# NUTRITIONAL QUALITY OF SELECTED POTATO (*Solanum tuberosum L.)* CULTIVARS GROWN IN RWANDA

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***Abstract***
*The aim of this study was to determine nutritional composition of six varieties and four potato clones grown in Rwanda to understand their potential utilization in food applications. The experiment was arranged in Completely Randomized Design (CRD). The proximate composition and minerals were determined using standard methods. Collected data were subjected to Analysis of Variance (ANOVA) using SAS version 9.2. Means separation was done using Tukey's test at 5% level of significance. Potato composition ranged from 73.07-79.55% for moisture content, 16.90-22.33% for total carbohydrates on fresh wet basis (FWB), 0.68-1.08% for crude ash FWB, 0.09-0.22% for crude lipids FWB, 1.82-2.84% for crude protein FWB and2.06-2.96% for crude fibers FWB. Minerals FWB ranged from 4.41-10.21 mg/100g for calcium, 13.40-23.99 mg/100g for magnesium, 0.53-1.06 mg/100g for iron, 0.12-0.37 mg/100g for zinc, 400.00-593.73 mg/100g for potassium and 41.19-74.83 mg/100g for phosphorus. Orthogonal contrast showed that clones had lower fibers, higher crude ash and higher lipids than varieties on average. On average varieties had lower zinc, more iron and more phosphorus than clones. There was a positive correlation between Mg and Fe, Mg and K, Mg and P, Fe and P, Zn and K as well as between K and P. Potatoes in this study had different nutrients in different proportions for both clones and varieties and they can be used as source of nutrients in formulation of different diets.*

**Keywords:** cultivars, nutritional, proximate composition, potato, Rwanda

Received: 24.06.2019 Reviewed: 25.09.2019 Accepted: 26.09.2019

## INTRODUCTION

Potato production and consumption in Rwanda has been increasing steadily since the beginning of the last decade. Rwanda is the fifth potato producer in Africa and the thirtieth in the world (FAO, 2008;National Potato Council, 2016).The production was 957,198 in 2000 and 1,789,623 tonnes in 2010 (Stone*et al*., 201; National Potato Council, 2016). In 2011 production was 2,171,518 tonnes and 2, 225,080 tonnes in 2014 (National Potato Council, 2016).The main potato producing area in Rwanda is northwest of the country due to its favorable climate and soil. Potatoes produce more protein and calories than any other crop per unit area, unit time and unit water(FAO, 2008; Burke, 2016). One hectare can produce two to four times of grains and requires a smaller amount of water than cereals (FAO, 2008; Burke, 2016). The edible to non-edible ratio is higher for potato than for cereals being 85% for potatoes and 50% for cereals(Burke, 2016). On dry weight basis potato protein is comparable to the one of cereals, superior to other roots and tubers and it is low in fat(FAO, 2008). Potato is the second source of calories in Rwanda after cassava and the average consumption is 125 kg per person per year, it is the first in Africa and the sixth in the world(FAO, 2008). The world potato average consumption is 31.3 kg per capita, while Africa is at 13.9 kg per capita(FAO, 2008). Potato consumption in Rwanda is above the average of global consumption, it is the main supplier of nutrients in Rwandan diet and it is consumed by people from different socio-economic classes.

Potato is the main source of macro and micronutrients which play a big role for the nourishment of the body. The main components of potatoes are water, carbohydrates, proteins, ash and low amount of lipids. The highest proportion of chemical composition of potato is made of water which is at around 80% and the remaining 20% is made of dry matter(Burke, 2016). High moisture content is responsible for perishability of potatoes. The dry matter of potatoes is mainly dominated by carbohydrates where starch can be as high as 60 to 80% of the total dry matter(FAO, 2008). Carbohydrates are made of starch, non-starch carbohydrates and sugars. Carbohydrates especially starch and sugars are source of energy for brain and their presence spares the use of protein for energy and reserved for body building. Potatoes with high dry matter have high energy and are good for manufacturing different potato products with high yield (Vreugdenhil *et al.*, 2007). Potatoes contain fibers which are types of carbohydrates comprising all plant materials that are not digested by digestive enzymes. Crude fibers are made of cell wall and intracellular components of potato tuber like cellulose, hemicellulose, pentosane and pectin, while dietary fibers are made of insoluble and soluble polysaccharides of cell wall along with lignin and resistant starch (Vreugdenhil *et al.*, 2007). Fermentation of fibers in intestine produces short chain fatty acids and butyric acid is one of them and it was revealed for defense against colon cancer (Lister and Munro, 2000). Moreover, dietary fibers have been reported to have numerous benefits like regulating blood lipid levels, controlling blood glucose, and increasing satiety which is related to weight loss(Food and Nutrition Board, 2005).Recommended total fibers is 38 and 25 g per day for men and women of 19 to 50 years respectively(Food and Nutrition Board, 2005). Fibers are important in human body and potato consumption contributes to the fibers required by the body.

Potatoes contain low amount of protein with high biological value. They are a source of between 18 to 20 amino acids and some of them are essential amino acids with biological quality rounding to 70% comparing to the whole egg(Lister and Munro, 2000).Moreover, considering biological value of egg as 100, potatoes have 90-100, while soya beans have 84 and beans have 73 (Donnelly and Kubow, 2011).They have high amount of lysine and less for sulfur containing amino acids (methionine and cysteine) which limit their nutritive value. They can be complemented with food rich in sulfur containing amino acids like cereals.

Potatoes contain lipids and ash at low concentrations. Lipids in potatoes are very low at the level of less than 1%(Burke, 2016). Despite the low nutritional density of potato lipids, they contribute to the palatability and increases cellular integrity by mitigating in tuber membrane permeability during storage(Singh and Kaur, 2009). Potato lipids are cholesterol free with high unsaturated fatty acids which are essential for human health (Ramadan and Oraby, 2016). Moreover, potato contain ash at the average of 1.1%(Donnelly and Kubow, 2011). This is combination of all minerals found in potatoes and they are in different proportions. Nutritional content of potatoes vary from one variety to another and by agricultural practices.

Potatoes contain a good amount of a wide range of minerals in different concentrations. They contain both macro and micro minerals. Macro elements are needed by the body in amount exceeding 100 mg/day and micro elements are required in less than 100mg a day*(*Bhattacharya *et al*., 2016). Macro minerals encompass calcium, potassium, phosphorus, sodium, magnesium, sulfur and chloride, while micro elements are copper, iron, zinc, chromium, cobalt, iodine, molybdenum, and selenium(Bhattacharya *et al*., 2016). Minerals play different roles to maintain organism in normal conditions. They are used in metabolism as cofactors in different enzymes which are useful for biochemical pathways (Soetan*et al*., 2010). The biological function of macro and micro minerals was also reported by Singh and Kaur(2009). Inadequate consumption or lack of minerals in food leads tomicronutrients deficiency and malfunction of biological system.

Potatoes are staple food in Rwanda. They are consumed all over the country in different forms and they are among the highly consumed food in many areas of the country by people from different socio-economic classes. There are many potato cultivars in Rwanda and new ones are being generated due to the advancement of potato breeding. However, nutritional composition of Rwandan potatoes was not investigated. It is important to understand nutritional quality of Rwandan potatoes in order to predict their contribution in the diet. The objective of this study is to investigate macronutrients and minerals of selected potato varieties and clones grown in Rwanda.

## MATERIALS AND METHODS

Potato tubers were procured from Busogo farm of the University of Rwanda in Musanze district, Northern Province of Rwanda situated at 1$^{o}$33'26'' S and 29$^{o}$32'39''E. The area is made of Andosol which is volcanic soil. The annual mean temperature is 16.2$^{o}$C with rain fall of 1420 mm (Climate-Data.Org, 2016).Potato seeds were procured from Rwanda Agriculture Board (RAB) and grown in standard cultural conditions in the year 2016/17. Laboratory experiment was arranged in Completely Randomized Design (CRD) with three replications where treatments were assigned to the experimental units completely at random. Randomization was done without any restrictions. Cultivars used included six varieties which are Gikungu, Kigega, Kinigi, Kirundo, Mabondo, and Sangema and four clones such as CIP399075.22, CIP392617.54, CIP393251.64 and CIP399062.115. Laboratory analysis was conducted at the University of Rwanda in Rwanda and at Egerton University in Kenya.

### Sample preparation

About one kilogram of undamaged fresh potato tubers of 40 mm diameters and above was well washed in portable water, comminuted into small particles and sundried for one day. They were then milled into powder, kept in clean dry containers and refrigerated (4±2) $^{o}$C for further analysis. Potato powder was carefully homogenized and used for chemical analysis and the results were converted in fresh weight basis by adopting the method of Reiling (2011).

### Proximate analysis

The method suggested by CIP (2006) was used for moisture content. Nine potatoes of processing size were sliced and thoroughly mixed. There after about10 g were weighed in a crucible with three replications and heated in forced air oven at 80$^{o}$C for 72 h. The moisture content was calculated using the formula below:

$$\text{Moisture content \%} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Fresh weight}} \text{x100}$$

Crude protein content was analyzed using Kjeldahl method and the percentage of protein was calculated from nitrogen content (Nx6.25)(AOAC, 2000). Crude fat was analyzed using Soxhlet extraction apparatus and petroleum ether (B.P. 40-60°C) as extracting solvent for 8 hours(AOAC, 2000). Ash content was obtained by incinerating 2 g of sample in muffle furnace at 600$^{o}$C for 4 hours(AOAC, 2000). Crude fibers consisted of weighing about 2g of sample which wastreated with1.25% sulfuric acid and 1.25% sodium hydroxide for 30 minutes successively, followed by filtration, overnight oven drying at 105$^{o}$C and incineration at 600$^{o}$C for 4 hours(AOAC, 1995). Carbohydrates were determined by subtracting form 100 the sum of other proximate components. That is % carbohydrates = 100- (%Moisture content + %Crude protein + % crude ash + %Crude lipid).

### Minerals analysis

The method described by AOAC (2000) was used. Amount of 5 ml conc. $HNO_3$ and 1ml conc.$HClO_4$were used to digest 1 g of sample. They were allowed to stand closed overnight at room temperature to predigest the sample and thereafter placed in oven at 100$^{o}$C for 8 hours and cooled to room temperature in fume hood. Atomic absorption spectrophotometer (Thermo Jarrell Ash Corporation model 6) was used for analysis of calcium, iron, zinc, and magnesium. Flame spectrophotometer (Flame photometer model 410, United Kingdom) was used for potassium and UV/visible spectrophotometer (JENWAY 7315) for phosphorus.

### Statistical analysis

Data were subjected to analysis of variance (ANOVA) and means separated by the Tukey's test at 5% level of significance using Statistical Analysis System (SAS version 9.2) with General Linear Model (GLM) procedure(SAS institute Inc., 2008). Strength of the association between variables was analyzed using Pearson's correlation coefficient and orthogonal contrast was performed on varieties vs clones.

## RESULTS AND DISCUSSION

### Moisture content of potatoes

Moisture content accounts for the highest proportion in fresh potatoes. Moisture content of potato cultivars tested in this study was statistically significantly different at (*P<0.05*). Orthogonal contrast showed than moisture content of varieties did not differ significantly from the one of clones on average. Moisture content ranged from 74.07 to 79.55% as presented in Table 1. Kirundo had the lowest moisture content, while CIP392617.54 had the highest moisture content. Average moisture content in potatoes was reported to be 83.29% (Liu, 2013). Norell *et al.* (2016) reported moisture content of 75 to 85% which aligns with this study. Similarly, four potato varieties grown in four regions of Japan were reported to have moisture content ranging from 78.09 to 82.98%(Sato *et al.*, 2017). Moisture content is influenced by variety, level of maturity, growing location, seasonal effects, fertilizer application and storage conditions (Norell *et al.*, 2016).Nitrogen fertilizer increases tuber yield and moisture content (Ahmed *et al.*, 2009).Potatoes with low moisture content below 80% are suitable for frying and dehydrated products, while high moisture content potatoes are for canning (Marwaha *et al.*, 2010).Moisture content of varieties did not differ from clones and they can be used interchangeably. Potatoes with low moisture content are high in dry matter which is an indicator of good potato processing quality.

### Total carbohydrates of potatoes

Carbohydrates are the highest components of potato after water. Carbohydrates of potato cultivars tested in this study were statistically significantly different at (*P<0.05*).Orthogonal contrast showed that there was no significant difference in carbohydrates content of varieties and clones on average. Carbohydrates ranged from 16.90 to 22.33% FWB as depicted in Table 1. Kirundo had the highest total carbohydrates, while CIP392617.54 had the lowest. The results align with the ones of Abong *et al.* (2009)who reported carbohydrates ranging from 16.34 to 19.74% FWB. A study conducted on four potato varieties from four different areas in Japan showed carbohydrates of 14.25 to 19.16% FWB(Sato *et al.*, 2017). Similarly, Donnelly and Kubow (2011)reported a wide range of carbohydrates from 10 to 30% FWB. Carbohydrates in potatoes are mainly dominated by starch and other components are in small amount and they are the main source of energy. High amount of carbohydrates is associated with high dry matter which is a good indicator of potato for processing and a source of calories for consumers. An average person requires between 2000 to 2500 kcal per day (Singh and Kaur, 2009). A boiled potato contains 72-75 kcal (Singh and Kaur, 2009). Four kilograms of potatoes are enough to cover calories and energy requirement per day (FAO, 2008).Total carbohydrates of varieties and clones of this study did not differ. They had relatively high amount of carbohydrates which is a good indicator for processing and high calorie reservoir.

### Crude protein of potatoes

Potato protein is relatively in low amount with high biological value. Potato protein of cultivars tested in this study were statistically significantly different at (*P<0.05*).Orthogonal contrast revealed that protein content of cultivars and clones did not differ significantly. This study showed crude protein content ranging from 1.82 to 2.84% FWB as presented in Table 1. Gikungu had the lowest protein content, while kigega had the highest amount of crude proteins.

**Table 1. Major nutrients of potato in percentage of fresh weight**

| | Cultivars | Moisture content | Crude ash | Crude lipids | Crude Protein | Crude fibers | Carbohydrates |
|---|---|---|---|---|---|---|---|
| Varieties | Gikungu | $79.07\pm0.59^{a}$ | $0.84\pm0.14^{bc}$ | $0.20\pm0.04^{bc}$ | $1.82\pm0.18^{c}$ | $2.55\pm0.21^{abcd}$ | $18.09\pm0.61^{bc}$ |
| | Kigega | $78.88\pm0.33^{a}$ | $0.75\pm0.09^{c}$ | $0.09\pm0.04^{e}$ | $2.84\pm0.13^{a}$ | $2.37\pm0.13^{cd}$ | $17.74\pm0.30^{bc}$ |
| | Kinigi | $76.12\pm0.39^{ab}$ | $0.70\pm0.08^{c}$ | $0.18\pm0.04^{c}$ | $2.26\pm0.03^{bc}$ | $2.18\pm0.15^{cd}$ | $20.74\pm0.38^{ab}$ |
| | Kirundo | $74.07\pm0.18^{b}$ | 1.08±0.11a | $0.18\pm0.05^{c}$ | $2.58\pm0.11^{ab}$ | $2.79\pm0.17^{ab}$ | $22.33\pm0.13^{a}$ |
| | Mabondo | $76.33\pm0.23^{ab}$ | $0.80\pm0.09^{c}$ | $0.15\pm0.04^{d}$ | $2.54\pm0.13^{ab}$ | $2.62\pm0.12^{abc}$ | $20.18\pm0.21^{abc}$ |
| | Sangema | $77.07\pm0.44^{ab}$ | 0.79±0.10c | $0.17\pm0.03^{c}$ | $2.32\pm0.11^{bc}$ | $2.96\pm0.07^{a}$ | $19.65\pm0.42^{abc}$ |
| Clones | CIP399075.22 | $77.47\pm0.20^{ab}$ | $1.03\pm0.08^{ab}$ | $0.21\pm0.03^{ab}$ | $2.57\pm0.13^{ab}$ | $2.06\pm0.10^{d}$ | $18.72\pm0.22^{bc}$ |
| | CIP392617.54 | $79.55\pm0.20^{a}$ | $0.85\pm0.09^{bc}$ | $0.22\pm0.05^{a}$ | $2.48\pm0.13^{ab}$ | $2.19\pm0.08^{cd}$ | $16.90\pm0.15^{c}$ |
| | CIP393251.64 | $76.67\pm0.48^{ab}$ | $0.84\pm0.07^{bc}$ | $0.20\pm0.03^{bc}$ | $2.62\pm0.19^{ab}$ | $2.54\pm0.04^{abcd}$ | $19.43\pm0.44^{abc}$ |
| | CIP 399062.115 | $77.49\pm0.28^{ab}$ | $0.68\pm0.07^{c}$ | $0.14\pm0.03^{d}$ | $2.23\pm0.15^{bc}$ | $2.23\pm0.15^{cd}$ | $19.46\pm0.30^{abc}$ |
| | Minimum | 74.07 | 0.68 | 0.09 | 1.82 | 2.06 | 16.90 |
| | Maximum | 79.55 | 1.08 | 0.22 | 2.84 | 2.96 | 22.33 |
| | CV | 1.62 | 8.43 | 5.06 | 8.14 | 7.26 | 6.32 |
| | MSD | 3.6629 | 0.2065 | 0.0258 | 0.5779 | 0.5207 | 3.5694 |

MSD: Minimum significant difference (Tukey at 5%), Means followed by the same letter in the column do not differ by Tukey's test at 5%.

The results agree with the study of Pal *et al.*(2008)where protein content ranged from 1.70 %to 2.44 % FWB in eleven potato varieties grown in India. A study conducted by Sato *et al*.(2017) showed lower protein content ranging from 1.37 to 1.92% FWB. Potato protein ranges from 0.69 to 4.63% (Lister and Munro, 2000). The average was reported to be 2% on wet basis and 8% on dry basis (Lister and Munro, 2000; Stone *et al.*, 2011).Liu (2013) reported the average of potato protein to be 2.57%. Protein content depends on genetics, level of maturity and fertilizer application (Ahmed *et al.*, 2009). Nitrogen fertilizer increases protein content(Ahmed *et al.*, 2009). Protein requirement is 0.8g/kg of body weight per day(Singh and Kaur, 2009).Consumption of 100g of boiled potatoes supplies 8-13% and 6-7% of FAO-WHO recommended daily allowance for children and adults respectively (Vreugdenhil *et al.*, 2007).Protein content of varieties did not differ from the ones of clones. Potato is a reliable source of protein, both clones and varieties can be used interchangeably.

## Crude ash of potatoes

Ash encompasses different types of minerals which contribute both in nutrition and metabolism. Ash content of potato cultivars of this study were statistically significantly different at ($P<0.05$). Orthogonal contrast showed that clones had significantly higher ash content than varieties on average. The ash content varied from0.68 to 1.08% FWB being the lowest in CIP399062.115and the highest in Kirundo as shown in Table 1. The average of minerals in tubers was reported to be 1.1% FWB(Donnelly and Kubow, 2011). Total ash from eight Kenyan potato varieties was reported to be 0.94% on FWB, while in fried ones, it was 1.01 to 1.14% (Abong *et al.*, 2009).Stone *et al.* (2011)reported total ash of four potato varieties from four different areas of Japan to range from 0.88 to 1.03%. The main contributors for the variation is related to the genotype, soil characteristics, and fertilizer application(White *et al.*, 2009).Clones had higher ash content than varieties and they can all be considered in diet formulation.

## Crude lipid content of potatoes

Potatoes contain very low amount of lipids. High amount of potato lipid is concentrated between the vascular ring and the peel and thinly peeling is encouraged(Ramadan and Oraby, 2016). Potato lipids of the studied cultivars were statistically significantly different at ($P<0.05$). Orthogonal contrast showed a significant difference between varieties and clones. On average clones had higher lipid content than varieties. Lipid content ranged from 0.09 to 0.22% as illustrated in Table 1. The highest amount was for CIP392617.54, while the lowest was for Kigega. The results align with the ones reported by Lister andMunro (2000)where lipid content of potatoes ranged from 0.02 to 0.2mg/100g FWB. However, they were lower than the ones reported by Burke (2016)stating lipid content of 1%.A study conducted on eight potato varieties grown in Kenya revealed lipid content higher than the findings of this study ranging from of 0.38 to 0.53% FWB(Abong *et al*., 2009).On the other hand, Sato *et al.* (2017)reported very low amount of lipid content of four potato varieties grown in three different areas of Japan ranging from 0.03 to 0.06%. Potato lipid is influenced by genotype, agricultural practices, storage, cooking and processing(Ramadan and Oraby, 2016). Lipid content in potato is very low and its contribution to the calorie is insignificant. Around 75% of fatty acids of potato lipids are polyunsaturated linoleic and they impart a desirable flavour in cooked tubers (Ramadan and Oraby, 2016). Fatty acid compounds like glycolipids, phospholipids, sterols, tocopherols and carotenoids have been reported as components of potato lipids and for their health benefits(Ramadan and Oraby, 2016). Clones had more lipids than varieties and they can both be considered in human diet. Potato lipids though present in small amount, they contribute to the protection of the body and flavour of food.

**Crude fiber content of potatoes**

Fibers are plant materials that remain after solvent extraction followed by digestion with dilute alkali and acid. Crude fibers of potato cultivars tested in this study were statistically significantly different at ($P < 0.05$). Orthogonal contrast revealed a significant difference in fiber content between varieties and clones. Clones had lower crude fibers than varieties on average. They varied from 2.06 to 2.96 mg/100g FWB as presented in Table 1. Sangema had the highest fiber content and the lowest was for CIP399075.22.The results agree with the ones reported by Lister and Munro (2000) where crude fibers of potatoes ranged from 0.17 to 3.48%. Similarly, Liu (2013) reported dietary fiber of 2.5% and Visvanathan *et al*. (2016) reported dietary fiber of 2.7 and 1.4% FWB with and without skin respectively. Amount of fibers may be related to the genotype and agronomic factors. Dietary fibers are not uniformly distributed but they are higher in the skin than in the flesh and cooking affects them by solubilizing pectin and resistant starch (Vreugdenhil *et al.*, 2007). It is recommended to consume 14 g of fibers for every 1000 calories (Madhu *et al.*, 2017). Fibers contribute to the bulk of feces, bind undesirable materials such as mutagenesis, carcinogen, and aids in digestion by creating a favorable environment for valuable microflora in the intestine (Visvanathan *et al*., 2016; Madhu *et al.*, 2017). Potato fibers revealed defense against different types of cancer by inducing apoptosis which is the annihilation of abnormal cells (Lister and Munro, 2000; Madhu *et al*., 2017). Numerous health benefits are associated to dietary fiber and they include but not limited to regulating blood lipid levels, controlling blood glucose, hemorrhoids, coronary heart diseases, and increasing satiety which is related to weight loss (Food and Nutrition Board, 2005; Madhu *et al.*, 2017).Varieties had high crude fibers than clones which also have acceptable range of crude fibers. Regular consumption of potatoes can be helpful for digestion and protection against different types of diseases.

**Minerals content in potatoes**

Minerals are inorganic nutrients which are needed by human body in small amount. Human body needs less than 1 to 2500mg a day (Soetan *et al.*, 2010).Potato minerals of cultivars tested in this study were statistically significantly different at ($P<0.05$). Orthogonal contrast revealed that on average there was no significant difference in calcium, magnesium and potassium content of varieties and clones. However, a significant difference was found for iron, zinc and phosphorus. On average varieties had higher iron and phosphorus than clones, while clones had higher zinc content than varieties. This study revealed the amount of calcium ranging from 4.41 mg/100g for Kigega to 10.21 mg/100g for Mabondo, magnesium from 13.40 mg/100g for CIP393251.64 to 23.99mg/100g for Kirundo, iron from 0.53 mg/100g for Kigega to 1.06 mg/100g for Kinigi, zinc from 0.12 mg/100g for Gikungu to 0.37 mg/100g for Kinigi, potassium from 400.00 mg/100g for CIP399075.22 to 593.74 mg/100g for Kirundo and phosphorus from 41.19 mg/100g for Sangemato 74.83 mg/100g FWB for Kirundo as presented in Table 2.The results agree with the study of Furrer *et al.*(2018)who reported mineral content of potatoes on average as 421 mg/100g for potassium, 57 mg/100g for phosphorus, 23 mg/100g for magnesium, 12 mg/100g for calcium, 0.78 mg/100g for iron, and 0.29mg/100g for zinc. Moreover, the results align with the study of Pal *et al.* (2008) except for potassium and phosphorus and they reported 28.61 to 38.77mg/100g for potassium, 6.36 to 10.50 mg/100g for calcium, 15.23 to 29.36mg/100g for magnesium, 10.40 to 15.55 mg/100g for phosphorus, 0.35 to 1.49mg/100g for iron, 0.51 to 0.88 mg/100g for zinc. Minerals are not distributed equally in all parts of the tuber. Calcium, potassium, magnesium, iron, manganese, zinc and copper are more concentrated in the skin than in the flesh (Singh and Kaur, 2009). Potato skin holds 17% of total zinc, 34% of calcium and 55% of iron and concentration of phosphorus, copper and calcium decreases from the periphery towards the center of the potato tuber (Subramanian *et al.*, 2011). Potassium intervenes in prevention of bruising, it is higher in skin and cell layers nearing the skin than other parts of the tuber and it increases with maturity (Vreugdenhil *et al.*, 2007). A research done in Canada showed that one serving contributes 30 to 48%and 6 to 82% of recommended daily intake (RDI) of macro and micro minerals respectively with exception of calcium and sodium (Donnelly and Kubow, 2011). Potato minerals were widely distributed in varieties and clones and they play an important role in human diet.

**Correlation of minerals in potatoes**

There was a significant correlation of minerals in the studied cultivars. Correlations were significant and positive between Mg and Fe, Mg and K, Mg and P, Fe and P, Zn and K as well as K and P as presented in Table 3. Correlation of minerals in potatoes was also reported by Subramanian *et al.*(2011). Potassium and phosphorus were present in the highest amount followed by magnesium, while iron and zinc were in smallest amount. Mineral content depends on genotype, minerals present in soil and fertilizer application(White *et al.*, 2009). Minerals should be present in the soil to facilitate plant uptake which in return are absorbed by people once consumed.

**Table 2. Mineral composition of potato in mg/100g of fresh tubers**

| | Cultivars | Ca | Mg | Fe | Zn | K | P |
|---|---|---|---|---|---|---|---|
| Varieties | Gikungu | 5.59 ±0.25$^{bcd}$ | 20.91±0.35$^{abc}$ | 0.81±0.09$^{c}$ | 0.12±0.03$^{g}$ | 450.66±1.81$^{d}$ | 63.11±0.76$^{ab}$ |
| | Kigega | 4.41±0.27$^{e}$ | 18.36±0.33$^{cd}$ | 0.53±0.08$^{d}$ | 0.20±0.05$^{e}$ | 514.87±1.53$^{bc}$ | 47.86±0.51$^{cd}$ |
| | Kinigi | 6.35±0.12b | 19.45±0.37b$^{cd}$ | 1.06±0.08$^{a}$ | 0.37±0.04$^{a}$ | 509.72±1.45$^{c}$ | 52.92±0.75$^{bcd}$ |
| | Kirundo | 5.09±0.12$^{cde}$ | 23.99±0.62$^{a}$ | 0.96±0.09$^{ab}$ | 0.34±0.05$^{ab}$ | 593.74±1.56$^{a}$ | 74.83±0.71$^{a}$ |
| | Mabondo | 10.21±0.31$^{a}$ | 21.63±0.34$^{abc}$ | 0.59±0.07$^{d}$ | 0.27±0.03$^{d}$ | 565.93±1.55$^{ab}$ | 45.58±0.55d |
| | Sangema | 4.72±0.09$^{de}$ | 21.70±0.38$^{abc}$ | 0.96±0.04$^{ab}$ | 0.15±0.05$^{fg}$ | 417.63±1.50$^{d}$ | 41.19±0.54$^{d}$ |
| Clones | CIP399075.22 | 6.24±0.14$^{b}$ | 18.34±0.39$^{dc}$ | 0.61±0.03$^{d}$ | 0.30±0.03$^{cd}$ | 400.29±1.71$^{d}$ | 46.47±0.66$^{cd}$ |
| | CIP392617.54 | 5.92±0.19$^{bc}$ | 16.49±0.39$^{de}$ | 0.83±0.09$^{bc}$ | 0.19±0.03e | 439.50±1.76$^{d}$ | 46.45±0.31$^{cd}$ |
| | CIP3932.64 | 6.45±0.17$^{b}$ | 13.40±0.26$^{e}$ | 0.62±0.04$^{d}$ | 0.18±0.04$^{ef}$ | 409.70±1.45$^{d}$ | 45.94±0.86$^{cd}$ |
| | CIP 399062-115 | 4.80±0.13$^{cde}$ | 22.96±0.51$^{ab}$ | 0.87±0.09$^{bc}$ | 0.32±0.04$^{bc}$ | 578.79±1.83$^{a}$ | 58.52±0.91$^{bc}$ |
| | Minimum | 4.41 | 13.40 | 0.53 | 0.12 | 400.00 | 41.19 |
| | Maximum | 10.21 | 23.99 | 1.06 | 0.37 | 593.74 | 74.83 |
| | CV | 6.37 | 6.98 | 5.86 | 4.80 | 3.85 | 8.35 |
| | MSD | 1.1148 | 4.0305 | 0.1345 | 0.0342 | 55.029 | 12.787 |

MSD: Minimum significant difference (Tukey at 5%). Means followed by the same letter in the column do not differ by Tukey's test at 5%.

Table 3: Pearson correlation coefficients (r) for minerals of potato tubers

| | Ca | Mg | Fe | Zn | K |
|---|---|---|---|---|---|
| **Mg** | -0.77 NS | | | | |
| **Fe** | -0.30NS | 0.41* | | | |
| **Zn** | 0.16NS | 0.35NS | 0.30NS | | |
| **K** | 0.15NS | 0.60*** | 0.19NS | 0.59*** | |
| **P** | -0.26NS | 0.51** | 0.37* | 0.34NS | 0.51** |

NS: Not significant; $*P < 0.05$: Significant; $** P < 0.01$: Highly significant; $***P < 0.001$: Very highly significant.

## CONCLUSION

Potato moisture content, total carbohydrates, crude ash, crude lipids, crude protein, minerals (calcium, magnesium, iron, zinc, potassium, and phosphorus) were analyzed. The moisture content in this study was low, while total carbohydrates was high. There was no significant difference in moisture content, carbohydrates and protein content between varieties and clones. Crude ash and crude lipids were higher in clones than in varieties, while crude fibers were higher in varieties than in clones. Regarding minerals, there was no significant difference in calcium, magnesium and potassium of varieties and clones. Varieties had higher iron and phosphorus, while clones were higher in zinc. Considering nutritional content of both varieties and clones, they are good source of nutrients and they can be used for processing of different potato products and for preparation of different dishes. Selection should base on individual cultivar rather than considering them as groups.

## Acknowledgements

The authors are grateful for NUFFIC, NICHE/ RWA 185 and Q- point for financial support of this research, the University of Rwanda for providing study leave for postgraduate studies, farm and laboratory facilities, Egerton University for admitting the student and providing laboratory facilities, Rwanda Agriculture Board (RAB) for providing planting materials and Hollanda Fair Food (Winnaz), a potato processing company in Rwanda, for processing facilities.

## REFERENCES

[1]. Abong, G. O., Okoth, M. W., Karuri, E. G., Kabira, J. N. and Mathooko, F. M. (2009). Levels of reducing sugars in eight Kenyan potato cultivars as influenced by stage of maturity and storage conditions. *J. Anim. Plant Sci.*, **2**(2): 76–84.

[2]. Ahmed, A., Abd, M., Ghoname, E. A. and Riad, G. (2009). Potato tuber quality as affected by nitrogen form and rate. *Middle E. Russ .J. Plant Sci. Biotechnol.*, **3**: 47–52.

[3]. AOAC. (1995). The association of official analytical chemists. 16th ed. Virginia. USA.

[4]. AOAC. (2000). The association of official analytical chemists.17th ed. Maryland, USA.

[5]. Bhattacharya, P. T., Misra, S. R. and Hussain, M. (2016). Nutritional aspects of essential trace elements in oral health and disease. *Sientifica*., *2016*: 1.-12.

[6]. Burke, J. J. (2016). Growing the potato crop. Vita, Equity House, Upper Ormond Quay, Dublin 7, Ireland: 19-230.

[7]. CIP. (2006). Procedures for standard evaluation trials of advanced potato clones. International Potato Center.Apartado 1558,Lima12, Peru: 10-93.

[8]. Climate-Data.Org. (2016). https://en.climate-data.org/323937/. viewed on July16th, 2016.

[9]. Donnelly, D. and Kubow, S. (2011). Role of potato in human health. *CRAAQ-Colloque Sur La Pomme de Terre*, 1–6.

[10]. FAO. (2008). New light on a hidden treasure. International year of poto 2008. FAO, Rome, Italy: 51p. *http://www. potato2008.org/en/index.html (Accessed on 20/10/2017).*

[11]. Food and Nutrition Board. (2005). Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein and amino acids. washington D.C.: The National Academies Press, Washington, D.C.1-982.

[12]. Furrer, A. N., Chegeni, M. and Ferruzzi, M. G. (2018). Impact of potato processing on nutrients , phytochemicals , and human health. *Crit. Rev. in Food Sci.Nutr.*, **58(**1):146–168. https://doi.org/10.1080/10408398.2016.1139542

[13]. Lister, C. E. and Munro, J. (2000). Nutrition and health qualities of potatoes - a future focus. Crop & Food Research Confidential Report. New Zealand Institute of Crop and food Research Limited. Private Bag 4704, Christchurch, New Zealand **143**: 1–47.

[14]. Liu, R. H. (2013). Health-promoting components of fruits and vegetables in the diet. *ASN*., **4**(3), 384–392. https://doi.org/10.3945/an.112.003517.

[15]. Madhu, C., Krishna, K. M., Reddy, K. R. and

Lakshmi, P. J. (2017). Estimation of crude fibre content from natural food stuffs and its laxative activity induced in rats. *Int. J. Pharm. Res. Health Sci.*, **5**(3), 1703–1706. https://doi.org/10.21276/ijprhs.2017.03.04

[16]. Marwaha, R. S., Pandey, S. K., Dinesh, K., Singh, S. V. and Parveen, K. (2010). Potato processing scenario in India : Industrial constraints , future projections , challenges ahead and remedies.*J.Food Sci. Technol.*, **47(**2): 137–156. https://doi.org/10.1007/s13197-010-0026-0

[17]. National Potato Council. (2016). Potato Statistical Year Book. Potato USA.washington D.C. USA: National Potato Council.1-84.

[18]. Norell, R. J., Glaze, J. B., Chahine, M. and Olsen, N. (2016). Measuring potato dry matter content on the farm. *University of Ihado Extension*, 1–3.

[19].Pal, S., Bhattacharya, A., Konar, A., Mazumdar, D. and Das, A. K. (2008). Chemical composition of potato at harvest and after cold storage. *Inter. J. Veg. Sci.*, **14**(2), 162–176. https://doi.org/10.1080/19315260801934779

[20]. Ramadan, M. F. and Oraby, H. F. (2016). Fatty acids and bioactive lipids of potato cultivars.*J.of Oleo Sci.*, **65**(6): 459–470. https://doi.org/10.5650/jos.ess16015

[21]. Reiling, B. A. (2011). Feed dry matter conversions. University of Nebraska-Lincoln Extension, Institute of Agriculture and Natural Resources: 1-4.

[22]. SAS institute Inc. (2008). *SAS/STAT® 9.2 User's Guide.* USA:Cary, NC: SAS Institute Inc.

[23]. Sato, H., Koizumi, R., Nakazawa, Y., Yamazaki, M., Itoyama, R., Ichisawa, M., … Takano, K. (2017). Data on the weights , specific gravities and chemical compositions of potato ( Solanum tuberosum ) tubers for food processing from different areas of Hokkaido , Japan. *Data in Brief*, **11**: 601–605. https://doi.org/10.1016/j.dib.2017.03.009

[24]. Singh, J. and Kaur, L. (2009). Advances in potato chemistry and technology (1st edit). New York, USA.: Elsevier Inc: 1-458.

[25]. Soetan, K. O., Olaiya, C. O. and Oyewole, O. E. (2010). The importance of mineral elements for humans, domestic animals and plants. *Afr. J. Food Sci.*, **4**(5): 200–222.

[26]. Stone, R., Temu, A., Kalisa, M. and Cabello, M. (2011). Rural and agricultural financial services strategy. Ministry of Agriculture and Animal Resources and DFID Rwanda.Oxford Policy Management Limited, 6 St Aldates Courtyard, 38 St Aldates, Oxford OX1 1BN, United Kingdom., 1–109.

[27]. Subramanian, N. K., White, P. J., Broadley, M. R. and Ramsay, G. (2011). The three-dimensional distribution of minerals in potato tubers. *Annals of Botany*, **107**:681–691.

[28]. Visvanathan, R., Jayathilake, C., Jayawardana, C. B. and Liyanage, R. (2016). Health-beneficial properties of potato and compounds of interest. *J. Sc.Food and Agric.*, **96**(15), 4850–4860. https://doi.org/10.1002/jsfa.7848

[29]. Vreugdenhil, D., Bradshaw, J., Gebhardt, C., Govers, F., Mackerron, D. K. L., Taylor, M. A. and Ross, H. A. (2007). Potato biology and biotechnology advances and perspectives (First edit). Amsterdam, The Nethelands: Elsevier: 1-796.

[30]. White, P. J., Bradshaw, J. E., Dale, M. F. B., Ramsay, G., Hammond, J. P. and Broadley, M. R. (2009). Relationships between yield and mineral concentrations in potato tubers. *Hort. Sci.*, **44**(1): 6–11.