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Dotto, Joachim

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Nutrient composition and selected physicochemical properties of fifteen *Mchare* cooking bananas: A study conducted in northern Tanzania

Joachim Dotto[a,c,*], Athanasia O. Matemu[a], Patrick A. Ndakidemi[b]

[a] *Department of Food Biotechnology and Nutritional Sciences, Nelson Mandela African Institution of Science and Technology, P.O. Box 447, Arusha, Tanzania*
[b] *Department of Sustainable Agriculture, Biodiversity and Ecosystems Management, Nelson Mandela African Institution of Science and Technology, P.O. Box 447, Arusha, Tanzania*
[c] *Centre for Research, Agricultural Advancement, Teaching Excellence and Sustainability in Food and Nutrition Security (CREATES-FNS), Nelson Mandela African Institution of Science and Technology, P.O. Box 447, Arusha, Tanzania*

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ABSTRACT

This study investigated the proximate composition, selected minerals potassium (K), calcium (Ca), iron (Fe) and zinc (Zn) and some quality attributes of fifteen *Mchare* cooking bananas mainly consumed in northern Tanzania. Analyses were conducted using the standard methods to ascertain bananas' potential in food-based strategies in order to improve nutrition-sensitive agriculture and address hidden-hunger. Data were subjected to analysis of variance and means were compared. There were significant differences in all parameters assessed. Results further indicated that the moisture content ranged from 66 to 74 g/100 g; ash 0.66 to 1.50 g/100 g; fat 0.10 to 0.60 g/100 g; fiber 1.0 to 3.0 g/100 g; carbohydrate 22 to 30 g/100 g. Mineral content ranged from 306 to 469 mg/100 g; 3.0 to 6.0 mg/100 g; 0.4 to 1.0 mg/100 g and 0.10 to 0.20 mg/100 g for K, Ca, Fe and Zn respectively, indicating potential nutritional significance. The total titratable acidity (TTA) ranged from 1.5 to 2.3%, total soluble solids (TSS) 1.0 to 2.0 ° Brix while pH ranged from 5.4 to 6.0 suggesting a substantial contribution to the sensory attributes of bananas, which is an important sensory attribute for consumers. Cooking bananas could, therefore, play a key role in contributing to alleviating hidden-hunger and food insecurity through developing new food recipes.

Introduction

Cooking banana (*Musa* spp.) is cultivated primarily as a carbohydrate staple food in many developing countries, particularly in Africa [1]. According to the FAO statistical division [2], 145 million tons worth about USD 31 billion were produced globally, with the global contribution of about 20% from Africa. Bananas make up the largest production of fruits and one

* Corresponding author at: Department of Food Biotechnology and Nutritional Sciences, Nelson Mandela African Institution of Science and Technology, P.O. Box 447, Arusha, Tanzania.
E-mail addresses: j.dottoe@gmail.com, dottoj@nm-aist.ac.tz (J. Dotto).

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of the most important cash crops in the global market in comparison to apple, orange, grape and melon. In East African countries and Eastern Democratic Republic of Congo, cooking banana is an important food crop, providing a good source of carbohydrates, vitamins (A, B_1, B_2, B_6, and C), minerals (K, Fe, Zn, Se, Mg, Ca and P), polyphenols, resistant starch, and antioxidants all-year-long [3,4]. Cooking bananas are an important staple food to over 30 million people and play a key role in addressing both nutrition and food security in the region. East African Highland Bananas (EAHBs), for example, inhabit about one-third of the cultivated land of the African Great Lakes region comprising of Tanzania, Burundi, Uganda, and the Eastern part of Democratic Republic of Congo, Kenya and Rwanda. EAHBs are locally named differently giving rise to multiple names. For example, in Tanzania, mature green EAHB fruits are well known as *Mchare, Embirabire, Enzinga, Endeishya, Ekitoke Kisamunyu* and *Ndizi za kupika*; while in Uganda, they are referred to as *Nakinyika, Nakhaki, Nakawere, Lwezinga* and *Kibiddebidde*. For Rwanda and Burundi green EAHB bananas are famously known as *Ingumba Inyamunyu, Mbirabire, Inzirabu shera, Bakurura* and *Insira* which are normally cooked, steamed or boiled before consumption [6,7]. Of specific interest in this study, was *Mchare* banana family largely grown and consumed in the northern parts of Tanzania. Tens of preferred cooking banana cultivars in the region belong to this family, making it a popular choice among the northern residents. Considerable studies have been done aiming at the improvement of these banana cultivars focusing on the desirable agronomic characters such as disease resistance and high-yielding traits [8–11]. However, there is a lack of consistent practical information about the nutritional quality and physicochemical quality parameters of this popular banana family. Evidently, the need to evaluate the nutrients and quality parameters of *Mchare* bananas cannot be overemphasized. Commercially, cooking bananas provide a household annual income of about USD 1500. This is one of the highest income-generating commodity in the region [5]. The purpose of the present study was threefold (i) to analyze the proximate composition, (ii) quantify mineral concentration (K, Ca, Fe, and Zn) and (iii) assess the physicochemical quality parameters of fifteen *Mchare* accessions – namely, *Mlelembo mchare, Huti* white, *Kahuti, Ijihu inkundu, Makyughu* 1, *Makyughu* 2, *Mchare laini, Huti* green, *Akondro mainty, Njuru, Muraru mchare, Majimaji, Muraru, Muraru* white and *Muraru* red which are predominantly consumed in northern Tanzania. Knowledge of the nutrient and physicochemical properties of the bananas could be vital to local farmers and banana snacks' processors as a reliable selection tool for *Mchare* cooking bananas. Additionally, breeders would also benefit through developing new improved cultivars that can be readily adopted by local farmers and consumers. The information from the present study may also be used to ascertain the potential of cooking bananas as a food-based strategy in order to improve nutrition-sensitive agriculture, address hidden hunger and food security in general.

Material and methods

Research plant materials

Fifteen indigenous cooking bananas of *Mchare; Mlelembo mchare, Huti* white, *Kahuti, Ijihu inkundu, Makyughu* 1, *Makyughu* 2, *Mchare laini, Huti* green, *Akondro mainty, Njuru, Muraru mchare, Majimaji, Muraru, Muraru* white and *Muraru* red were used in this study. They were all obtained at unripe green stage 1 of maturity [12], sourced from two research centers; (i) the International Institute of Tropical Agriculture (IITA) and (ii) the World Vegetable Center (WVC) in 2018, in Arusha, Tanzania. The banana varieties under study were grown at a spacing of 3.0 m × 3.0 m at both IITA and WVC trial sites under rain-fed settings and received additional irrigation at every 9–12 day's interval during the dry seasons. The cultivars were chosen based on the consumption popularity among consumers in the northern region of Tanzania [5] and secondly, due to the demand of an ongoing IITA breeding program that is currently developing new *Mchare* cultivars with superior agronomic potential and similar or improved nutritional value and physicochemical quality parameters.

Sample preparation

Sample preparation followed the procedures described by Dadzie and Orchard [13], where three freshly harvested banana bunches from each cultivar were collected to be used for the study. From the bunch of each cultivar, 16 fingers were randomly taken from the second and third hand of each bunch to make a sample set for each cultivar. Laboratory samples were prepared, whereby the fruits from each set were peeled and sliced to 2 mm size, followed by drying the sliced pulp in a forced air oven (Mmermet, Germany) at 70 °C for 12 h. Dried samples were ground (Waring blender, Thomas Scientific, Swedesboro, USA) and kept at −20 °C [13] for subsequent nutrient analyses at the Nelson Mandela – African Institution of Science and Technology (NM-AIST) laboratories in 2018. All the analyses were performed in triplicate.

Determination of proximate composition

All proximate analyses were performed according to AOAC [14]. Moisture content was determined by weighing, 5 g of wet pulp dried at 105 °C for 24 h in a forced air oven (Memmert, Germany). The change in weight before and after drying was recorded as moisture. Ash content was determined by the change in weight, which involved incinerating off moisture and all organic components at 550 °C in a muffle furnace (Thermo Scientific, Waltham, USA). The ash content was obtained by weighing the incinerated sample. Crude fat was determined by Soxhlet method. Crude fat was extracted from the sample powder with petroleum ether as the solvent, and the solvent was evaporated off to get the fat extract. The difference between the initial and final weight of the extraction flask was recorded as the crude fat content. Crude protein content was measured by the Kjeldahl method using Behrotest InKjel System (Behr Labor-Technik, Dusseldorf, Germany). The method involved digestion of the sample with concentrated sulfuric acid catalyzed by Kjeldahl Selenium tablets (Merck Chemical PTY Ltd, South Africa) at 420 °C for 1 h to liberate the organically bound nitrogen in the form of ammonium sulfate. The ammonia in the digest was then distilled off into a boric acid receiver solution and then titrated with standard hydrochloric acid. A conversion factor of 6.25 was used to convert total nitrogen to percentage crude protein. Dietary fiber was determined by an enzymatic-gravimetric technique using AOAC Method 2009.01. Total available carbohydrate content was calculated as the difference between 100% and the sum of the percentages of moisture, ash, lipids, protein and total dietary fiber.

Determination of concentration of selected minerals

The mineral concentrations of the sample materials were evaluated using the technique described by Onwuka [15]. Potassium (K), calcium (Ca), iron (Fe) and zinc (Zn) mineral concentrations were measured by Atomic Absorption Spectrophotometer (AAS) (Thermo Scientific iCE 3500, Waltham, USA). One gram of each sample was weighed into a 150 mL Erlenmeyer flask and 20 mL of the acid mixture (containing 325 mL conc. Nitric acid, 40 mL Perchloric acid, and 10 mL of sulfuric acid) was added. The content was mixed and heated gently in a digester at a medium heat under a fume hood and heating continued until dense white fume appeared. Heating continued for 40 s and then allowed to cool followed by the addition of 50 mL of distilled water. The solutions were filtered using filter paper (Thomas Scientific, Swedesboro, USA) into a 100 mL volumetric flask and made up to mark with distilled water. The resultant solutions were read on the AAS. The instrument was adjusted with commonly used standards (K 2 ppm, 6 ppm, 10 ppm; Ca 5 ppm, 15 ppm, 30 ppm; Fe 2 ppm, 4 ppm, 10 ppm; Zn 2 ppm, 4 ppm, 6 ppm) and samples were analyzed at corresponding wavelength. The required hollow cathode lamp corresponding to the required mineral and holders in the lamp compartment was installed to determine the concentration of each mineral. The dilution factor for potassium and calcium was 50 and 20, respectively, while for iron and zinc was 1.

Physicochemical analysis

Ten freshly harvested fruits from each sample set were used to study the quality parameters. All physical quality assessments of the fruits were conducted according to Dadzie and Orchard [13] procedures.

The total soluble solids of the fruit

The total soluble solids (TSS) content was measured with the use of a hand-held refractometer (Erma Refractometer 0–32% Brix, Tokyo, Japan) equipped with automatic temperature compensation system at 25 °C, according to Dadzie and Orchard [13] and reported as degree Brix.

Fruit pH

The pH value of the fresh fruits was determined by the potentiometric method [14] using a digital pH Meter (Greisinger Model GMH 3500, Regenstauf, Germany).

Titratable acidity of the fruit

The level of titratable acidity (TA) in the banana pulp was determined using titration method as described by Dadzie and Orchard [13] by titrating the banana pulp with 0.1 N NaOH using a semi-automated titration system (TITRONIC Basic, Rose Scientific Inc., Canada) and a phenolphthalein indicator. The values were expressed as percentage malic acid.

Statistical analysis

Data collected from analyses and experimental runs were subjected to Analysis of Variance (ANOVA) and reported as mean ± standard error (SE) of three replicates. Significant means were subjected to Tukey's Honestly Significant Difference (HSD) at $p = 0.05$ using Statistica 10 for Windows (TIBCO Software Inc., 3307 Hillview Avenue Palo Alto, CA 94304 USA).

Results and discussion

Proximate composition

The results of the proximate composition are summarized in Table 1. There were significant varietal differences in all parameters analyzed. Moisture content for *Majimaji, Kahuti* and *Huti* white were notably higher than that observed in other varieties respectively; while *Huti* green had the lowest moisture content. The mean moisture content for the studied bananas ranged from 65.53 to 74.44 g/100 g. These findings are in line with previous results reported by Aurore et al. [12] for unripe

Table 1
Effect of varieties on the proximate composition (in g/100 g).

Variety	Moisture	Total Ash	Protein	Fat	Total fiber	Carbohydrate[a]
Mlelembo M.	66.62 ± 0.17^{fgh}	1.12 ± 0.01^{d}	0.61 ± 0.01^{g}	0.14 ± 0.01^{ef}	2.30 ± 0.10^{ab}	29.19 ± 3.46^{abc}
Huti white	71.69 ± 0.13^{abcd}	0.91 ± 0.01^{e}	0.73 ± 0.01^{efg}	0.39 ± 0.03^{bcde}	2.29 ± 0.08^{ab}	23.99 ± 0.45^{abcd}
Kahuti	72.00 ± 1.56^{abc}	1.17 ± 0.01^{cd}	0.69 ± 0.01^{efg}	0.44 ± 0.02^{abc}	2.29 ± 0.76^{ab}	22.55 ± 1.91^{bcd}
Ijihu inkundu	67.72 ± 0.28^{efgh}	1.45 ± 0.02^{a}	0.91 ± 0.05^{def}	0.22 ± 0.01^{def}	1.65 ± 0.15^{bc}	28.05 ± 0.70^{abcd}
Makyughu 1	69.64 ± 0.43^{cde}	0.87 ± 0.04^{e}	0.80 ± 0.06^{defg}	0.15 ± 0.03^{ef}	2.70 ± 0.10^{ab}	25.84 ± 1.08^{abcd}
Makyughu 2	65.97 ± 0.22^{gh}	0.66 ± 0.01^{f}	1.75 ± 0.01^{a}	0.53 ± 0.03^{ab}	2.47 ± 0.20^{ab}	28.75 ± 0.75^{abcd}
Mchare laini	66.52 ± 0.37^{fgh}	1.32 ± 0.01^{ab}	1.29 ± 0.04^{bc}	0.38 ± 0.05^{bcde}	0.92 ± 0.01^{c}	29.57 ± 1.19^{ab}
Huti green	65.53 ± 0.48^{h}	1.28 ± 0.02^{bc}	0.90 ± 0.06^{def}	0.30 ± 0.06^{cde}	2.03 ± 0.05^{abc}	29.96 ± 2.22^{a}
Akondro M.	70.59 ± 0.04^{bcde}	1.30 ± 0.05^{bc}	1.34 ± 0.05^{b}	0.12 ± 0.01^{f}	2.48 ± 0.06^{ab}	24.17 ± 0.99^{abcd}
Njuru	73.43 ± 0.14^{ab}	0.85 ± 0.01^{e}	0.66 ± 0.04^{fg}	0.60 ± 0.15^{a}	2.13 ± 0.03^{ab}	22.33 ± 0.90^{cd}
Muraru M.	71.37 ± 0.42^{bcd}	0.86 ± 0.02^{e}	1.03 ± 0.03^{cd}	0.30 ± 0.06^{cde}	1.89 ± 0.07^{abc}	24.55 ± 1.06^{abcd}
Majimaji	74.44 ± 0.25^{a}	0.92 ± 0.01^{e}	0.76 ± 0.03^{efg}	0.09 ± 0.01^{f}	1.86 ± 0.12^{abc}	21.59 ± 1.69^{d}
Muraru	68.76 ± 0.59^{defg}	0.89 ± 0.03^{e}	1.51 ± 0.04^{ab}	0.42 ± 0.03^{bcd}	1.64 ± 0.07^{bc}	26.78 ± 0.71^{abcd}
Muraru wh.	69.34 ± 0.59^{cdef}	0.90 ± 0.02^{e}	0.84 ± 0.04^{defg}	0.48 ± 0.03^{ab}	2.16 ± 0.03^{ab}	26.28 ± 0.60^{abcd}
Muraru red	70.78 ± 0.89^{bcd}	0.94 ± 0.05^{e}	0.94 ± 0.03^{de}	0.18 ± 0.01^{def}	2.79 ± 0.07^{a}	24.37 ± 0.55^{abcd}
F statistics	23.30^{***}	78.55^{**}	47.71^{***}	10.79^{***}	4.81^{***}	4.03^{***}

Values are mean ± SE; $n = 3$. Values are on dry weight basis except for moisture content.
**, *** significant at $p \leq 0.01$ and at $p \leq 0.001$, respectively.
Mlelembo M. – *Mlelembo mchare, Muraru M.* – *Muraru mchare, Muraru* wh. – *Muraru* white.
Means with different superscript letters within columns are significantly different from each other by Tukey's test ($p = 0.05$).
[a] Carbohydrate content was calculated by difference.

bananas (63.00–74.00 g/100 g). The moisture content, in contrary, was lower than the findings of *Grand Naine* cultivars grown with bio-fertilizer reported by Vazquezshy et al. [16] which ranged from 77.77 to 78.76 g/100 g.

The moisture level of foods or food products provides a clue of its freshness and shelf life [17]. Foodstuffs with more moisture level are susceptible to increased microbial damage and reduced shelf life, which may in turn result in its decomposition [18]. The level of moisture content in any raw food crop is greatly dependent on the genetic factors of individual variety and the site factors (e.g. soil) [19]. This explains why there may have been differences in the moisture content observed between the studied banana cultivars.

There were significant varietal differences in the total ash content of the assessed varieties. The ash content of the studied bananas ranged from 0.66 to 1.45 g/100 g. The lowest ash content of the studied sample was 0.66 g/100 g for *Makyughu* 2 may indicate low mineral concentration [20]. In contrast, the higher values were symbolic of high mineral levels of cooking bananas. The present results tie well with the previous conclusion reached by Ohizua et al. [21] who found the ash content of the unripe banana flour to be 1.09 g/100 g, which is in line with average ash content for the *Mchare* bananas. According to some studies conducted by Vazquezshy et al. [16] and Pragati et al. [22], it was revealed that ash content values for cooking bananas ranged from 2.89 to 2.93 g/100 g and 3.52 to 3.75 g/100 g, respectively, which were higher than the present findings. This varietal variation might be attributed to the different varietal ability to absorb minerals.

Looking at Table 1, there was a significant difference in protein concentration of the analyzed banana varieties. The protein content of the varieties analyzed ranged from 0.61 to 1.75 g/100 g. This was within the range recorded for dried and dehydrated unripe banana flour (0.80–3.10 g/ 100 g) by Ashokkumar et al. [24] and Ohizua et al. [21]. Contrary to the present findings, the protein content of the bananas was higher than the values 0.8 g/100 g and 1.06 g/100 g reported in the TFCT report by Lukmanji et al. [23] and Vazquezshy et al. [16] respectively. The value of crude protein concentration for the *Makyughu* 2 (1.75 g/100 g) was highest tailed by *Muraru* (1.51 g/100 g), *Akondro mainty* (1.34 g/100 g) and *Mchare laini* (1.29 g/100 g) while *Mlelembo mchare* had the lowest value of protein concentration. The mean value of crude protein for the studied bananas (0.98 g/100 g) is lower than other starchy staples. One hundred grams of the cooking banana supply roughly 6% of the Recommended Daily Allowance (RDA) for protein. Protein is required to the human body to supplies an adequate amount of required amino acids [24]. The crude protein level of the studied samples was also relatively lower when compared to other sources of protein-rich foods such as beans, gourd seeds and soybeans which ranges between 23% and 34% [25]. This suggests that consumers should consume protein-rich foods to supplement the protein deficit in bananas.

The fat content of the studied bananas ranged from 0.09 to 0.60 g/100 g which was significantly different. The present results are lower from findings of previous studies (2.34 g/100 g and 1.03–1.44 g/100 g) reported by Ohizua et al. [21]; Pragati et al. [22] and Vazquezshy et al. [16]. However, the values of the studied bananas were higher than the values for unripe banana (0.20 g/100 g) reported in the Tanzania Food Composition Tables (TFCT) by Lukmanji et al. [23]. *Njuru* had the highest value of fat content followed by *Makyughu* 2, *Muraru* white, *Kahuti* and *Muraru*. These may be good sources of fat-soluble vitamins and might also contribute substantially to the caloric level of cooked bananas. *Majimaji*, on the other hand, had the lowest value. The variation in the crude fat content of the cooking bananas may be due to the genetic differences in varieties and ecological reasons [17]. Despite the fact that the amounts of fat were generally low, variations among the varieties were statistically significant. One hundred grams of the evaluated bananas can provide not more than 4% of the

RDA for fat [15]. Banana-based foods and other low-fat diets can help lose weight and reduce the risk of serious medical conditions, including heart disease and diabetes.

The dietary fiber results of the varieties studied were significantly different. The fiber content of the studied bananas ranged from 0.92 to 2.79 g/100 g (Table 1). These findings are in sparing agreement with previous results for the dietary fiber content of unripe banana flour which ranged from 2.34 g/100 g and 2.75 g/100 g and 2.96 g/100 g reported by Anggraeni and Saputra [26] and Ohizua et al. [21] respectively. *Muraru* red was found to have the highest fiber content (2.79 g/100 g) followed by *Makyughu* 1 (2.70 g/100 g), *Akondro mainty* (2.48) and *Makyughu* 2 (2.47) while *Mchare laini* had the lowest fiber content (0.92 g/100 g). Dietary fiber plays a central role in human nutrition. It has been associated with increased removal of impending mutagens, and also helps control blood sugar levels; maintains bowel health, not to mention lowering of the cholesterol levels [27]. A hundred grams of the studied banana might deliver 12% of the recommended allowance for dietary fibers. Tapsell et al. [28] reported that one of the recent dietary trends in nutrition and health is to consume low-fat and high-in-fiber food products. Consumers demand foods which show two main properties; (i) traditional nutritional aspects of the food, and (ii) additional health benefits expected from the regular ingestion [29]. Some of the studied bananas are rich in fibrous carbohydrates, which offer the named benefits.

Table 1 also presents variations in carbohydrate contents of the evaluated banana accessions. Results revealed the significant varietal difference ($p \leq 0.001$) in the mean values of carbohydrate. The carbohydrate content of the studied bananas ranged from 21.59 to 29.96 g/100 g. The content of carbohydrate was the most abundant among all proximate parameters analyzed. While *Huti* green had highest values of carbohydrate tailed by *Mchare laini, Mlelembo mchare, Makyughu* 2 and *Ijihu inkundu; Majimaji* had the lowest value. A similar pattern of results was obtained in a report by Aurore et al. [12] who found that carbohydrate content for the unripe bananas ranged from 21.80 to 32.00 g/100 g. One hundred grams of the assessed bananas can provide roughly 17% of the RDA for carbohydrate [15]. This suggests that studied bananas may be used to fight against hidden hunger and food security in banana growing regions. Moreover, some carbohydrates in cooking bananas are reportedly able to speed up the calorie-burning process in the body due to the available inherent short-chain fatty acids [30]. Studies have also found that this type of fatty acids can improve the body's ability to absorb nutrients, particularly calcium [31].

Potassium, calcium, iron and zinc

Potassium, calcium, iron and zinc concentrations were analyzed and results are presented in Fig. 1. Significant variations ($p \leq 0.001$) in mineral concentrations were observed. Potassium was found to be the most abundant element in all the varieties studied with the mean value of 410 mg/100 g (Fig. 1A). On the other hand, *Akondro mainty* had the highest iron and calcium concentrations (Fig. 1B and C), whereas *Makyughu* 1 had the highest potassium concentration (Fig. 1A) while *Ijihu inkundu* had the highest zinc concentration followed by *Akondro mainty, Makyughu* 1 *and Huti* green (Fig. 1D). The high levels of potassium obtained in this study make these cultivars useful to people with cardiovascular compromised conditions [32]. However, there was a wide variability in calcium content between *Akondro mainty* (6.07 mg/100 g) and the rest of the bananas analyzed which ranged from 2.59 to 4.55 mg/100 g. The reason for this variation might be the exceptional physiological ability of *Akondro mainty* to absorb the mineral [33]. Calcium is very important in the formation of strong bones and teeth, for blood clotting, growth, cell metabolism and heart function [4]. In TFCT, Lukmanji et al. [23] reported that the concentration of K, Ca, Zn and Fe of unripe bananas to be 465 mg/100 g, 2.00 mg/100 g, 0.10 mg/100 g and 0.60 mg/100 g respectively which are very close to what was observed in the present study. The average value obtained for zinc was rather the lowest for the mineral of interest in this study (Fig. 1). The levels of potassium, zinc and iron show a similar pattern with the findings from other studies on unripe bananas [12,24]. However, Ohizua et al. [21] reported 1.26 mg/100 g iron content of unripe bananas from other varieties, which was higher than the findings of the present study. Generally, iron serves as a carrier of oxygen to the tissues from the lungs by thrombocyte's hemoglobin, and as an integrated part of important enzyme systems in various tissues. Zinc, on the other hand, is present in all body tissues and fluids. Zinc is also an essential component of a large number of enzymes and it plays a central role in the immune system. Compared with the calcium level of the studied bananas, the level has been reported to be relatively higher in other unripe varieties as well as in plantains [12,24]. Of specific importance, while focusing on the nutritional significance from staple food crops is the contribution of micronutrients, which are widely reported to be deficient and causing severe public health concerns in low-income communities in Tanzania and Africa in general (Tanzania Demographic Health Survey – Malaria Indicator Survey, 2016). Deficiencies of iron and zinc are core public health concerns, especially for child and maternal health [34]. Cooking bananas contain very little amount of iron and zinc (Fig. 1C and D). Additionally, Frossard et al. [35] and Njoumi et al. [36] suggested that bioavailability of these minerals and other nutrients like protein from other sources such as beans, legumes, edible insects, poultry and meat is likely to be higher than from the cooking bananas. Therefore, banana-based diets could receive a boost with the addition of the mentioned sources to the diets to make them nutritionally balanced.

Physicochemical quality parameters

Total soluble solids (TSS), total titratable acidity (TTA), and pH were the quality parameters of interest in this study and results are summarized in Fig. 2. There was a significant varietal difference ($p = 0.001$) in the mean values of TSS for the

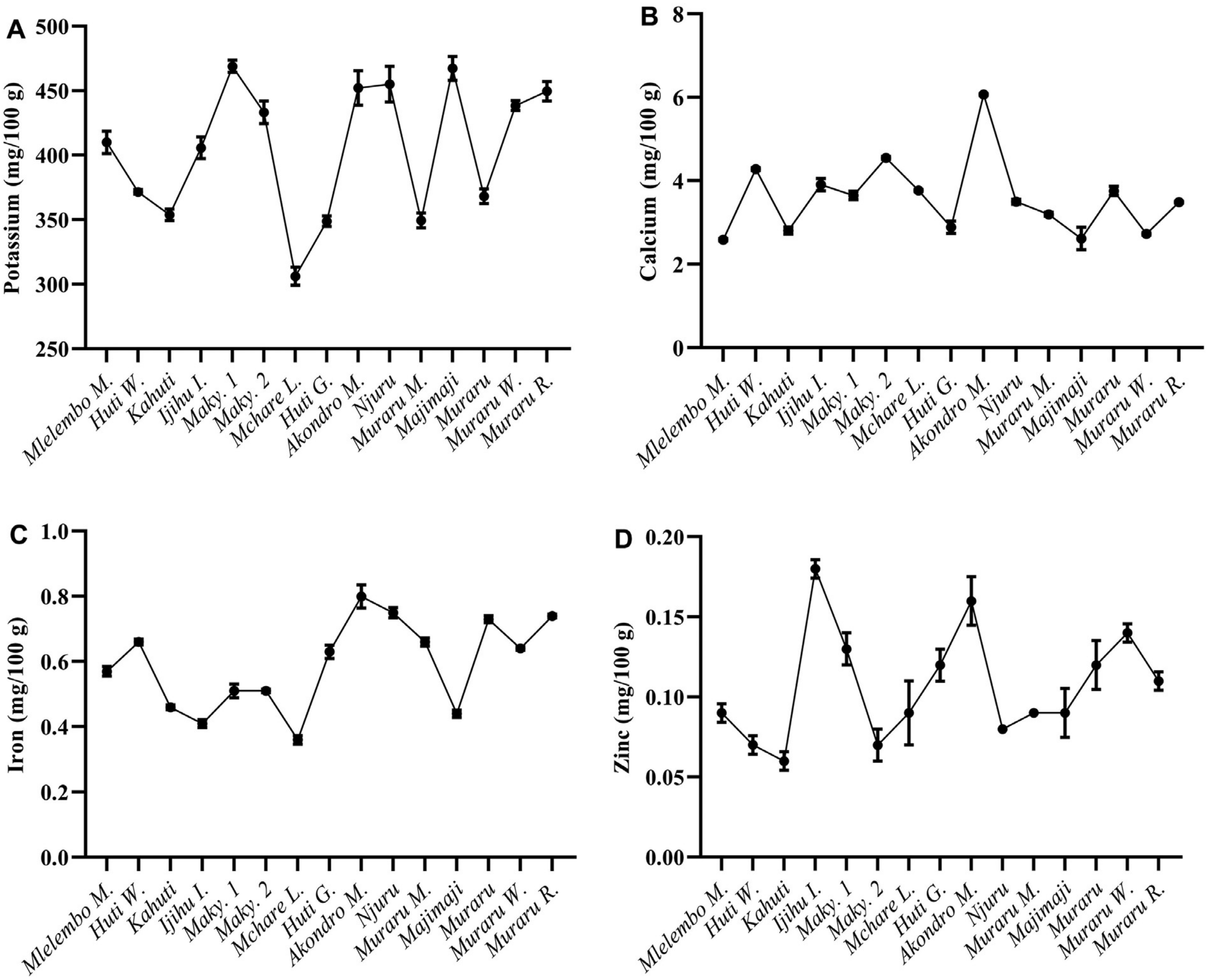

Fig. 1. The mineral contents: potassium (A), calcium (B), iron (C) and zinc (D) for the fifteen studied *Mchare* bananas.

studied varieties whose range was from 1.3 to 1.9° Brix (Fig. 2A). A similar finding was reported by Zulkifli et al. [37] for unripe *Musa acuminate* spp. with a range from 1.14. to 2.38° Brix. The TSS values of the present study was lower than the findings for unripe Cavendish bananas (2.00–6.00° Brix and 3.66–6.30° Brix) reported by Liew and Lau [38] and Aquino et al. [39], respectively. In principle, TSS indicates soluble solid content of the fruits, and high TSS has been linked with high sucrose concentration in fruit pulp, also together with dry matter and some other factors, TSS influences the taste of cooked bananas [40]. Contrary to the present study, Ferris et al. [41] and Muchui et al. [42] established that the TSS genotypic variation in banana fruit at the unripe mature stage is not significant, however, they added that the differences became more apparent as fruit ripened. Therefore, for tastier bananas, consumers are advised to cook semi-ripen or consume ripen bananas. Dadzie and Orjeda [43], on the other hand, clarified that any variation in TSS values in banana pulp might be because of the differences in textural and chemical contents of the pulp which could influence the TSS values of banana at unripe green stage 1 of maturity.

The TTA values for the *Mchare* bananas under study were statistically significant ($p = 0.05$). *Akondro Mainty* had the highest value of TTA, followed by *Muraru mchare, Ijihu inkundu* and *Kahuti* while *Muraru* white had the lowest value (see Fig. 2B). High level of acidity indicates that mentioned varieties contain high amount of malic acid in its pulp and vice versa. The pulp TTA results are consistent with the findings from [43] who reported malic acid content to be ranging from 1.5% to 2.5% at harvest for plantain hybrids and FHIA cooking bananas. Furthermore, the TTA parameter is essential for sensory attributes in cooked banana recipes. The TTA measures the total hydrogen ion concentration (both dissociated and undissociated), which is more relevant to the flavor than pH [44]. Similarly, varieties had a significant difference in pulp pH values. *Mlelembo mchare, Makyughu 2* and *Mchare laini* both had equal highest pH values, succeeded by *Huti* green and *Njuru* whereas Akondro mainty had the lowest pH value (Fig. 2C). According to Dadzie and Orjeda [43], the pH level presented in Fig. 2C paralleled the values for banana fruits at a maturity stage, this proves the nature of the fruit samples used in this study. This may, therefore, be used as a maturity indicator for banana harvesting [13]. Furthermore, both pH and titratable

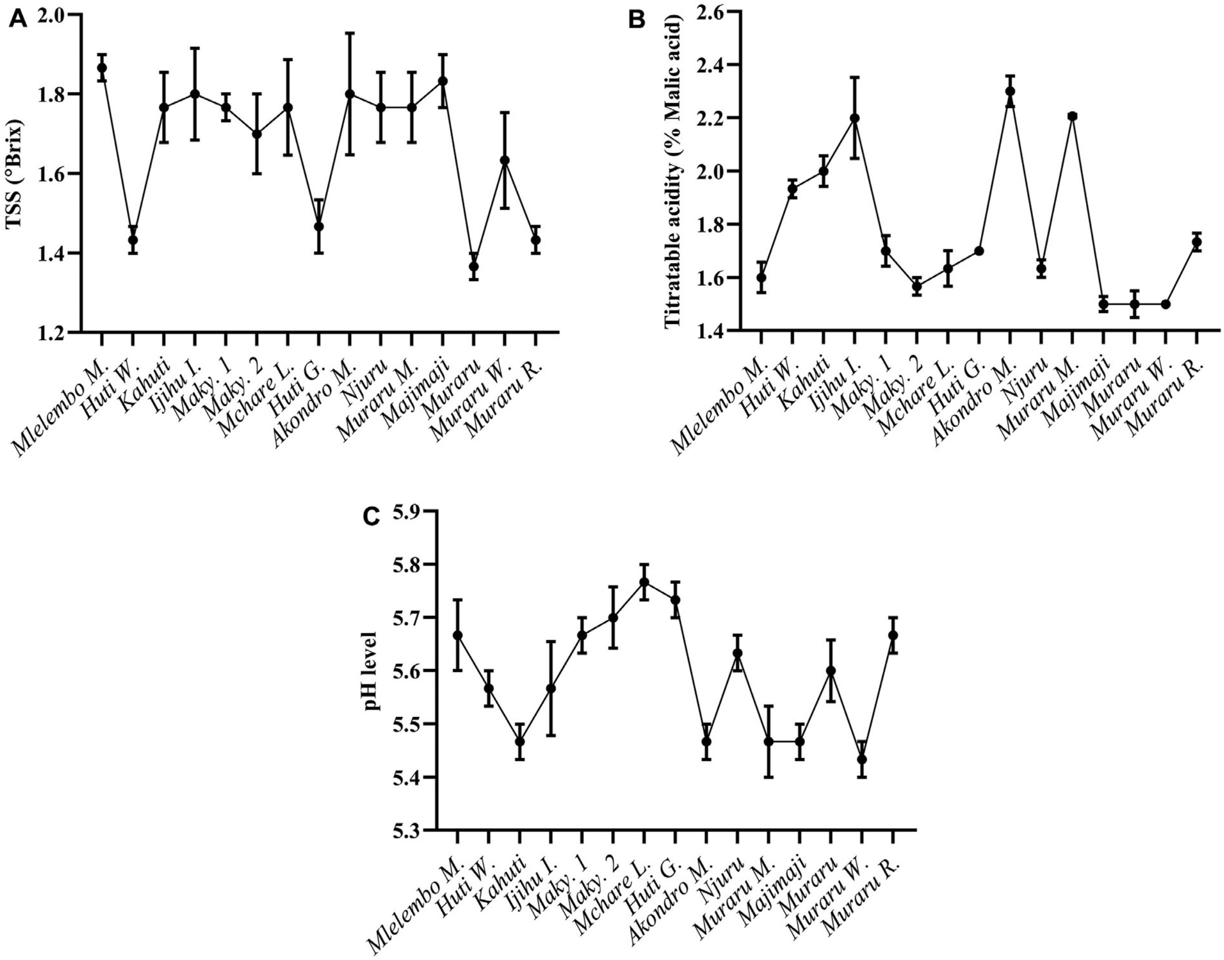

Fig. 2. Selected physicochemical quality parameters: total soluble solids (TSS) (A), total titrable acidity (TTA) (B) and the pH level (C) of the fifteen studied *Mchare* bananas.

acid are indicators for the number of organic acids and inherent salts contained in a fruit [45], the higher the value of the parameter, the higher the amount of acids and salts. Adding to that, Daniells [32] reported that both parameters affect gel formation during the cooking process, hence they determine the final texture and mouthfeel of the cooked bananas.

Conclusion

The present study was designed to provide an overview of the nutrient composition and physicochemical parameters of fifteen cooking bananas of *Mchare* family consumed in northern Tanzania. The results show that *Ijihu inkundu* had the highest ash, zinc and TSS values. The highest fat content of 0.60% was led by *Njuru; Makyughu* 2 contained the highest level of protein 1.75% and pH value while the water content of 74.78% led by *Majimaji.* The highest carbohydrate content of 29.96% was observed in *Huti* green while highest dietary fiber content amounted to 81% was found in *Muraru* red. *Makyughu* 1 contains the highest concentration of potassium 469 mg/100 g; *Akondro mainty* had the highest content of calcium, iron and total acidity 6.07 mg/100 g, 0.80 mg/100 g and 2.3%, respectively, while *Mlelembo mchare, Makyughu* 2 and *Mchare laini* had highest pH among studied varieties. With these findings, it is suggested that nutritional and sensory parameters should be given a top priority to future strategies in banana breeding programs for improvement. In addition, further understanding of the cultivars chosen by consumers, which would result from their uses and preferences is of specific importance for that matter. Findings from the present study could be crucial to be considered in the national food composition database of Tanzania for enhancing its value.

Declaration of Competing Interest

None.

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