Proximate Composition, Mineral Composition and Phytic Acid in Three Common Malawian White Rice Grains

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Abstract

Rice is the second most important food crop in Malawi, after maize. Some studies have reported on losses of macro- and micronutrients in rice grains subjected to different polishing rates. In this study, the proximate composition, mineral contents and phytic acid profile of three white (i.e. polished) rice varieties in Malawi were investigated. Proximate composition was determined by adopting AOAC method. Mineral contents were determined using flame atomic absorption spectrophotometer and phytic acid determined using standard procedures. The results show that proximate composition for the three varieties were variable in the with ranges being 9.35-10.42%, 0.69-0.90%, 5.43-7.03%, 0.72-1.71%, 1.42-3.15%, 81.41-82.45% and 39.56-42.10%, for moisture, ash, crude protein, crude fat, crude fibre, carbohydrate and energy content, respectively. Significant amounts of minerals were present in all three rice varieties in the ranges: 5.19-7.81 mg/100g for calcium; 30.21-40.32 mg/100g for magnesium; 216-268 mg/100g for potassium; 0.33-0.58 mg/100g for manganese; 0.77-1.40 mg/100g for zinc; 0.26-0.47 mg/100g for copper; and .83-2.49 mg/100g for iron. Phytic acid ranged between 93.10 and 204.92 mg/100g in all the three rice varieties, whereas heavy metals such as lead, chromium and cadmium were not detected in all varieties. The results suggest that the white rice varieties could serve as an alternative source of food for humans and animals after quality processing.

Keywords: *Malawian White Rice Grains, Proximate Composition, Minerals, Nutrient Content, Phytic Acid.*

1 INTRODUCTION

Food is vital in our daily life and survival. One important source of food is rice (*Oryza sativa L*.) which is a monocot plant of the genus Oryza and family Poaceae which has ben cultivated for more than 10, 000 years (Lema, 2018). Awareness on nutritive value and health benefits of rice is of vital importance as rice is one of the most important cereals in human nutrition and is consumed by over 50% of the global population (Oko & Ugwu, 2010). Rice is not only a very important source of energy but also contains micronutrients such as vitamins, minerals and secondary metabolites (WHO, 2004). The dietary minerals in rice include Calcium (Ca), Iron(Fe), Magnesium (Mg), Phosphorous (P), Potasium (K), Sodium (Na), Zinc (Zn), Copper (Cu), Manganes (Mn) and Selenium (Se) (Bagirathy, 2014). In humans, dietary minerals are required to maintain human health, and their deficiencies can lead to undesirable pathological conditions (Fraga, 2005). For example, rice is essential for strong bones and teeth, healthy gums, and bone growth and mineral density in children. Calcium also helps regulate the heart rate and nerve impulses, prevent atherosclerosis, lower cholesterol, develop muscles, prevent muscle cramp and prevent blood clotting (Paul et al., 2018).

Most of iron in the body is found in hemoglobin and myoglobin, both involved in oxygen transport. Iron deficiency is the sixth cause of illness and diseases in low income countries (Sant-Rayn et al., 2013). Magnesium is the fourth most common cation in the body and is required for an extensive range of metabolic, regulatory and structural activity. Magnesium deficiency is associated with increased risk of many age-related diseases such as cardiovascular disease, hypertension, diabetes, osteoporosis and some cancers (DiNicolantonio et al., 2018). Potassium is a cofactor in many enzymes involved in energy transfer, protein synthesis, and the storage of carbohydrates for use as fuels in muscles. Manganese as a constituent of numerous enzymes and a cofactor, plays an important role in a number of physiologic processes in mammals. It is an essential trace nutrient that is potentially toxic at high levels of exposure (Soldin & Aschner 2007). Other health benefits of rice includes stabilizing blood sugar levels, a source of vitamin B_1 to human body and managing fast and instant energy (Verma & Shukla, 2011).

According to some studies, the variation in the mineral composition of rice depends on the chemical nature of the soil (quality of soil), fertilizers and herbicides used in rice cultivation, crop management, irrigation methods, processing methods and other factors (Birla et al., 2017; Kuppusamy et al., 2017; Fardin et al., 2018). Rice is a staple food crop for millions of households in Sub-Saharan Africa (Terdoo & Giuseppe, 2016). The distribution of minerals in rice kernels is not uniform with about 50% of the mineral content located in the bran layer and 10% in the embryo; and both are removed when producing white rice (Liang et al., 2008). Polishing is an important operation leading to the production of white rice where the shelf-life is extended and easy spoilage prevented. During the whitening process, the outer bran is removed leaving the core component of mostly carbohydrate leading to a significant change in nutrient composition, favour, texture and appearance as compared to brown rice. It has been reported that loss of minerals, particularly of iron and zinc during rice polishing is high (Liang et al., 2007). Zubair et al. (2015) reported that the complete milling and polishing of brown rice into white rice destroys 80% of the vitamin $B_{1,}$ 67% of the vitamin B_3, 90% of the vitamin B_6, 50% of the manganese and phosphorus, 60% of the iron and all of the essential fatty acids and dietary fibre. Some studies have reported on the effects of polishing on losses of macro- and micronutrients in rice grains subjected to different polishing rates (Aadil et al., 2011; Bao-Min et al., 2020).

Furthermore, rice contains phytic acid (a unique natural substance found in plant seeds) and an important anti-nutritional factor impeding availability of divalent minerals. Phytic acid or phytate is a chelating agent which is involved in binding mineral ions, such as Fe^{2+}, Zn^{2+}, and Ca^{2+}, and making them unavailable for dietary absorption which may promote mineral deficiencies (Masum et al., 2011; Liang et al., 2007). Thus, owing to the formation of indigestible chelates, the bioavailability of nutritionally relevant minerals can be limited. Contents of phytic acid in milled white rice were found to depend on varieties and locations (Jiafen et al., 2008). Although plant foods supply considerable amounts of minerals, intakes of phytic acid are also very high. Thus, intake of high levels of phytic acid might be one important factor causing deficiency of essential nutrients. Generally, strategies at the food production level include plant breeding, the use of fertilizers, and genetic engineering to enhance the content and bioavailability of micronutrients in plant-based staples (Gibson et al., 2000).

In Malawi, rice is the second most important crop in terms of nutrition and food security after maize. Many varieties of rice are grown in different agro-ecological zones of the country. At a national level, on average, there was 13 g $capita^{-1}$ d^{-1} of rice available for consumption in 2011 of which >99% was produced domestically compared to 360, 8 and 5 g $capita^{-1}$ d^{-1} for maize, sorghum and millet, respectively (FAO, 2015). Micronutrient deficiencies are widespread in Malawi especially of calcium, iron, and zinc and are caused by insufficient intake and poor bioavailability (Joy et al., 2017). In many micronutrient-deficient regions, rice is the dominant staple food making more than 50% of the diet. Rice is usually consumed in polished form (white rice) in Malawi and the main white rice varieties grown are Kilombero, Faya 14M69 and Pusa nuncile. Kilombero rice is superior and highly versatile rice that is mostly grown in the northern part of Malawi, particularly in Karonga District. A huge quantity of Faya rice is grown in Nsanje District in the southern part of Malawi. The aim of this research project was to compare the proximate composition, mineral contents and phytic acid concentrations in three Malawian white rice varieties (Kilombero, Faya 14M69 and Pusa 33 nuncile). Proper quantification of mineral nutrients in common Malawian white rice varieties may also help in food fortification strategies as there is evidence of insufficient intake and poor bioavailability of minerals in Malawi, especially in rural areas (Felix et al., 2019; Watts et al., 2015). Potentially harmful substances such as heavy metals were also determined. The heavy metals may arise from soil the rice is grown and the water that is used for irrigation.

2 MATERIALS AND METHODS

2.1 Sample collection and preparation

Samples of three Malawian local white rice varieties (Kilombero, Faya 14M69 and Pusa 33 nuncile) of 2 kgs per variety were collected from Lifuwu Research Station, Salima District. Lifuwu Research Station supplies rice seeds to farmers in Malawi and the white rice varieties found at Lifuwu Research Station is the same throughout Malawi. The rice samples were checked in the laboratory visually for dirt, stones, and other extraneous objects which were removed manually. The rice was then milled with a moulinex blender and sieved through a 250 nm sieve to obtain white rice flour. Flour samples of each rice variety were placed in zip lock polythene bags and kept at room temperature for analyses.

2.2 Proximate Analyses

Proximate analyses in rice varieties were determined following official methods of Association of Official Analytical Chemists (Aboagye, 2019) for moisture content, dry matter content, ash content, crude fiber, crude protein, crude fat, carbohydrate content, energy content, elemental analysis and phytic acid analysis.

2.2.1 Moisture Content

The moisture content was determined by oven drying method. Exactly 3.00 g of each rice variety were dried in an oven set at 105°C overnight. Samples were then taken out from the oven and put in a desiccator with partially covered lid for 30 minutes to allow for cooling to room temperature and then weighed. The moisture content was calculated using the formula:

(%) moisture = $(W1 - W2/W1)$x 100

Where: W1 = weight (g) of sample before drying; and W2 = weight (g) of sample after drying

2.2.2 Dry Matter

Percentage dry matter was determined after moisture content determination using the formula:

(%) dry matter = $\frac{W2}{W1} \times 100\%$

Where: W1 = weight (g) of sample before drying; and W2 = weight of sample after drying

2.2.3 Ash Content

Exactly 10 g of white rice flour was placed in a pre–weighed dry crucible. The crucible and the sample were placed in the muffle furnace set at 550°C incineration of the sample was for 12 hrs to ensure that impurities on the surface of crucibles were burned off. The crucible and ash were cooled in a desiccator to room temperature and weighed. Percentage ash was calculated using the following equation:

(%) Ash = $\frac{Weight\ of\ ash}{Weight\ of\ sample} \times 100\%$

2.2.4 Crude Fibre

Exactly 2 g of the white rice flour were transferred into a 500 mL conical flask followed by 200 mL of boiled 1.25% H_2SO_4 solution. The mixture was boiled for 30 min under reflux. The digest was filtered through a Whatman filter paper number 54. The residue was washed with boiling water until the washing was free from acid. The acid free residue was quantitatively transferred into the refluxing flask followed by exactly 200 mL of 1.25% sodium hydroxide solution and refluxed for 30min. The digest was filtered, washed with boiling water, then alcohol and lastly with diethyl ether before being dried at 100°C for 1 h. The dried residue was transferred into a porcelain crucible and incinerated for 1 h at 400-500°C using a muffle furnace. The crucibles were removed from the furnace and let to cool in the desiccator and immediately transferred and weighed. Percentage fibre was calculated using the following equation:

(%) Crude fibre = $\frac{weight\ of\ residues\ after\ oven\ drying}{Weight\ of\ sample\ used} \times 100\%$

2.2.5 Crude Protein

Exactly 1.00 g of pre–dried samples were weighed and quantitatively transferred into digestion flasks followed by addition of mixed catalyst (1.00 g of $CuSO_4$ and 5.00 g of K_2SO_4 and 0.50 g of selenium powder and 25 mL of concentrated H_2SO_4). The contents of the flask were digested by heating in a fume chamber at 420 °C until the colour of the solution changed from black to a clear green blue. The contents of the flask were cooled to room temperature and diluted to exactly 100 mL with distilled water. Exactly 10 mL of the aliquot of the digested solution was quantitatively transferred into a distilling flask and mixed with 15 mL of 40% NaOH. The mixture was distilled while collecting distillate into a receiving flask that contained 50 mL of 4% boric acid mixed indicator solution. After collecting about 60-80 mL of the distillate the mixture was titrated against 0.1N Hydrochloric acid (HCl) using methyl red indicator until colour changed from blue to green orange marking the endpoint. The percentage of protein nitrogen was calculated using the following formula:

$$(\%)\ \text{Nitrogen} = \frac{(Titre - Blank)mL \times 0.014077}{Weight\ of\ samples\ (g)} \times 100\%$$

The percentage protein was calculated from the percentage nitrogen using the factor 6.25 for the plant material as follows:

% Protein = % Nitrogen x 6.25

2.2.6 Crude Fat

A round bottomed flask was dried for 30 min. and then it was weighed on the balance. After that 5 g of rice sample was weighed on a paper filter and it was wrapped. The sample was taken into the extraction thimble and transferred into Soxhlet. Thereafter the round bottomed flask was filled with 250 mL of petroleum ether and then placed on the heating mantle. The Soxhlet apparatus was connected. After that the heating mantle was switched on. The sample was heated for 1 hr. The solvent (petroleum ether) was evaporated using the vacuum condenser. Thereafter the bottle was incubated at 80-90 °C until petroleum ether completely evaporated and the bottle was completely dry. After drying, the bottle was transferred to the desiccator to cool. The bottle and its dried content were weighed on the balance.

Fat content was determined using the formula: $\text{Fat}\ \% = \frac{Weight\ of\ fat}{Weight\ of\ sample} \times 100\ \%$

2.2.7 Carbohydrate Content

The carbohydrate content was estimated by the difference method. It was calculated by subtracting the sum of percentage of moisture, fat, protein, fibre and ash contents from 100% as follows: Carbohydrate content = 100%–[% crude protein + % fat content + % moisture content + % fibre + % ash].

2.2.8 Energy Content

The energy content of rice samples was determined using the bomb calorimeter. The bomb calorimeter used for this work was a Parr 6200 oxygen bomb calorimeter with Parr 6510 water handling system manufactured by Parr Instrument Co., Moline, Ill. USA (Shizas & Bagley, 2004). Essentially, the sample to be analyzed was dried, weighed, and pelletized and combusted in a pressurized oxygen atmosphere. The typical mass of a pellet was approximately 0.600 g weighed on analytical balance to ensure that the temperature rise in the water jacket did not exceed the range of the thermometer and to provide a safe level of combustion. The volume of sample required to be dried for combustion depended upon the total solids content of the sample. After combustion, the temperature rise in the 2 L water jacket surrounding the stainless steel bomb was measured and used to calculate the energy content of the sample. Benzoic acid was used as the standard to determine the heat capacity of the bomb.

2.3 Elemental Analysis

Levels of essential elements: Fe, Cu, Zn, Na, Ca, Mg, K, Mn, and toxic Cr, Cd and Pb were determined by using an Agilent 240 FS flame atomic absorption spectrophotometer (Agilent Technologies, USA), after calibrating the equipment with respective standard solutions according to official method prescribed in AOAC (Vega-rojas et al. 2016). In a typical experiment, 1.0 g of white rice sample was weighed and placed in a 100 mL conical flask. Thereafter, 5 mL of concentrated nitric acid (HNO_3) was added into the flask and it was left was for 8 h. After pre-digestion, 10 mL of di-acid mixture (6.1 mL of HNO_3 and 3.1 mL of $HClO_4$) was added to the flask. The contents in the flask were heated at 180-200 °C on a hot plate until dense white fumes evolved and transparent white contents were left. The solution was cooled and then 25 mL of double distilled water was added to the flask and the solution filtered into a 100 mL volumetric flask and the volume made to the mark using distilled water. The digestion was done simultaneously in three replicates including one blank digestion for each rice sample and elemental analysis carried out by flame atomic absorption spectrophotometer. All other chemicals used for analysis were of analytical grade and used without further purification.

2.4 Phytic Acid Analysis

A method by (Wheeler and Ferrel, 1970) was used where finely grounded powder of rice sample was weighed (2.0000g) on analytical balance and put into a 125 mL Erlenmeyer flask. 50 mL of Trichloroacetic acid (TCA) (3%) was added to extract the analyte for 30 min. on a mechanical shaker. The suspension was centrifuged and 10 mL aliquot of the supernatant was transferred into a 40 mL conical centrifuge tube. Exactly 4 mL ferric chloride (2 mg ferric iron per mL made in 3% TCA) was added to the solution in 40 mL conical centrifuge tube. The tube was heated in a boiling water bath for 45 mins until the supernatant was clear. After boiling the contents were centrifuged again and supernatant decanted. The remaining residues were washed with 3% TCA twice and residues were dispersed with 3 mL of water. Then 3 mL of sodium hydroxide (1.5 N) was added and mixed. The volume of the contents was brought to 30 mL with water and boiled in a water bath for 30 min. While still hot the mixture was filtered using a Whatman filter paper and washed with 70 mL hot water and the filtrate was discarded. All the precipitates on the filter paper were dissolved with 40 mL hot nitric acid (3.2 N) into a 100 mL volumetric flask. The residues were washed with several portions of water, collecting all washings in the same flask. The contents were cooled and volume brought to the mark with distilled water. Exactly 5 mL of the aliquot was transferred into another 100 ml volumetric flask and 70 ml of water was added followed by 20 mL of Potassium thiocyanate (1.5 N KSCN) and made to the mark.

Standards were prepared in small denominations of 0, 0.1, 0.2, 0.3, 0.4 and 0.5 mg/L from Ferric nitrate (1.5 N) and were treated in a similar manner as samples from 5 mL of aliquot stage. Standards and all samples were run on Analytik Jena Spercord Plus UV-VIS Spectrophotometer at 480 nm wave length. Calibration curve was developed and phytate phosphorous was calculated from the iron results assuming a 4:6 iron: phosphorous molecular ratio.

2.5 Data Analysis

All determinations were carried out in triplicate for each sample and the data were expressed as mean ± standard deviation (SD). All statistical analyses were performed using SPSS software (version 20.0) for the analyses of variance (ANOVA). Multiple comparisons by Duncan’s Multiple Range Test (DMRT) were used for varietal differences at $P < 0.05$ level.

3 RESULTS AND DISCUSSIONS

3.1 Proximate Composition

The findings of proximate composition of three different white rice varieties investigated are presented in Table 1. Significant differences were recorded in the proximal composition between different varieties of rice evaluated. Moisture content, which is a very important parameter in determining the shelf-life, was recorded to vary between 9.35-10.42%, with the highest value observed in Kilombero and the lowest in Pusa nuncile varieties below the acceptable range of 12-14% moisture content which is suitable for rice storage. The differences in moisture content among the rice varieties might be due to handling of samples in the laboratory and some of moisture content in the zip-lock bags during packaging.

The ash content is generally recognized as a measure of quality for the assessment of the functional properties of foods (Hofman et al., 2002). The values for percentage ash content ranged between 0.69 to 0.90% (Table 1) with a high content in Kilombero (0.90%) and low in Faya 14M69 (0.69%) and Pusa nuncile (0.69%). The amount of ash present in a food sample plays an important role while determining the levels of essential minerals and may affect the sensory quality of the rice especially colour and taste (Verma & Srivastav, 2017). The differences in ash content could be attributed to differences in mineral content of the soils and the water used for irrigation (Verma & Srivastav, 2017). The values for ash content recorded in the study for the three rice varieties are in accordance with those reported by (Juliano & Bechtel, 1985; Sotelo et al., 1990).

Proteins are building blocks of all muscles of our body. They are important constituents to tissues and cells of the body, and essential macronutrients for building up the human health (Subramanian et al, 2013). Protein content of rice influences the nutritional quality of rice and comprises up to 8% of the grain with outstanding unique composition of amino acids (Verma and Srivastav, 2017). In this study, crude protein content in different varieties ranged between 5.43% to 7.03 (Table 1), with Faya 14M69 variety having the highest protein value, followed by Pusa nuncile and Kilombero varieties. The difference in protein content in the three varieties could be attributed to environmental conditions and genetic variations (Tasie & Gebreyes, 2020). The protein contents in this study are within the range reported by Rosniyana et al. (2011), where they obtained protein content in rice within the range of 8.85 to 9.91% for white rice and brown rice varieties. Srisawas & Jindal (2007) reported protein content in 14 rice varieties ranging from 6.38 to 8.99%; this finding is highly close to the current study. Malawians can benefit from this extra source of protein to improve health and supplement the costly protein sources, especially in rural and low-income communities.

It has been reported in literature that fat content influences the taste of cooked rice because rice with high fat content tends to be tastier and has less starch (Verma, and Srivastav, 2017). In this study, crude fat content ranged between 0.72% up to 1.71%, with a low-fat content recorded in the Faya 14M69 varieties. These results are in agreement with earlier findings by (Oko & Ugwu, 2010), where they obtained fat content in the range of 0.5–3.5% from five rice varieties. Oko & Onyekwere (2010) also found a fat content in the range of 1.5–3.5%, in five lowland rice varieties in Ebonyi state, Nigeria. The differences in fat content in the three varieties could be attributed to the differences in the degree of milling and since most of the fat in rice is concentrated in the aleurone layer of the kernel (Kalpanadevi et al., 2018).

Fiber is an important part of carbohydrates and it's a collective name given to those components of food that cannot be readily digested. The major types of fiber in rice are cellulose, hemicellulose, lignin, pectin and gums (some hemicelluloses and storage polysaccharides). The crude fibre content affects the rice digestibility whereby high content of crude fibre in rice lowers its digestibility (Verma & Srivastav, 2017). Fibre helps to lower serum cholesterol levels in humans (Edeogu et al., 2007). It has been reported that there is a relationship between the absence of fibre in diet and the incidence of a wide range of diseases (O'Keefe, 2019). In this study, the crude fibre content of the different varieties ranged between 1.42% and 3.15%. Kilombero variety showed the highest fibre content while the Pusa nuncile variety recorded the lowest value (Table 1). The findings in the current study are somehow more compared to 1.0–2.0% value obtained for five new lowland rice varieties as established by Oko & Onyekwere (2010).

Carbohydrates are a source of energy and are essential for growth and nourishment of plants and animals. Rice carbohydrates are mainly starch which is made up of amylose and amylopectin. In this study, the carbohydrate content was high in all varieties and ranged between 81.41% and 82.45% which was within the desired range (> 80%) and hence all the varieties can be considered to be a good source of carbohydrate. These findings are in agreement with results reported by Rosniyana et al. (2011). Their findings were in the range of 76.45 to 81.23%. In addition, Oko & Onyekwere (2010) reported the results obtained for carbohydrate in the five rice varieties ranged from 51.53 to 85.57.

Food energy is a value that measures the available amount of energy obtained from food via cellular respiration (Lunn & Buttriss, 2007). Food that is ingested contains energy and the maximum amount being reflected in the heat that is measured after complete combustion to water and carbon dioxide (CO_2) in a bomb calorimeter. Food energy values were appreciably different among all the three white rice varieties. Kilombero grain provided the highest energy among all the samples analyzed (42.10 kJ per 100g); followed by Faya 14M69 (40.98 kJ per 100g), whereas the lowest value was recorded in Pusa nuncile (39. 56 kJ per 100g). The variation in results may be due to the differences in varieties used, soil type and environmental conditions. Similar results have been obtained by other studies (Lyu et al., 2018; Wu et al., 2007).

Table 1: *Variation in proximate composition of three white rice varieties in Malawi*

Varieties	**Moisture (%)**	**Ash (%)**	**Crude Protein (%)**	**Crude Fat (%)**	**Crude Fiber (%)**	**Carbohydrate *(%)**	**Energy (KJ/g)**
Kilombero	10.42 ± 0.10	0.90 ± 0.00024	5.43	0.80 ± 0002	3.15 ± 0.03	82.45 ± 0.10	42.10 ± 1.70
Faya 14M69	10.15 ± 0.02	0.69 ± 0.04	7.03± 0.56	0.72 ± [illegible]	2.77 ± 0.0034	81.41 ± 0.58	40.98 ± 2.19
Pusa nuncile	9.35 ± 0.18	0.69 ± 0.02	6.07 ± 0.56	1.71 ± 0.01	1.42 ± 0.01	82.19 ± 0.59	39.56 ± 1.75
P <0.05	0.0185	<0.0001	0.0005	<0.0001	<0.0001	0.0249	0.0805

*Calculated by difference; Each value is an average of three observations; There were some significant differences among rice varieties at P< 0.05.

3.2 Mineral Composition

Minerals are essential nutrients and play a vital role in the effective functioning of the body activity. White rice grain is a good source of minerals which are present in varied amounts. The mineral composition of white rice grain depends considerably on the availability of soil nutrients during crop growth and generally present in higher levels in the grain layer of rice kernel (Juliano, 2016). It should be noted that the degree of polishing has a significant effect on the quality and nutritional aspects of white rice grain, thus affecting the essential minerals. In this study, the major minerals in the samples are presented in (Table 2). In general, the mean concentrations of macro-minerals follow the sequence K>Mg>Ca>Na for all samples and micro-minerals follow the sequence Mn>Zn> Fe>Cu for all samples. Potassium was found to be very dominant in all three rice samples than other mineral elements. Potassium content was in the range of 216.02-268.78 mg/100g. Potassium content in Kilombero differed significantly from that of Pusa nuncile and Faya 14M69 but there was no significant difference between Kilombero and Faya 14M69. Potassium content in all three varieties is within the range of values as reported by (Nadia et al., 2009).

Magnesium was the second most abundant element found in the three rice varieties. Statistical test using one-way ANOVA at 0.05 significant levels showed that there was a significant difference in magnesium content among the three rice varieties. Magnesium concentration in rice samples was in the range between 30.21-40.32 mg/100g (Table 2). Magnesium content was dominant in Faya and Kilombero with concentrations of 40.32 and 40.31 mg/100g respectively while in Pusa the concentration was 30.21 mg/100g. The values were within ranges earlier reported by Oko & Ugwu (2010). Calcium content was in the range of 5.19-7.81 mg/100g. This range is lower than the range obtained by Verma & Shukla (2011), who reported a calcium content of 24 mg/100g and 60 mg/100g in raw and parboiled white rice, respectively. Bagirathy (2014) reported calcium content in eight white rice varieties in the range of 4.4-9.5 μg/g. Furthermore, Verma & Shukla (2011), showed a higher calcium value of 24 mg/100g in white rice than this study. Sodium was below detection limit in all three samples.

However, the study showed that the three white rice varieties under investigation are low in sodium as compared to the Recommended Daily Allowance of 70 mg/100 g. The concentration of manganese in Kilombero, Faya 14M69 and Pusa 33 nuncile was in the range between 0.33-0.58 mg/100g. There was a significant difference in manganese content among the three rice varieties particularly, manganese content in Pusa 33 nuncile differed significantly from that of Kilombero and Faya 14M69 but there was no significant difference in manganese content between Kilombero and Faya 14M69. Manganese content in rice was dominant in Faya 14M69 and Kilombero with concentrations of 0.58 mg/100g and 0.53 mg/100g, respectively (Table 2). Similar results were reported by Mbatchou & Dawda (2012). The mean concentration of zinc in samples was found in the range of 0.77-1.40 mg/100g. The values for zinc were low than those reported by Joy et al. (2016), where researchers presented a mean value of 18.8 and 14.7 mg kg^{-1} for brown rice and white rice varieties.

Copper in the rice varieties was found at low quantities in the range of 0.26-0.47 mg/100g. Copper is essential to human life but it is needed in small quantities; as such, the copper found in the three rice varieties is a big contribution to the daily intake of copper. Copper content in Faya 14M69 differed significantly from Kilombero and Pusa 33 nuncile but there was no significant difference in copper content between Kilombero and Pusa rice. Iron concentration ranged between 1.83-2.49 mg/100g. Analysis of variance at 0.05 significance level showed that there was no significant difference in iron content in Kilombero, Faya 14M69 and Pusa 33 nuncile. It should however be mentioned that some previous studies have shown a relatively large proportion of Fe, Mg, K and Mn associated with the outer grain layers and these elements are rapidly lost during polishing (Lamberts et al., 2007). Many studies have shown that variation in mineral contents depend on availability of soil nutrients, geographical factor, agriculture practices, processing conditions and varietal differences (Welch ,2002).

For the other trace elements such as cadmium, chromium and lead, their concentrations in all the three samples were below the detection limit. Heavy metal toxicity to humans has proven to be a major threat with severe health risks associated with it (Jan et al., 2015); hence, their absence in the white rice varieties is desirable.

Table 2: *Mineral composition (mg/100 g) of three rice varieties.*

Varieties	Ca	Mg	K	Na	Mn	Zn	Cu	Fe	Cd	Cr	Pd
Kilombero	5.19 ± 1.75	40.31 ± 2.51	258.64 ± 15.89	Bdl	0.53 ± 0.10	1.14	0.37 ± 0.06	2.35 ± 0.39	Bdl	Bdl	Bdl
Faya 14M69	6.45 ± 1.28	40.32 ± 2.22	268.78 ± 19.07	Bdl	0.58 ± 0.02	0.77	0.26 ± 0.02	1.83 ± 0.20	Bdl	Bdl	Bdl
Pusa nuncile	7.81 ± 1.94	30.21 ± 0.29	216.02 ± 8.61	Bdl	0.33 ± 0.02	1.40	0.47 ± 0.07	2.49 ± 1.28	Bdl	Bdl	Bdl
P <0.05	0.0185	<0.0001	0.0005	-	<0.0001	<0.0001	<0.0001	0.0024			

Each value is an average of three observations; There were some significant differences among rice varieties at P< 0.05;
Bdl: Below detectable levels

3.3. Phytic Acid Content

Phytic acid is the major storage form of phosphorous in legumes, cereals, nuts, and oil seeds. Phytic acid is known as a food inhibitor which chelates micronutrient and prevents it to be bioavailable for monogastric animals, including humans, because they lack enzyme phytase in their digestive tract (Wu et al., 2009). In the present investigation, phytic acid content was analyzed and results showed that Pusa nuncile grain had the lowest level of phytic acid (93.10 mg/100g), followed by Kilombero grain (200.25 mg/100g) and the Faya 14M69 grain with the highest level of phytic acid (204.92 mg/100g) (Table 3). Therefore, we could speculate that the Pusa nuncile variety could show a high level of bioavailable bi- and trivalent minerals (Zn, Cu and Fe, Mg and Mn) compared to Kilombero and Faya 14M69 varieties. The results for phytic acid were low compared to those reported by (Magdy et al., 2010), where researchers presented values of 411.25 mg/100g for white rice grain (high amylose content) and 522.25 mg/100g for white rice grain (low amylose content). In the present study, it is believed that the genetic differences and environmental effects play a crucial role in the level of phytic acid in rice varieties.

Table 3: *Phytic acid in three white rice varieties*

Variety	Phytic acid (mg/100g)
Pusa nuncile	93.10 ± 0.29
Kilombero	200.25 ± 1.69
Faya 14M69	204.92 ± 1.82

Each value is an average of three observations. (Mean ± SD, n = 3).

4 CONCLUSIONS

Results of this study indicates that the three white rice varieties could be an important source of mineral elements particularly the micronutrients and the varieties showed a significant variation in proximate composition, mineral content and phytic acid composition. The Kilombero grain exhibited higher moisture, crude fibre and carbohydrate and food energy contents than the other two varieties. The Faya 14M69 grain showed a higher protein and low ash contents while the Pusa nuncile grain exhibited low ash, higher crude fat and lower food energy contents. The mineral content in the three rice varieties were found at low quantities and this is in agreement with the low levels of ash contents. Though the mineral content was low, potassium was found in high content in the three rice varieties than any other mineral element. The carbohydrate content in the rice varieties was very high, thus a very good source of energy with a significantly high amount of carbohydrate found in Kilombero rice. However, protein content was found to be very low though a significant high amount of protein was found in Faya 14M69 variety. These differences were attributed the genetical difference of the rice varieties, environmental conditions, and soil type. Concentrations of cadmium, chromium and lead are below detection limits and are likely to represent minimal risk to human health based on the study data. Phytic acid concentrations in all three varieties were low with Pusa nuncile variety having the lowest concentration, and Faya 14M69 variety showing the highest concentration. Overall, the result of this study can be exploited by rice consumers in Malawi in the choices regarding proximate and mineral compositions. Furthermore, the results and data may be very important for nutritionists for designing nutrition programs to reduce malnutrition in Malawi.

Conflict of interest

The authors confirm that this manuscript has no conflicts of interest.

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