Food Research 8 (2) : 382 - 396 (April 2024)
Journal homepage: https://www.myfoodresearch.com

FOOD RESEARCH

RESEARCH PAPER

Nutritional composition and mineral bioavailability of selected root and tuber crops in the Bicol Region, Philippines

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Article history:
Received: 1 November 2022
Received in revised form: 11 January 2023
Accepted: 14 January 2023
Available Online: 16 April 2024

Keywords:
Root crops,
Tuber crops,
Total mineral,
Bioavailability,
In vitro simulated digestion,
Malnutrition

DOI:
https://doi.org/10.26656/fr.2017.8(2).548

Abstract

Filipinos consume root and tuber crops as inexpensive sources of nourishment. However, the limited information on the nutritional and mineral bioavailability of root and tuber crops inhibits their optimal utilization in what could possibly address nutrient deficiencies among the populations. This study determined the proximate composition of cassava, sweet potato, taro, giant swamp taro, cocoyam, and purple yam through the Association of the Analytical Chemists (AOAC) standard method. The mineral bioavailability was determined *in vitro* by simulating digestion from the oral up to the intestinal phase. Mineral and trace metal contents were quantified using a Microwave Plasma Atomic Emission Spectrometer (MP-AES). The crops' ash, protein, fat, and total dietary fiber contents ranged from 1.23-3.53%, 2.01-9.32%, 0.18-0.83%, and 4.23-19.3%, respectively. Taro (9.32%) and purple yam (6.71%) have the highest protein contents among the crops examined and can be considered as sources of protein based on the recommended nutrient intake (RENI) for Filipino adults. Except for cassava, most of the studied crops were high sources of total dietary fiber, with the giant swamp taro (48% RENI) as the highest. Total minerals such as K, Ca, Mg, Na, and considerable quantities of Zn, Mn, Fe, and Cu were detected. The mineral bioavailability varied for Zn (47.0-98.0%), Cu (37.5-86.8%), Mn (31.5-91.8%), Mg (31.9-90.2%), Ca (2.54-31.1%) and Fe (4.7-20.7%). Consumption of 100 g of the examined crops, except for giant swamp taro and cassava, can contribute to the daily Cu for adults aged 19-29. Taro contributes to the daily nutritional requirement for bioavailable Ca and Mg, while giant swamp taro contributes to Zn and Mn requirements. None of the examined crops contained sufficient bioavailable Fe to contribute to Filipinos' daily requirements. The study can help address the limited information on the nutritional and mineral bioavailability of root and tuber crops, which hampers their utilization to address some nutrient deficiency among the Filipino population, and emphasizes the consumption of these crops to enhance dietary diversification, which can alleviate some nutrient deficiencies in the country.

1. Introduction

Protein-energy malnutrition and micronutrient deficiencies have been significant issues in many developing, as well as some sectors of the populations in affluent countries. One of the major and prevalent effects of nutrient deficiency is malnutrition. In all its forms, including acute malnutrition, chronic undernutrition, and underweight, it is associated with insufficient nutrients such as vitamins and minerals in the body, to name some. In developing countries, poverty increases the risk and consequences of malnutrition. Underprivileged people are more likely to suffer from various forms of malnutrition that contribute to raising healthcare costs, reducing productivity, slowing economic growth, and potentially perpetuating a cycle of poverty and illness (de Juras *et al.,* 2021). The poorest of the poor are the most affected by nutrient deficiencies among a varied age group of Filipinos (Angeles-Agdeppa *et al.,* 2019).

In the Philippines, the rate of food security and malnutrition is an extremely high public concern. In the 2018 national nutrition survey, 53.9% food insecure households were recorded. Three out of ten (36.6%) children were stunted, which peaked at the age of <2

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eISSN: 2550-2166 /
Published by Rynnye Lyan Resources

years old; 18.8% of children were underweight for age 2 years, and 6.8% of children were classified as wasting, which means that the children's weights were much lower than what were expected for their height (DOST-FNRI, 2019). The Philippines ranked fifth with the highest frequency of stunting among East Asian and Pacific countries and was one of the top ten countries with the most stunted children (de Juras *et al*., 2021). Chronic energy deficiency among adults contributed to 8.0% of the population and overweight people almost doubled from 16.6% to 37.2% between 1993 and 2018 (DOST-FNRI, 2019).

Nutrient deficiency such as protein-energy and micronutrients are major concerns caused by a lack of dietary diversity in poor and developing world (Müller and Krawinkel, 2005; Palanog *et al.,* 2019). Nutrient deficiencies can be addressed by appropriate diet to address the daily nutrient requirement such as energy-yielding macronutrients (fat, carbohydrates, protein) and those that aid energy production micronutrients (vitamins and minerals). Unhealthy diets and inadequate nutrition are among the leading risk factors for noncommunicable diseases worldwide, such as heart attacks and strokes that are frequently associated with high blood pressure, certain cancers, and diabetes (de Juras *et al.,* 2021). Having a balanced nutrition is an important way to maintain good physical and mental health. It requires several essential nutrients, including both micronutrients and macronutrients. Micronutrients, for example, help the body produce enzymes, hormones, and other substances required for proper growth and development. Furthermore, essential nutrients are needed in different physicochemical and metabolic processes in life, like pH balance, transport of gases, tissue repair, bone formation, vitamin synthesis, as well as to sustain energy in everyday activities (Biziuk and Kucynska, 2007). Minerals are one type of essential inorganic nutrients that are needed in amounts ranging from 1 to 2500 mg/day, depending on the type of mineral (Soetan *et al.,* 2010). Microminerals include calcium (Ca), magnesium (Mg), potassium (K), and phosphorus (P), and sodium (Na) while manganese (Mn), copper (Cu), zinc (Zn), chromium (Cr), and selenium (Se) are considered micro or trace minerals (Moreda- Piñeiro *et al*., 2016; Kafaoglu, 2016). Macrominerals must be consumed in quantities greater than 100 mg/day and are needed in larger quantities, while microminerals or trace elements, on the other hand, must be consumed in amounts less than 100 mg/day by the body (Gharibzahedi and Jafari, 2017; Affonfere *et al*., 2021). Ultra-trace elements are required in minute amounts and are essential to life. Specific minerals are absorbed from different parts of the gastrointestinal tract; however, most minerals are absorbed in the small intestine (Goff, 2018). It is also important to know that consuming foods high in nutrients does not always mean that these are 100% bioavailable. In normal physiological settings, bioavailable nutrients are the portion of the ingested component that is readily absorbed by the body (Trinidad *et al.,* 2010; Gharibzahedi *et al.,* 2017; Millena and Sagum, 2018; Affonfere *et al.,* 2021).

To address daily nutritional requirements, humans can get mineral nutrients from a variety of animal- and plant-based food products. Nutrients from plant sources such as root and tuber crops are an economical source of food and nourishment for many of the poorest populations and households in developing countries. Rice remains the staple food in most Asian countries and is substituted with sweet potatoes and other root and tuber crops depending on the season. Filipinos typically obtain nutrition from the foods available in their locality; the typical Filipino diet consists primarily of rice, fish, and vegetables, and the consumption of maize, starchy roots, and tubers as rice substitutes or supplements, which are commonly found and cultivated in the area. The root crops are consumed boiled, or included in the soup, as ingredients for different dishes, as flavored desserts, and other delicacies. Root crops such as cassava (*Manihot esculenta*) or locally known as *kamoteng kahoy*, sweet potato (*Ipomoea batatas*) or *kamote*, taro (*Colocasia esculenta*) or *gabi*, giant swamp taro (*Cyrtosperma merkusii*) or *palauan;* and tuber crops such as cocoyam (*Xanthosoma sagittifolium*) or *linsa*, and purple yam (*Dioscorea alata*) yield starchy materials that are of economic importance in the Philippines as food sources. The country, along with Thailand, Indonesia, India, China, and Vietnam, are major producers of root and tuber crops in Asia (Trinidad *et al.,* 2010). Starchy root and tuber crops are an important staple, secondary to cereals as source of dietary energy globally which are of great importance for many developing countries due to their affordability, availability, and ease of growth. Root and tuber crops store their edible starchy material in their corms, roots, rhizomes, and tubers, which originate from a vast array of botanical sources (Chandrasekara and Kumar, 2016). Starch from these crops contributes to the world's food requirements and is used in different industries. Several species and varieties of root and tuber crops are consumed in different countries. About 90% of global production of root and tuber crops consist of cassava, potatoes, and sweet potatoes (Food and Agriculture Organization of the United Nations (FAO), 2013). The contribution of root and tuber crops in energy supply varies from different populations within the country (Chandrasekara and Kumar, 2016).

Several studies were conducted to assess the

https://doi.org/10.26656/fr.2017.8(2).548

nutritional contributions of the different root and tuber crops, specifically on the total minerals and trace metals (Englberger *et al.*, 2008; Baah *et al.,* 2009; Mwenye *et al.,* 2011; Mergedus *et al.,* 2015; Paul *et al*., 2015). However, there are very limited studies on the bioavailability of selected crops (Trinidad e*t al.,* 2010; Luis *et al.,* 2013; Andre *et al.,* 2018; Padhan *et al.,* 2018; Rashmi *et al.,* 2018). The purpose of this study was to assess the nutritional and mineral bioavailability of different commonly and underutilized root and tuber crops available in the Philippines using an *in vitro* method, to provide a more reliable estimate of the amount of minerals absorbable after digestion.

2. Materials and methods

2.1 Plant materials

The six root and tuber crops used in the present study (Figure 1) are sweet potato (*Ipomoea batatas*), purple yam (*Dioscorea alata* L.), cassava (*Manihot esculenta*), taro (*Colocasia esculenta*), cocoyam (*Xanthosoma sagittifolium*) and giant swamp taro (*Cyrtosperma merkusii*). Samples were obtained from the experiment field of Albay Provincial Agriculture Office (APAO), Camalig, Albay, 13° 08' 13.80'N; 123° 39' 26.39' E and from accredited farms in the Albay area. A minimum of six kg per crop were harvested upon maturity. No mineral fertilizers were applied and no pesticides were used for pest and weed control. These root and tuber crops were thoroughly washed with acidified water (pH = 3) and further rinsed with deionized water. The samples were boiled separately for 20 to 40 minutes in a stainless-steel pot, depending on the size with demineralized water (1:1 ratio) before they were peeled manually. After boiling and peeling, composite samples (approximately 300 g) were lyophilized using Labo-gene Scanvac Coolsafe (Lynge, Denmark) drier, milled using 1095 Foss Knifetec mill (Hoganas, Sweden), and finally sieved to a particle size less than 0.2 mm. Samples were then stored in polyethylene bottles with hermetic seals at -25°C (BIOBASE, Shandong, R.P China) until analyzed.

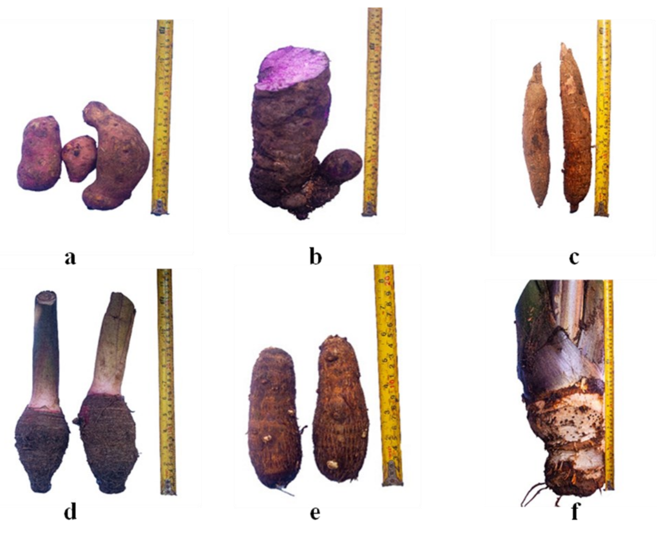

Figure 1. Sample root and tuber crops: (a) sweet potato, (b) purple yam, (c) cassava, (d) taro, (e) cocoyam, and (f) giant swamp taro.

2.2 Reagents and standards

Ultrapure water produced by the Milli-Q system (Millipore, Molsheim, France) with a resistance of 18.2 MΩcm was used throughout the experiment. Merck (Darmstadt, Germany) and Sigma Aldrich (Buchs, Switzerland) brands of chemicals were used and are traceable to the NIST (National Institute of Standards and Technology) with 99.99% purity. All standards and reagents used in the study were of analytical grade. For the determination of total dietary fiber, the enzymes used were heat-stable alpha-amylase, protease, amyloglucosidase and pepsin (Megazyme, Sigma-Aldrich). Prior to instrumentation, nitric acid (Merck, Darmstadt, Germany) was used for the digestion of samples for mineral analysis. Certified/Standard Reference Materials, such as LGC 7103 (Queens Road, Teddington, Middlesex, UK) and NIST SRM 1567b Wheat flour (NIST, Gaithersburg, MD, USA), were used alongside the sample analysis to ensure the validity of results. Minimum of three replicate analyses were conducted per sample. Elemental composition was reported after blank correction, and mineral values were expressed as mg/kg and percentage (%) for mineral bioavailability.

2.3 Determination of proximate composition

Proximate analysis was carried out by adopting the AOAC 21st edition (2019).

2.3.1 Determination of ash content

For the ash content, AOAC 950.49 lifted from the standard method was utilized. Approximately 1±1.0 g of sample was weighed in crucible previously dried in an oven at 105°C charred, cooled and weighed. The sample was subjected to ashing using furnace (Cole-Parmer, Asheville, NC, USA) by gradual increase in temperature to reach up to 525°C for 1 hr until the residue was white or nearly white. The results were reported as g /100 g ash content.

2.3.2 Determination of protein content

The protein content was determined using AOAC 950.48 which is an improved Kjeldahl method, using automated FOSS instrument Labtec DT208 Digestor and Kjeltec 8100 distillation (FOSS Analytical Hillerod, Denmark). A 1 g of sample was used and digested at 420°C for 1 hrs. The distillate was back titrated with

https://doi.org/10.26656/fr.2017.8(2).548

standard hydrochloric acid (0.1 N HCl). The amount of crude protein was expressed as g/100 g, which was calculated by multiplying the amount of nitrogen by protein factor of 6.25.

2.3.3 Determination of fat content

The total fat content was quantified by adopting AOAC 948.22. A 2±1.0 g sample was used and dried for an hour at 100°C to remove excess water that may interfere with the analysis. The fat was extracted using a Soxhlet fat extraction unit FOSS Soxtec 2045 (Hilleroed, Denmark) and petroleum ether as solvent. The fat content was expressed as g/100 g.

2.3.4 Determination of soluble dietary fiber, insoluble dietary fiber and total dietary fiber content

2.3.4.1 Quantification of total dietary fiber

The enzymatic-gravimetric method was used to determine dietary fiber in accordance with AOAC 985.29 and is applicable to low (<10%) fat analytes. Approximately 0.5 g of samples were weighed and transferred to the incubation flask. A phosphate buffer solution (pH 6.00) of 50 mL was added and stirred carefully until completely dispersed, followed by the addition of 50 µL α-amylase (Megazyme, Sigma-Aldrich). The flask was covered with aluminum foil and incubated in shaking water bath at 95°C with continuous agitation for 30 mins. Samples were removed from the water bath and cooled after incubation. Approximately 100 µL protease was added, covered with aluminum foil, and then incubated again in a shaking water bath for 30 mins at 60±1°C with continuous agitation. After incubation, the pH of the digest was adjusted to 4.35-4.45 with 1 N NaOH solution or 0.561 N HCl solution and 200 µL amyloglucosidase was added. The final incubation was performed for 30 mins with continuous agitation at 60±1°C. Analysis was done in parallel with blanks. Total dietary fiber (TDF) was computed by adding the soluble dietary fiber (SDF) and insoluble dietary fiber (IDF).

2.3.4.2 Quantification of insoluble dietary fiber

A pre-dried crucible heated at 525°C for 5 hrs was prepared. An approximately 0.5 g of celite 545 was added, redistributed through wetting with deionized water, oven dried at 105°C for 8 hrs, cooled for 1 hr, and weighed. The enzyme digest was filtered using the prepared crucible in the filtration unit with vacuum. The residues were washed twice with 10 mL of distilled water, 10 mL of ethanol, and 10 mL of acetone. The crucibles containing the filtered residues were dried in an oven at 105°C for 8 hr and cooled for 1 hr prior to weighing. The filtrate was recovered for the determination of soluble dietary fiber. Residue was analyzed for protein and ash, which were subtracted to determine the corrected IDF. Quantification was done in triplicate.

2.3.4.3 Quantification of soluble dietary fiber

A pre-dried crucible heated at 525°C for 5 hrs was prepared. The combined filtrate and washing from the quantification of IDF were precipitated with 400 mL of 95% ethanol preheated to 60°C for 1 hr. The celite bed was redistributed using 78% ethanol with vacuum. The precipitate was filtered and washed with three portions of 20 mL of 78% ethanol, two 10 mL portions of 95% ethanol, and two 10 mL portions of acetone. The crucibles containing the filtered residues were dried in an oven at 105°C for 8 hrs, cooled for 1 hr, and weighed. Residue was analyzed for protein and ash, which was subtracted from the value to determine the SDF.

2.3.5 Determination of carbohydrate content

The percent carbohydrate content of the samples was calculated by subtracting the sum of moisture, ash, fat, protein, and total dietary fiber from 100%.

2.4 Determination of total mineral and trace element

The freeze-dried samples were subjected to acid digestion in a closed vessel set up for mineral analysis using a Microwave Plasma Atomic Emission Spectrometer, MP-AES 4200 (Agilent Technologies, Santa Clara, CA, USA). Three replicates were made for every sample, including blanks. Clean glassware was immersed in 10% nitric acid overnight, washed three times with ultrapure water the following day, and finally air-dried. A sample having a mass of 0.5 g was weighed and transferred into a Teflon vessel containing 10 mL of concentrated HNO_3 (65%). The temperature and pressure conditions for acid digestion in a microwave digester, Model Speedwave4 (Berghof, Eningen, Deutschland, Germany), were set to 200°C and 30 bar. After completing digestion, the digest was filtered into a 50 mL volumetric flask using a funnel and Whatman filter paper No. 42. The Teflon vessel and filter paper used were rinsed with 0.1 N HNO_3 to get most of the remaining digest. In the study by Millena and Sagum (2018), the derived working standards for the minerals and trace metals of the instrument were 0-10 mg/L and 0 -2.5 mg/L, respectively. Serial dilution was performed on the samples with a common diluting factor if the concentrations were not within the working standards. The wavelengths in nanometer (nm) used to determine the concentration of analytes present in the samples are the following: minerals Na (589.592), Fe (259.94), Ca (393.366), K (766.49), and Mg (279.08); trace metals Cu (324.75), Zn (213.86), and Mn (257.61). Triplicates were done for the analysis. Results were corrected with the

https://doi.org/10.26656/fr.2017.8(2).548

mean of blank samples, and values were reported in mg/kg.

2.5 Determination of in vitro mineral bioavailability

The *in vitro* protocol was performed as described in Trinidad *et al.* (1996) and Millena and Sagum, (2018) with the addition of simulation of the oral phase. The availability of minerals in different crops was estimated through solubilized fraction under simulated gastrointestinal condition. The analyses were done in quadruplicate.

2.5.1 Simulating oral phase of digestion

To simulate the oral phase digestion, a mass of 10 g of the sample was placed in 250 mL Erlenmeyer flask and added with 90 mL saliva solution [1% (w/v) α-amylase and 150 mmol/L NaCl solution dissolved in a 1000 mmol/L $NaHCO_3$ buffer having pH 6.8] (Oliveira *et al.,* 2021). The mixture was placed in a shaking water bath for 5 mins using FOSS WB 1024 (Hilleroed, Denmark) at 150 rpm and the temperature was set to 37°C.

2.5.2 Simulating gastric phase of digestion

To simulate the gastric phase, the sample was acidified using 6N HCl to achieve pH 2.0. The mixture underwent enzymatic digestion using a 3.2 mL pepsin-HCl solution (8 g pepsin in 50 mL of 0.1 M HCl) and incubated at 37°C for 3 hrs in shaking water bat set at 100 rpm.

2.5.3 Simulating intestinal phase (small intestine) of digestion

To simulate the intestinal phase, a 30 cm dialysis membrane tubing was prepared by soaking in deionized water for 1 min, and tightly sealed at one end, Spectra/Por 1, 23 mm, 6000-8000 MW (Spectrum Laboratories Inc., CA, USA). An aliquot of 20 g digest gastric phase digestion was transferred into the prepared dialysis membrane tubing followed by the addition of a 5 mL pancreatin-bile solution (1 g pancreatin and 6.25 g bile diluted with 0.1M $NaHCO_3$ to 250 mL) while the other end of the dialysis membrane tubing was tightly sealed. The amount of $NaHCO_3$ in the first dialyzing solution was determined through titration to pH 7.5 of 20 g pepsin digest mixed with 5 mL of pancreatin-bile solution using 0.5 M KOH. The amount of $NaHCO_3$ was equal to four times the total volume of KOH used and was then diluted to 100 mL with ultrapure water, which was the first dialyzing solution. The membrane tubing was submerged in the prepared first dialyzing solution, which was incubated for 12 hrs at 37°C in a shaking water bath to simulate small intestine digestion. Dialysate was collected after 3 hrs and filtered using Whatman filter paper No. 42. For the succeeding three simulations, a 100 mL deionized water was used as dialyzing media and collected every 3 hrs. Dialysis uses deionized water and performed for another three successive 3 hrs dialysis. *In vitro* mineral bioavailability was estimated by analyzing the dialysate using Microwave-Plasma Atomic Emission Spectrometry (MP-AES), and values were expressed as percentages.

$$\text{Total µg mineral in dialysate} = \left[\left(\frac{\mu g}{mL}\right)_{D1} + \left(\frac{\mu g}{mL}\right)_{D2} + \left(\frac{\mu g}{mL}\right)_{D3} + \left(\frac{\mu g}{mL}\right)_{D4}\right](100\ mL)$$

Where D1, D2, D3, and D4 represent the four dialysate collections for every three hours during the intestinal phase and dialysis. The summation of mineral concentration in dialysates was multiplied by 100 mL, which is the volume used for the dialyzing solution.

$$\%\ \text{mineral bioavailability} = \frac{(\text{total µg mineral in dialysate})(100\%)}{(\text{total } \frac{\mu g}{g} \text{ in test sample})\ (\text{g test sample})}$$

2.6 Determination of nutritional contribution

The amount of nutrients present per 100 g of root and tuber crops were calculated. The values obtained were then multiplied by the corresponding percent bioavailability to obtain the bioavailable minerals when 100 g of crop was consumed. Calculated bioavailable minerals were compared against the Recommended Nutrient Intake (RNI) and tolerable upper intake for young adults (19-29 years old) of the Philippine Dietary Reference Intake (PDRI 2018). For the nutrients not included in the PDRI 2018, reference values from Dietary Reference Intake (DRI) by the Food and Nutrition Board, Institute of Medicine, National Academies were used. To determine how much the nutrient from 100 g of crop contributes to the RNI, the amount of nutrient in 100 g was divided by the RNI and results were expressed as % RNI.

2.7 Statistical analysis

A minimum of three replicates, unless otherwise specified, were used in the analyses. The results were expressed as percentages on a dry weight basis. All statistical calculations were performed using IBM SPSS version 26 software (USA). Descriptive statistics was used, and results were reported as mean ± standard deviation (SD), mineral bioavailability was expressed as percentage. One-way ANOVA was used to determine the statistical significance of the results, and the differences between means were compared using post-hoc Tukey's test. A p-value that is <0.05 was considered significant.

3. Results and discussion

3.1 Analytical quality control

To ensure validity of the results, certified reference

https://doi.org/10.26656/fr.2017.8(2).548

material (CRM) sweet digestive biscuit LGC 7103 (OLY, UK) and standard reference material (SRM) NIST 1567b wheat flour (GMA, Washington, DC, USA) were used. The values obtained for the control samples are shown in Table 1. All values were within the uncertainty range of certified value, which indicates that the values obtained during experimentation were accurate and reliable. The precision varied between analyses which were within the pre-established criteria based on the validation conducted, with percent error ranging from 1.21 to 15.6% for proximate analysis and -10.7 to 6.03% for metals and trace elements. The calibration curves from the standard were higher than set R^2 at 0.9950, which ranges from 0.9993 to 0.9999. The preset quality assurance and control were met to ensure validity of results.

3.2 Proximate composition

The mean values of the proximate composition of the crops studied are presented in Table 2. Ash is the reflection of inorganic materials remaining after organic materials have been removed through dry oxidation. Giant swamp taro (3.53%) exhibited the significant highest ash content among the crops. Taro (2.72%) exhibited the second highest ash content, followed by purple yam (2.50%), sweet potato (2.27%), and cocoyam (2.17%), which were significantly different (p<0.05). Cassava exhibited (1.23%) the lowest ash content. In comparison to Taer and Taer (2020) study, the ash value obtained for giant swamp taro was lower. The ash content obtained in taro was almost two-fold less in comparison to the study of Igbabul *et al*. (2014) due to effect of fermentation that resulted to reduction of ash. The ash contents obtained for purple yam, sweet potato, and cassava agree with the study of Trinidad *et al.* (2010). Determination of ash content provides an estimation of the mineral level present in food products. In this study, variability in the mineral contents were observed. According to the order of the ash contents obtained of the evaluated crops, giant swamp taro, which is not commonly consumed, may provide a promising source of inorganic compounds such as minerals through its ash content.

Determining protein content is essential to evaluate its contribution to human growth. In the present study, the exceptional protein content of taro (9.32%) and purple yam (6.71%) showed the highest values that were significantly different among the other samples. Low amounts were observed for cocoyam (4.20%), cassava (2.21%), giant swamp taro (2.15%), and sweet potato (2.01%). The data obtained are comparable with the studies of Taer and Taer (2020) and Trinidad *et al.* (2010) for purple yam and taro, respectively. It is well known that the protein content of root and tuber crops is lower compared to animals. The present study demonstrated that taro and purple yam may provide a significant contribution which are considered as source of protein (>10% DV) for human diet.

In general, the crops examined are low sources of fat, which provides only <1%. Cassava and cocoyam had the highest fat content among the crops, with values of 0.82% and 0.86%, respectively, which were not significantly different from one another. The lowest fat content was recorded for sweet potato, giant swamp taro, and taro, which were also not significantly different from each other. The reported fat content for sweet potato, taro, cassava, and purple yam agrees well with the study of Trinidad *et al*. (2010). Giant swamp taro also presented a higher value for fat in comparison with the study of Taer and Taer (2020).

Table 1. Accuracy performance test of proximate analysis and MP-AES method obtained using the analysis of certified/standard reference materials.

CRM/SRM	Analyte	Certified Value[a]	Obtained Value[b]	% Error
LGC 7103	Moisture (g/100 g)	2.88±0.76	2.43±0.08	15.60
	Total Fat (g/100 g)	21.2±0.45	19.6±0.03	7.41
	Ash (g/100 g)	1.60±0.08	1.53±0.02	4.31
	Nitrogen (g/100 g)	1.07±0.03	1.06±0.01	1.21
NIST SRM 1567b	K (mg/kg)	1325±20	1467±17	-10.70
	Mn (mg/kg)	9.00±0.78	9.60±0.26	-6.66
	Cu (mg/kg)	2.03±0.14	2.46±0.06	-6.40
	Fe (mg/kg)	14.11±0.33	14.71±0.72	-4.25
	Ca (mg/kg)	191.4±3.3	197.3±18.8	-3.10
	Mg (mg/kg)	398±12	397±0.18	0.32
	Na (mg/kg)	6.71±0.21	6.49±2.25	3.27
	Zn (mg/kg)	11.61±0.26	10.91±0.48	6.03

[a]Values are presented as certified Value±Uncertainty (U), n = 3.
[b]Values are presented as mean±SD, n = 3.

https://doi.org/10.26656/fr.2017.8(2).548

Table 2. Proximate composition of different root and tuber crops.

Root Crops	Ash (%)	Fat (%)	Protein (%)	Soluble Dietary Fiber (%)	Insoluble Dietary Fiber (%)	Total Dietary Fiber (%)	Carbohydrates (%)
Sweet Potato	2.27±0.13^{cd}	0.20±0.02^{c}	2.01±0.01^{d}	2.58±0.18^{d}	5.47±0.31^{c}	8.47±0.48^{e}	82.3±0.42^{b}
Purple Yam	2.56±0.08^{bc}	0.51±0.05^{b}	6.71±0.26^{b}	2.10±0.00^{d}	11.0±0.00^{b}	13.1±0.00^{c}	72.2±0.26^{d}
Cassava	1.23±0.10^{e}	0.82±0.06^{a}	2.21±0.03^{d}	2.32±0.09^{d}	2.01±0.01^{e}	4.23±0.27^{f}	84.2±0.28^{a}
Taro	2.72±0.08^{b}	0.17±0.01^{c}	9.32±0.04^{a}	3.37±0.58^{c}	15.9±0.00^{a}	19.3±0.01^{a}	61.4±0.20^{f}
Cocoyam	2.17±0.09^{d}	0.86±0.04^{a}	4.20±0.04^{c}	8.52±0.02^{b}	4.39±0.01^{d}	13.0±0.03^{d}	75.2±0.21^{c}
Giant Swamp Taro	3.53±0.12^{a}	0.18±0.01^{c}	2.15±0.01^{d}	12.1±0.02^{a}	4.65±0.01^{d}	16.8±0.02^{b}	66.1±0.20^{e}
p	**	**	**	**	**	**	**

Values are presented as mean±SD, n = 3. Values with different superscripts within the same column are statistically significantly different by Tukey test.
** Significant at $p<0.05$.

Root and tuber crops store edible starch materials and concentrated source of carbohydrates. Cassava (84.2%) exhibited the highest carbohydrate that is significantly different among other crops, followed by sweet potato (82.3%). The taro (61.4%) provided the lowest amount of carbohydrates among the samples. The values obtained for the carbohydrate content of sweet potato, cassava, and purple yam corroborate with the study of Trinidad *et al.* (2010) but varies to some extent compared to the data of Moongngarm (2013). The carbohydrate content of giant swamp taro is in good agreement with the study of Taer and Taer (2020). Taro's carbohydrate content is comparable with the study of Kumoro *et al.* (2014). Root and tuber crop generally have great potential to provide an economical source of dietary energy in the form of carbohydrates.

Dietary fibers were brought to focus due to earlier studies recognizing them as beneficial to health. This leads to finding new sources of fiber and production of fiber-rich food products (Dhingra *et al.,* 2011). Based on the Philippine Dietary Reference Intakes (PDRI), the adequate intake of dietary fiber for adults is 20-25 g per day. The total dietary fiber content of the studied root and tuber crops ranges from 4.23% to 19.3%, indicating that some crops can be significant sources of dietary fiber. Taro and giant swamp taro presented the highest values of total dietary fiber among the other crops, with values of 19.3% and 16.8% respectively, which are significantly different from each other. Cassava (4.23%) provided the lowest total dietary fiber. The values for purple yam (13.1%) and cocoyam (13.0%) are in good agreement with the data established by Trinidad *et al.* (2010). Insoluble dietary fibers were highest in taro (15.9%) and purple yam (11.0%), while soluble dietary fibers were highest in giant swamp taro (12.1%) and coco yam (8.52%). Except for cassava, consumption of 100 g of all the crops tested can contribute to >20% DV, which can be considered as excellent sources of dietary fiber.

Soluble fibers are known to be readily utilized by probiotics in the gut. Also, soluble fibers have been linked to improved glycemic control and lower insulin requirements due to increased insulin sensitivity or changes in insulin receptors, and cholesterol-lowering effects (Prasad and Bondy, 2019). As established by data, giant swamp taro and cocoyam have high soluble fiber contents. These may be considered as potential prebiotic which can be further characterized and classified into the specific types of soluble fiber. While insoluble fiber, on the other hand, increases the fecal bulk, induces hydration of stools, enhances bowel movement and may reduce fecal transit time, preventing the risk of large bowel movement ailments such as diverticulitis, constipation, and several cancers (Mudgil and Barak, 2013). Fiber is widely recognized as an essential component of the human diet with numerous health benefits, such as lowering the risk of cardiovascular disease, obesity, diabetes, and colon cancer (Mallillin *et al.,* 2008; Baah *et al.,* 2009; Millena *et al.,* 2021). Fiber is essential since it delays gastric emptying, which can further increase the time of gastric digestion, making the nutrients more accessible for absorption and can also provide satiety, or the feeling of fullness. It can absorb bile acids and prevent reabsorption in the liver, therefore, inhibiting the synthesis of cholesterol and lowering blood cholesterol (Mallillin *et al.,* 2008).

As presented in this study, different types of root and tuber crops may provide varying nutritional contributions. Differences in proximate composition can be attributed to crop type, soil condition where they are planted, geographical location, variety, cultivar, maturity, agricultural practices, and post-harvest processing techniques (Baah *et al.,* 2009). Characterization of different root and tuber crops is essential in selecting an appropriate crop to cultivate in addressing a specific dietary requirement, as well as in developing nutritious and functional foods.

3.3 Total mineral and trace metal composition

The elemental composition of different root and

https://doi.org/10.26656/fr.2017.8(2).548

tuber crops was determined using the Microwave Plasma Atomic Emission Spectrometer (MP-AES), an emerging instrumentation with low running cost. The equipment is a new generation of nitrogen plasma-based induced by microwave radiation, which can analyze multiple elements. The total elemental composition of different crops is presented in Table 3. It was observed that macro and micro minerals' content showed the crops' varying concentrations.

A significant difference (p<0.05) in Na content among the crops was noted. Giant swamp taro exhibited the highest abundance of Na among all the samples with a value of 1665 mg/kg, followed by sweet potato (711 mg/kg), taro (265 mg/kg), purple yam (130 mg/kg), and cassava (173 mg/kg). Cocoyam showed the lowest Na content with a value of 71.5 mg/kg. Na is important in the body for nerve impulses, muscle contraction, and relaxation, most importantly in maintaining osmotic balance between interstitial fluid and the cell body (Soetan *et al.,* 2010). However, excessive intake of Na in the diet can lead to several chronic diseases such as high blood pressure, heart disease, and stroke (WHO, 2012).

Among the macro minerals, an abundance of K was observed. Purple yam exhibited the highest source of K (13431 mg/kg) wherein a significant difference among the samples was observed. This is followed by taro (11662 mg/kg), sweet potato (11340 mg/kg), and cocoyam (11121 mg/kg). On the other hand, cassava (5961 mg/kg) and giant swamp taro (4961 mg/kg), provided the least amount. K is important to the body as it is considered an electrolyte needed by all the tissues to function. Its main role is to maintain the normal level of fluids in the cell together with Na. However, excessive intake may lead to chronic diseases and affect osmotic balance in the cell (Soetan *et al.,* 2010; Newberry *et al.,* 2018). Among the other subject crops, giant swamp taro has the highest Ca content (9747 mg/kg). This is followed by taro (1866 mg/kg), sweet potato (607 mg/kg), purple yam (527 mg/kg), cocoyam (447 mg/kg) and cassava (414 mg/kg) which are significantly different from each other. Ca is essential in the growth and development of bones and teeth, and it helps in managing blood coagulation. Low intestinal pH facilitates Ca absorption due to its solubility (Soetan *et al.,* 2010).

The Mg content observed among the crops ranged from 313 mg/kgto 896 mg/kg. Taro (896 mg/kg) exhibited the highest amount of Mg compared to the other crops assessed, which is in agreement with the study of Ukom *et al.* (2018). Other crops such as purple yam (799 mg/kg), cassava (780 mg/kg), cocoyam (683 mg/kg), and giant swamp taro (599 mg/kg) provided considerable amounts. Sweet potato showed (313 mg/kg), which was the lowest Mg content among the others. Significant differences were observed in the Mg content of the crops except for purple yam and cassava which provided the same levels. The determined Mg content of cocoyam agrees with the study of Mwenye *et al.* (2011), while the value of giant swamp taro is quite elevated compared to the study of Englberger *et al.* (2008). Mg serves as a cofactor that regulates diverse biochemical reactions in the body. This activates pyruvic acid carboxylase, pyruvic acid oxidase and contributes to the citric acid cycle (Murray *et al.,* 2000). Excessive intake of Mg from food materials does not pose a health risk since the excess amounts are eliminated in the kidney and discharged in urine, as with Ca (Goldhaber, 2002).

The Fe content of the crops ranged only from 5.30 to 16.6 mg/kg. Giant swamp taro (16.6 mg/kg) exhibited the highest significant amount of Fe among the crops, which is in good agreement with the study of Englberger *et al.* (2008). This is followed by sweet potato (13.6 mg/kg), taro (12.9 mg/kg) and purple yam (12.2 mg/kg) which are not significantly different from each other. The Fe content of sweet potato in this study is nearly two-folds higher than in Luis *et al.* (2013), while cocoyam is two-folds lower than in the study of Ukom *et al.* (2018) and Sefa-Dedeh *et al.* (2002). Furthermore, the Fe content of purple yam in this study is lower than the reported value of Shajeela *et al*. (2011). The Fe content

Table 3. Total mineral content of different root and tuber crops.

Root Crops	Na (mg/kg)	K (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	Fe (mg/kg)	Zn (mg/kg)	Mn (mg/kg)	Cu (mg/kg)
Sweet Potato	711±6^{b}	11340±431^{b}	607±13^{c}	313±7^{e}	13.6±0.7^{b}	10.9±0.9^{c}	4.5±0.1^{d}	5.1±0.0^{d}
Purple Yam	130±10^{e}	13431±164^{a}	527±22^{d}	799±4^{b}	12.2±0.7^{b}	16.2±1.2^{b}	2.5±0.0^{e}	10.6±0.1^{a}
Cassava	173±15^{d}	5961±133^{c}	414±16^{e}	780±5^{b}	5.3±1.0^{d}	7.6±0.4^{d}	11.3±0.3^{b}	2.9±0.1^{e}
Taro	265±3^{c}	11662±253^{b}	1866±13^{b}	896±11^{a}	12.9±0.2^{b}	15.0±0.6^{b}	8.4±0.3^{c}	7.8±0.2^{b}
Cocoyam	71±1^{f}	11121±68^{b}	447±9de	683±12^{c}	9.2±0.3^{c}	10.8±0.9^{c}	4.6±0.1^{d}	6.1±0.1^{c}
Giant Swamp Taro	1665±22^{a}	4961±121^{d}	9747±62^{a}	599±6^{d}	16.6±0.4^{a}	100±2^{a}	336±6^{a}	2.5±0.1^{f}
p	**	**	**	**	**	**	**	**

Values are presented as mean±SD, n = 3. Values with different superscripts within the same column are statistically significantly different by Tukey test.
** Significant at p<0.05.

of cocoyam (9.20 mg/kg) and cassava (5.30 mg/kg) exhibited the lowest abundance. Non-heme Fe from plant sources is usually less absorbable (1 to 20%) compared to heme-Fe which is absorbed in the body in different mechanisms (Frossard *et al.,* 2000). The majority of Fe in the body is used in the synthesis of hemoglobin in erythrocytes and transferrin in plasma. Also, Fe is necessary for growth, neurological development, cellular functioning, synthesis of some hormones, and immune defense. Acidic conditions in human digestion as well as vitamin C enhance Fe absorption (Soetan *et al.,* 2010). Fe deficiency anemia affects billions of people worldwide and is one of the prevailing problems in the Filipino population (PDRI, DOST-FNRI, 2015). Many of the poorest regions consume less animal tissue as a source of heme Fe and rely mostly on non-heme Fe plant sources (Frossard *et al*., 2000). Excessive consumption of Fe may, however, lead to some conditions such as hemochromatosis and liver damage (Kim and Wessling-Resnick, 2014).

In terms of Zn, giant swamp taro (100 mg/kg) exhibited the highest significant abundance, which is almost tenfold higher than the other subject crops. This was followed by purple yam (16.2 mg/kg) and taro (15.0 mg/kg), with no significant differences from each other, and sweet potato (10.9 mg/kg), and cocoyam (10.8 mg/kg) which are also not significantly different from each other. Cassava, on the other hand, exhibited the lowest Zn content (7.56 mg/kg). The Zn content of giant swamp taro in this study was higher compared to the study of Englberger (2003). Cocoyam exhibited a lower Zn content compared to the study of Sefa-Dedeh *et al.* (2002), while the Zn content of the purple yam was in good agreement with the study of Baah *et al.* (2009). Zn is important for immune function as it plays a role in cell division, cell growth, wound healing, and a unique role in growth and development.

For the Mn content of the studied crops, the giant swamp taro (336 mg/kg) exhibited the significantly highest amount compared to other crops. The rest of the crops showed only trace amounts of Mn in this order; cassava (11.3 mg/kg) > taro (8.40 mg/kg) > cocoyam (4.60 mg/kg) > sweet potato (4.50 mg/kg) > purple yam (2.50 mg/kg). Cocoyam and sweet potato Mn contents are not significantly different from each other. The Mn content of taro is in good agreement with the study of Agbor-Egbe (1990). Mn is a cofactor of decarboxylase and transferase enzymes and is also involved as a cofactor in the synthesis of proteoglycan in cartilage (Murray *et al.,* 2000). Excessive intake of Mn, however, can decrease the absorption of Fe, which can lead to Fe deficiency (Goldhaber, 2002).

Variability in the Cu content of the assessed root and tuber crops was observed. Trace amounts of Cu were found in the crops that ranged from 2.50 to 10.6 mg/kg. Significant differences in the Cu content were also observed. Purple yam exhibited the highest Cu content among the crops, with a value of 10.6 mg/kg. This was followed by taro (7.80 mg/kg), cocoyam (6.10 mg/kg), and sweet potato (5.10 mg/kg). Cassava and giant swamp taro provided the lowest Cu content, with values of 2.90 and 2.50 mg/kg respectively. The value obtained for Cu in giant swamp taro was in good agreement with the study of Englberger *et al.* (2003). Cu is an essential trace metal found in food that plays a role in growth and bone formation. This helps the incorporation of Fe in hemoglobin and aids the absorption of Fe in the gastro-intestinal tract (Soetan *et al.,* 2010).

There are many possible factors that can affect the mineral composition of the root and tuber crops. Essential mineral nutrient from plant sources is absorbed from the soil's inorganic ions. Variation in elemental content may be accompanied by the mineral content of the specific crop, its capacity to accumulate minerals, the soil condition, agricultural practices employed, crop variety, processing method applied, as well as various geographical and environmental factors (FAO, 1990; Moreda-Piñeiro *et al.,* 2016). Given the total mineral content of the assessed root and tuber crops, the concentration of each macro and micromineral may vary from one another. Some root crops, such as giant swamp taro, were found to have an abundance of minerals, while others were found to have a deficiency. The total mineral content determination used in normal analysis in the laboratory cannot provide a more reliable estimate of what the percentage of these minerals absorbed in the body is. The mineral bioavailability determination may provide a more reliable estimate of absorbable minerals as well as an assessment of the nutritional contribution of these root and tuber crops.

3.4 Mineral bioavailability

Mineral bioavailability is a crucial parameter in determining the nutritional contribution of foods since it provides a more reliable estimate of how much of those minerals can be absorbed in the human body. Assessing bioavailable minerals is necessary to provide a good estimate of available minerals necessary for the maintenance of several biochemical processes essential to life. Figure 2 shows the percent bioavailability versus total mineral content of various minerals from the six different crops.

The Mg bioavailability of taro (90.2%) exhibits the highest percentage that is significant among root crops, followed by purple yam and cassava with values of

https://doi.org/10.26656/fr.2017.8(2).548

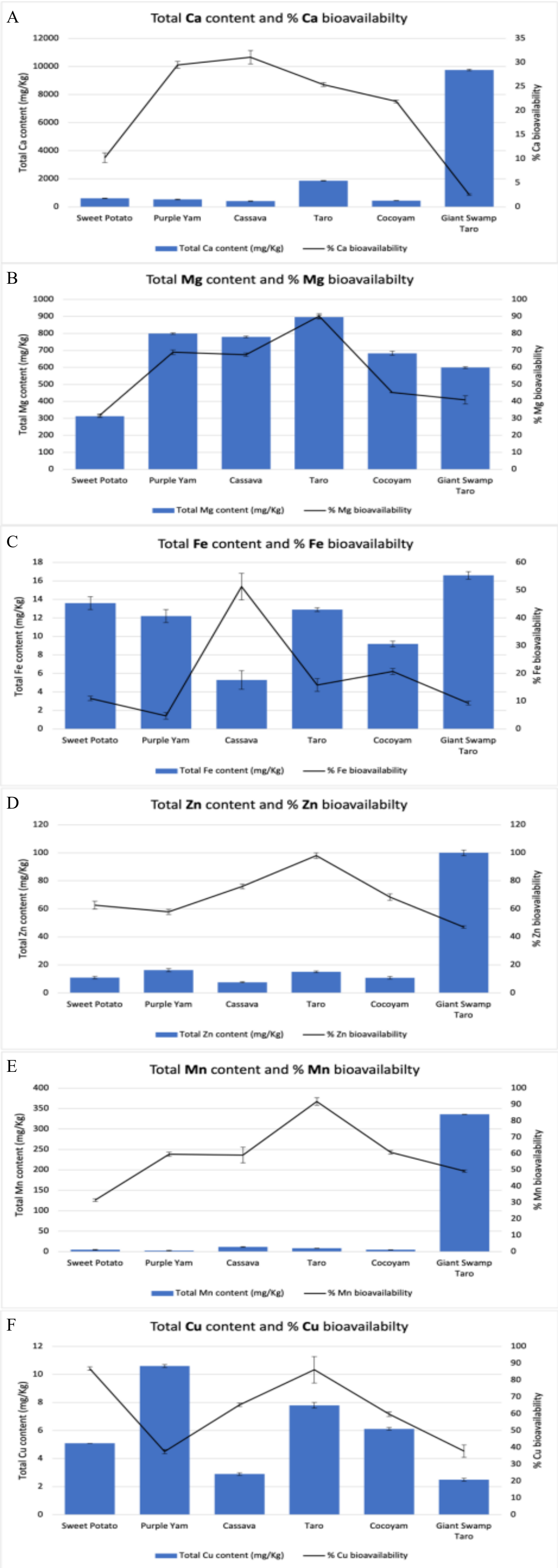

Figure 2. Total mineral content (mg/kg) and % mineral bioavailability of (a) calcium (b) magnesium (c) iron (d) zinc (e) manganese and (f) copper of different root and tuber crops.

68.9% and 67.5%, respectively, which are not significantly different (p<0.05). Sweet potato, on the other hand, showed the least absorbable Mg (31.9%). In terms of Ca, cassava had the highest bioavailability which was significantly the same as purple yam, with values of 31.1% and 29.5%, respectively. Giant swamp taro, despite the fact that it has the highest total Ca content among the crops, had the lowest Ca bioavailability providing only 2.54%. In terms of Cu bioavailability, taro and sweet potato were the leading crops, having values of 86.1% and 86.8%, respectively. The sample with the least Cu bioavailability were the giant swamp taro and purple yam with values of 37.8% and 37.5%. The purple yam, despite having the highest total Cu content, demonstrated the lowest Cu bioavailability. For Mn bioavailability, taro, with a bioavailability of 92.1%, was dominant compared to other crops. This was followed by cocoyam, purple yam, and cassava with significantly the same% bioavailability of 60, 59.6, and 59.1 respectively. Out of the six studied crops, sweet potato has the highest bioavailable Mn (91.8%). The Fe bioavailability varied significantly among crops, with decreasing availability: cassava (51.3%) > cocoyam (20.7%) > taro (15.8%) > sweet potato (11.0%) > giant swamp taro (9.30%) > purple yam (3.49%). Purple yam contains a high level of phytic acid, which may be attributed to its low bioavailability for Fe (Trinidad *et al.,* 2010). Tannic acid also inhibited Fe absorption (Delimont *et al.,* 2017). For the Zn bioavailability obtained among the crops studied, taro provided the superior value, which is almost 98%, followed by cassava, cocoyam, sweet potato, purple yam, and giant swamp taro, with Zn% bioavailability of 76.1, 68.4, 62.6, 57.8, and 47.0, respectively. Based on the data gathered, taro is the most superior, while giant swamp taro is the inferior crop as to the bioavailability for the three minerals namely, Ca, Cu, and Zn. It can be observed that all crops studied showed good bioavailability for Zn but low in Ca and Fe. Based on the present study, the absorption of minerals from studied root and tuber crops varies considerably.

From the review of literature conducted, only the study of Trinidad e*t al.* (2010) has the available related study with regard to the methods and samples used, save for a few differences. The former study only assessed the total bioavailability that simulates both the small intestine and large intestine for Fe, Zn, and Ca of selected root crops (*kamote, gabi, patatas, tugi, ube,* and *kamoteng kahoy*), four of which are similar to this study. In comparison with the present study, variabilities in bioavailability were distinguished in Fe, Zn, and Ca of the four similar root crops, except for the Fe and Zn of purple yam and Ca of cassava. There is also a notable difference in the Zn bioavailability of cassava between the studies. In general, both studies demonstrated low Ca and Fe bioavailability trends of root crops. However, the study of Trinidad *et al.* (2010) encompasses the total bioavailability, which accounts for both the intestine and colon. Overall, the present study obtained mostly larger percentages. Some of the possible reasons for these discrepancies are the absence of the oral phase digestion in the study of Trinidad *et al.* (2010) and the bioavailability up to the small intestine in the present study.

The low Ca and Fe bioavailability can be attributed to the amount of fiber contained in the samples. In Fe and Ca, complexes are formed due to the fibrous structure and viscosity of the fiber in the small intestine where minerals can be entrapped (Trinidad *et al.,* 1996). Plant sources' antinutrient content, such as phytic and tannic acids, influenced mineral bioavailability negatively (Hendek Ertop and Bektaş, 2018; Millena and Sagum, 2018). Antinutrients and fiber act as chelating ligands that bind with the minerals due to the electrostatic attraction, hence reducing the bioavailability. Between the two antinutrients, phytate is more concerning since it inhibits the absorption of Ca^{2+}, Zn^{2+}, $Fe^{2+,\ 3+}$, Mg^{2+}, Mn^{2+}, and Cu^{2+} through the formation of an insoluble complex in the alkali environment of the small intestine (Brune *et al.,* 1992; Kumar *et al.,* 2010). Phytate content can be lessened through several food processing techniques like cooking, sprouting, soaking, malting, hydrothermal processing, and fermentation (Kumar *et al.,* 2010). In the small intestine, there was competition in absorption between different minerals which can be another contributing factor in the reduction of mineral bioavailability (Solomons, 1983). Excessive intake of some minerals may affect the body's homeostatic balance and may cause several toxic side effects (Mergedus *et al.,* 2015). Aside from essential minerals, food may also contribute to exposure to some toxic elements and may pose a threat above the tolerable level that affects several tissues and organs, leading to a variety of diseases. It is established that root and tuber crops are highly nutritious, and this study provided scientific evidence that sweet potato, purple yam, cassava, cocoyam, taro, and giant swamp taro are rich sources of bioavailable minerals Zn, Cu, Mn, and Mg, but low sources of Ca and Fe. Mineral bioavailability provides valuable data on the reliable estimate of nutritional profiles of different crops.

3.5 Nutritional contribution

Mineral contributions from consuming 100 g of samples are shown in Table 4. The amount of absorbable minerals in the small intestine was determined using the data on percent bioavailability and was expressed as mg/100 g sample. The table includes reference values for tolerable upper intake for adult males and females in reference to Recommended Nutrient Intake (RNI) for adults aged 19-29 years (PDRI, DOST-FNRI, 2015) and Recommended Dietary Allowance (RDA) or Adequate Intake (AI). Determining the amount of bioavailable minerals provides more reliable data on how much minerals can be absorbed in the small intestine.

All the crops in this study, except giant swamp taro, were found to provide high amounts of bioavailable Cu but not sufficient to address the daily Cu requirement. Among the crops studied, only the giant swamp taro and taro showed notable mineral nutritional contributions. Consumption of 100 g of giant swamp taro can provide the daily requirement of Mn (>100% RDI) for both sexes, and can provide almost 50% of the daily Zn requirement. Taro, among other crops, is an excellent source of bioavailable Mg (23% RDI). Despite being the most famously consumed root crop in the Philippines,

Table 4. Amount of minerals in mg/day when root and tuber crops are consumed based on *in vitro* mineral bioavailability from the small intestine.

Root Crops	Ca	Mg	Fe	Zn	Mn	Cu
Sweet Potato	6.20	10.00	0.15	0.51	0.14	0.44
Purple Yam	15.60	55.10	0.04	0.94	0.15	0.40
Cassava	12.90	52.70	0.27	0.58	0.67	0.19
Taro	47.40	80.80	0.20	1.54	0.77	0.67
Cocoyam	9.80	30.90	0.19	0.69	0.28	0.36
Giant Swamp Taro	24.80	24.50	0.15	4.70	16.60	0.09
Recommended Dietary allowance and Adequate Intake	1000* mg/ day	420 mg/day (male) 320 mg/day (female)	8 mg/day (male) 18 mg/day (female)	11 mg/day (male) 8 mg /day (female)	2.3* mg/day (male) 1.8* mg/day (female)	0.9 mg/day
Tolerable upper intake (mg/day)	3000	350	45	45	11	10

Values were based on the consumption of ~100g root and tuber crops.
Recommended Nutrient Intake (RNI) for adult age 19-29 years. 2015, PDRI, DOST-Food and Nutrition Research Institute.
*Based on Recommended Dietary Allowance (RDA) and Adequate Intake (AI).

https://doi.org/10.26656/fr.2017.8(2).548

sweet potato had the lowest mineral contribution, particularly for bioavailable Mg, Ca, Mn, and Zn. Assessing minerals specifically, the bioavailable contribution is essential since this serves as cofactors of energy production, various biochemical pathways, and physiological functions in the human body. These minerals are also responsible for maintaining body homeostasis. Excessive intake, however, may lead to toxic side effects and homeostatic imbalance in the body. Most of the root crops may contribute to the recommended mineral intake, particularly in Cu, Mn, Mg, and Zn, but are low in Fe. Consumption of root and tuber crops along with other foods is necessary to address the daily nutritional prerequisites for human nutrition.

4. Conclusion

This study established the proximate composition and mineral profile of the assessed crops as well as their mineral nutritional contribution based on the recommended nutrient intake of Filipinos. All of the sample crops included in this study were unique and known to provide diverse nutrition to the human body. This study showed that the assessed crops have mostly varying proximate compositions. Some of the crops such as purple yam and taro (10-15% DV) are source of protein that can contribute to daily nutrient protein requirement. This study confirms that the crops can provide adequate amounts of the necessary carbohydrates and fiber nutrition. In terms of mineral content, all the studied crops possessed a high total K content in comparison with the other macrominerals analyzed. In terms of mineral bioavailability, all have generally high Mg, Cu, Mn, and Zn, but are low in Ca and Fe. Except for Ca and Fe, the majority of the crops studied were found to be good contributors to the recommended mineral intake when consumed in 100 g portions. Still, it is necessary to consume the commonly and underutilized known root and tuber crops along with other food varieties to address the daily nutritional requirements and achieve the recommended dietary allowance and adequate mineral intake. Further, consumption of available crops in the country through food diversification can alleviate some protein-energy and micronutrient deficiency. More research on the antinutrient contents of the crops, the effect of processing technology on the mineral bioavailability, as well as characterization of different carbohydrates, are recommended to elucidate the potential prebiotic characteristics of the studied roots and tuber crops. Lastly, a study on the determination of glycemic index of the root and tuber crops can be done to further explore their benefits.

Conflict of interest

The authors declare that they have no known conflicting personal relationships and financial interests that could influence the work presented in this paper.

Acknowledgements

The authors would like to acknowledge the technical and support staff of DOST V -RSTL, Ms. Aubrey Rosebud R. Balonzo, and Mr. Jem R. Rentoy. Gratitude is extended to Mr. Bernardo A. Altavano, who provided support and profound insights into the study. To Bicol University College of Science and Department of Science and Technology Regional Office No. V, thank you for all your help with the accomplishment of this paper.

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