioavailability (Grgiæ *et al*., 2020).

The range observed for tannins in this study (22.79 mg/100g to 107.50 mg/100g) was similar to that obtained by Lawal *et al*. (2014). Tannins in the underutilized crops were observed to be highest in white yam leaves (107.50 mg/100g). Tannins are capable of affecting protein digestibility (Lampart-Szczapa *et al*., 2003). This implies that the high levels of tannins observed would possibly impede protein digestibility upon consumption of the underutilized crops. The observed oxalates were below the toxic level of 250 mg/100g (Inuwa, 2011). This implies that the oxalate content of the underutilized crops is still low to pose a health effect.

When foods rich in these anti-nutritional compounds are consumed without culinary treatment or isolated, they can cause a negative effect on human health. However, in normal family settings, these foods are consumed in a food matrix, and can be given culinary treatment or processing through germination, fermentation or milling, in which they are reduced in concentration, or form synergies with other compounds beneficial to health, then the negative effects are greatly minimized (Lopez-Moreno *et al*., 2022). It should also be noted that anti-nutritional compounds such as phytates can offer antioxidant, antidiabetic, anticholesterolemic; neuroprotective and antiosteoporotic benefits if taken at optimum levels (Anekonda *et al*., 2011; Xu *et al*., 2011; Zajdel *et al.*, 2013; Palomeque *et al*., 2015; Sanchis *et al*., 2018; Lopez-Moreno *et al.*, 2022).

Conclusion

Each individual underutilized crop showed potential to provide required nutrients in diets for PLWHA by contributing significantly to the RDAs of individual nutrients. Oyster nut demonstrated potential to contribute greatly to the RDA for energy, proteins and zinc and had minimal anti-nutritional compounds. Cowpea seeds can contribute greatly to the RDA for protein, iron and zinc. Cowpea, pumpkin and white yam leaves were good in providing micronutrients but had high levels of phenols and tannins that may need culinary treatments to ensure safety. White yam tubers had the highest levels of carbohydrates and can contribute moderately to the RDA for proteins.

Acknowledgement

We acknowledge the financial support from the Government of Uganda under Makerere Research Innovation Fund (Mak. RIF).

Conflict of interest

The authors declare no conflict of interest

Ethical consideration

This study does not include any testing on humans or animals.

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