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EVALUATION OF NUTRIENT CONTENT IN RED KIDNEY BEANS, AMARANTH LEAVES, SWEET POTATO ROOTS AND CARROTS CULTIVATED IN RWANDA

Kambabazi MR*[1], Okoth MW[1], Ngala S[1], Njue L[1] and H Vasanthakaalam[2]

Marie-Rose Kambabazi

*Corresponding author email: marierosekambabazi@gmail.com

[1]Department of Food Science, Nutrition and Technology, University of Nairobi, P.O. Box 29053-00625, Nairobi, Kenya

[2]Department of Food Science and Technology, University of Rwanda, P.O. Box 210, Musanze, Rwanda

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ABSTRACT

No data exist on the nutrient composition of some important Rwandan staples. The aim of this study was to evaluate the nutrient content of red kidney beans, sweet potato roots, amaranth leaves and carrot roots. About 6 kg of each raw material were cleaned and conditioned prior to mechanical drying, ground and sieved [60-mesh] into flour and then subjected to quantitative analysis for proximate content, energy, calcium (Ca), iron (Fe), zinc (Zn), vitamin A and vitamin C. Proximate composition determination was done using Near Infrared Spectroscopy (NIRS), carbohydrates were determined by difference, energy was calculated, mineral analysis was done by Atomic Absorption Spectroscopy (AAS) and vitamin analysis was performed by High Performance Liquid Chromatography (HPLC) methods. The results showed that red kidney beans, sweet potato roots, amaranth leaves and carrots contain 21.48, 6.66, 29.46 and 13.8% of protein; 2.58, 1.68, 7.89 and 2.08% of fat; 60.86, 79.13, 19.29 and 57.38% of carbohydrate; 2.33, 2.68, 8.98 and 9.63% of fiber; 8.82, 8.74, 10.08 and 8.88% of moisture content; 3.94, 1.11, 24.30 and 5.16% of ash; 357.2, 363.7, 284.0, 322.9 kcal/100 g of energy; and 146.4, 182.7, 26,290 and 1,247 mg/kg of calcium, respectively. Red kidney beans, amaranth leaves and carrots contained 8.54, 30.48, and 15.55 mg/kg of zinc; and 21.36, 219.1 and 8.81 mg/kg of iron, respectively. Zinc and iron were, however, not detected in sweet potato samples analysed. Red kidney beans, sweet potato roots, amaranth leaves and carrot contained 768.0, 10,880, 399.4, and 6,413 IU/100 g of vitamin A; and 2.67, 30.99, 330.3 and 6.76 mg/100g of vitamin C, respectively. In conclusion, the staples analysed contained appreciable amounts of nutrients and could be used to overcome malnutrition and allow dietary diversity. It could be recommended to prepare a Rwandan food composition database in order to improve awareness on local grown crops' quality.

Key words: Amaranth leaves, Carrots, Nutrients, Red kidney beans, Sweet potato roots

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INTRODUCTION

Rwandan food insecure households particularly in rural areas are forced to depend on monotonous and poor diets due to inability to afford a balanced diet, ignorance, postharvest losses of fresh produce, and so on. Lack of food composition data for locally grown crops is also a challenge in the formulation of nutritious diets. All these are the factors contributing to the high prevalence of malnutrition in Rwanda among under- 5 year- old children, where 35% are stunted, 2% wasted and 12.6% underweight [1] mainly due to inadequate complementary food intake and low dietary diversity [2]. There is a need to formulate nutrient-rich shelf stable food products that are convenient and affordable to all. Food processing is applied to enhance nutritional value, preserve foods, add convenience, enhance food safety, improve flavour, and save energy.

Red kidney bean is an excellent source of vegetable protein, carbohydrates, vitamins, dietary fiber and minerals [3]. In an average Rwandan diet, beans provide 32% of energy intake and approximately 65% of protein intake, whereas animal source foods provide only 4% of protein intake. The HarvestPlus varietal adoption survey reported that nearly all (99.9%) rural households consumed beans in the past 7 days prior to the interview, with an average bean consumption frequency of 6 days a week [4]. Blanching, soaking and dehulling reduce tannin content and trypsin inhibitor activity while cooking decreases the phytic acid content and, therefore, increases nutrient availability and improves protein digestibility [5].

Sweet potato is considered an important crop in Rwanda and serves as food for domestic consumption and family income. Uganda is the biggest sweet potato producer in Africa followed by Rwanda and Burundi. The actual per capita consumption varies between 90 – 100 kg and 100 – 300 kg in Uganda and Rwanda, respectively [6]. Sweet potatoes have high nutritional value, and they are a source of carbohydrates, protein, vitamins, and minerals [7].

Amaranth leaves are a good source of protein, calcium, iron and vitamin C [8]. Leafy vegetables deteriorate rapidly after harvest and, therefore, require proper postharvest handling to preserve the quality.

Carrot is a root vegetable rich in β-carotene, vitamins, minerals and dietary fiber. However, fresh carrots wilt rapidly after harvest under inappropriate storage conditions; thus, drying has been used to extend shelf-life and preserve nutritional quality [9]. The current study aims at evaluating nutritional content of red kidney beans, sweet potato roots, amaranth leaves and carrot roots that are important food items produced in Rwanda but whose processing is almost non-existent and their nutrient composition have not been determined.

MATERIALS AND METHODS

Food materials

Samples were purchased locally from Kigali city, Kimironko and Kabuga markets. From each of the markets, 2 kg each of dried red kidney beans, fresh sweet potato

roots, fresh amaranth leaves and fresh carrots were purchased. The samples were transported in separate containers for preliminary preparations before being transported to the University of Rwanda, College of Science and Technology laboratories for dehydration and further processing. Red kidney beans were sorted to remove impurities and blanched in boiling water for 30 min and then rinsed 3 times with tap water before soaking overnight, beans were then dehulled [5] and dried in an oven at 60 °C for 10 hours. Fresh sweet potato roots were peeled, rinsed 3 times with tap water, sliced and soaked in 1% vinegar for 10 min to prevent browning [10] and then mechanically dried at 60 °C for 8 hours. Amaranth leaves were rinsed 3 times with tap water and then chopped before blanching in boiling water for 3 minutes [11]. They were mechanically dried at 55 °C for 8 hours. Carrots were peeled, rinsed 3 times with tap water, peeled, sliced and blanched in boiling water for 5 minutes [12] before dehydration at 60 °C for 12 hours. All the samples were mechanically ground, sieved to pass 60 mesh sieves, dried to the moisture content of less than 14%, and transported to Rwanda Standards Board (RSB) chemistry laboratories for nutrient analysis.

Nutrient analysis

Proximate analysis of the samples

For protein, moisture, fiber, fat and ash content determination, NIRS (Foss DS2500, Höganäs) was used [13]. Carbohydrate content was determined by difference:

Percentage Carbohydrates = 100 – (% Protein + % fat + %moisture +% fiber + %ash), all on a dry weight basis.

Energy content was calculated using the following formula [14].
Gross energy (Kcal/100g) = (4 × % Protein) + (4 × % Carbohydrate) + (9 × % Fat) + (2 × % Fiber)

Calcium determination

AAS (AAnalyst 800, PerkinElmer, Ohio) was used [15].

Iron and Zinc determination

Flame Atomic Absorption spectroscopy (240FS AA, Agilent Technologies, Santa Clara) was used according to the standard method AOAC, 2005 method 999.10.

Vitamin A determination

HPLC (Agilent Technologies 1260 Infinity, Santa Clara) with RP C18 column at 254 nm followed the standard method [16].

Vitamin C determination

HPLC (Agilent Technologies 1260 Infinity, Santa Clara) with ACE 5 C18 column using UV detector at 254 nm followed the method described [17].

Statistical analysis

All data were analysed by analysis of variance (ANOVA) at 5% level of significance. Differences in mean values were determined using step wise comparison method (Tukey). Data were set and analysed by SPSS version 16.

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RESULTS AND DISCUSSION

Proximate composition

The proximate composition of the ingredients analysed revealed appreciable results which are presented in Table 1.

Moisture content

The moisture content of the staples was less than 14%. These results confirm that the food crops analysed were shelf-stable because the environment did not favour microbial growth and insect infestation [18].

Protein Content

Protein is an essential macronutrient and the adult body requires 0.7 - 0.8 g/kg body weight/day unlike the growing infants and teens who require 1.5 – 2 g/kg body weight/day. Red kidney beans are a rich source of vegetable protein [19] and processing methods such as blanching, soaking, dehulling and dehydration do not significantly decrease the protein content as reported by Chaudhary R and S Sharma [5]. The finding in the present study of 21.48% is within the range (16.54% to 25.23%) previously reported [20]. All these results revealed that red kidney beans grown in Rwanda are rich in protein and the traditional processing methods did not affect the protein content. Sweet potato roots are poor in protein and they contained 6.66% in the present study [7]. A similar study reported that protein content in sweet potato roots was in the range of 1.73–9.14% on a dry weight basis and of good quality [21], which confirms the present results. Amaranth leaves are high in protein content and when combined with legumes the protein content increases. In the present study, protein was 29.5%. This was confirmed by previous research studies that reported 19.4% - 30% in amaranth leaves on dry weight basis [22]. Protein content in carrots found in the present study was 13.8% and was similar (12.69%) to another study [23]. Drying of foods concentrates the proteins, fats, and carbohydrates [24]. The differences observed may be due to soil composition or fertilizer [21].

Fat content

Red kidney beans are very low in fat [19]. The present study revealed that they were as low as 2.58%. These results corroborate with 2.52% fat content reported in similar studies [3, 25]. The sweet potato roots analysed in the present study contained 1.68% of fat, which is in agreement with 1.62% reported previously [14]. In general, sweet potato roots are low in fat [7]. The fat content of amaranth leaves analysed in the present study revealed 7.89%. The results were close to 7.56% obtained by other researchers [26]. Fat content in carrot roots was 2.08%. A lower value of 1.79% was previously reported on carrot powder [24]. Fats serve as energy reserves, as a source of essential fatty acids and as a solvent of vitamins [7]. This indicates that if carotenes have to be absorbed by the body, it should be accompanied by fat that can be added during processing for consumption.

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Carbohydrates

Beans are an excellent source of carbohydrates as demonstrated in the present study (60.86%). Other similar studies in East Africa conducted on different bean varieties confirmed these findings (62.7%) [5] and 59.01 to 61.59% [25]. Carbohydrates are also the main macronutrient in sweet potato roots and confirmed as 79.13%. Amaranth leaves contain low carbohydrate [8]. The present study found 19.29% which is in the same range with the values (10.20 – 25.68%) previously reported on different processed amaranth leaves [26]. Carbohydrate content in carrots in the present study was 57.38% dry weight; however, higher content (68.3%) has been reported [23]. The difference may be due to processing conditions and analysis methods. Carbohydrate plays a crucial role in the human body especially by providing energy for daily activities and growth of infants and children [7].

Fiber

Dietary fiber is a plant-based carbohydrate unlike sugars and starch that are easily digested. They play a vital role in gut health by maintaining the dynamism of the microflora in the intestine. In the present study, fiber was 2.33% in red kidney beans, 2.68% in sweet potato roots, 8.98% in amaranth leaves, and 9.63% in carrots. Similar studies conducted elsewhere indicated that the fiber content in red kidney beans was 2.3% [19], sweet potato roots was 3% [21] and amaranth was 8.61%. All these indicate that the present study gave similar results with others. The health benefits of eating a fiber-rich diet are many including regulation of blood sugar, protection against heart disease, prevention of constipation and prevention of certain forms of cancer [27].

Ash

Ash refers to the inorganic residue that remains in a food sample after complete oxidation of organic matter. The inorganic residue consists mainly of the minerals present in the food, an important quality attribute for some food ingredients. The ash content found in locally grown red kidney beans was 3.94% which compared with 3.6% in a similar study [5]. Sweet potato roots in the present study was 1.11%; similar results from analysed varieties ranged from 1.06% to 1.16% [7]. Ash content in amaranth was higher (24.30%) than what was observed in another study (16.33%) [26]. Carrot ash content in the present study was 5.16%. Previous studies reported a higher value of 6.4% [24]. Differences in ash content may be due to several factors such as plant age at harvest, or the mineral fertilizer used, soil mineral composition, and the proportion of individual mineral absorption by each plant [26].

Energy

The human body derives its energy from food and there is energy stored for both voluntary and involuntary activities. Red kidney bean is a good source of energy for consumers, particularly young children [28]. Of all the foods studied in this research, the energy value was high in sweet potato roots (363.7 kcal/100 g) and low in amaranth (284.0 kcal/100 g). Rwanda is a high consumer of beans and it can be argued that it contributes a lot to the energy needs of the population, especially among the poor. The present study found 357.2 kcal/100 g in red kidney beans, which was slightly higher than 332.5 kcal/100 g reported [29]. Sweet potato roots provided 363.7 kcal/100 g which was within the range of 363 - 374.1 kcal/100g reported on others [30]. The

energy content in carrots was 322.9 kcal/100 g and closely compared to 336 kcal/100 g [23].

Mineral content

The locally grown foodstuffs studied were analysed for selected mineral content and their results are presented in Table 2.

Calcium (Ca)

Calcium supports structures and provides firmness to the human body. Calcium is the basic mineral component of bones and teeth. It takes part in blood coagulation processes and is essential for the proper functioning of nerves and muscle contractions [31].

Calcium was quite high in dried amaranth (26,290 mg/kg) and low in beans (146.4 mg/kg). An earlier study reported 161.8 mg/kg in beans [32]. The difference in the values may be varietal. Sweet potato roots are fairly rich in calcium [31] and were found to contain 182.7 mg/kg in the present study. Calcium content in similar studies on amaranth varied between 15,120 mg/kg and 23,810 mg/kg in dried amaranth leaves [33].

Zinc (Zn)

Zinc is required for metabolism, wound healing, growth and vision and enables the proper functioning of the human body by fortifying the immune system [32]. The present study indicated that amaranth had high content of zinc (30.48 mg/kg) and it was half the quantity in carrots (15.55 mg/kg), which was half in beans (8.54 mg/kg), and not detected in sweet potato roots. Similar zinc content was reported in red kidney beans 7.11 mg/kg [32]. However, differences could be due to genotypes and environmental conditions. Analysis of numerous dried amaranth leaves revealed that zinc content ranged between 10.3 mg/kg and 34.6 mg/kg [33]. The present study's finding was within this range.

Iron (Fe)

Dietary iron exhibits as haem and non-haem iron. Plant-based foods provide non-haem iron. In this study, amaranth leaves had the highest quantity of 219.1 mg/kg, followed by 21.36 mg/kg in red kidney beans and 8.81 mg/kg in carrots while absent in sweet potato roots. Amaranth being widely available and consumed in Rwanda is a good source of non-haem iron and it has been found in another study to range between 148.4 mg/kg and 311.7 mg/kg on dry weight basis [33]. Iron content in kidney beans was 21.36 mg/kg, and was in agreement with the value of 21.07 mg/kg previously reported [28]. Iron content in carrots was in agreement with values ranging between 4 mg/kg and 22 mg/kg previously reported [27].

Iron is an essential mineral in human health, playing a role in immune function, cardiovascular health and cognitive development. The differences in mineral composition may be a result of leaching of minerals into the blanching and soaking water, and the removal of the seed coat of the kidney bean. The removal of bran or seed coat has been implicated in the reduction of minerals in grains [28].

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Vitamin content

Vitamins are broadly classified based on their solubility as fat soluble and water soluble. In this research vitamin A, the fat-soluble vitamin, and vitamin C, the water-soluble vitamin, were studied in the four foodstuffs analysed. The results are shown in Table 3.

Common beans contain only small amounts of vitamin C, and little fat-soluble vitamins because of the low level of lipid. The vitamin content measured in common beans varies widely depending on commercial market classes, wet or dry, origin, environment and analytical methodology used for analysis. Findings from this study for both vitamin A and C in amaranth leaves were higher than those previously reported by Ramdwar MN *et al* [8] but lower than another study findings [11]. The differences can be justified by different amaranth varieties analysed, the environment in which they were grown, processing method, and the analytical methods used. Sweet potato roots are rich in vitamin C [14] and vitamin A [7]. The present study obtained 30.99 mg/100g of vitamin C. Slightly lower values (20.26 – 24.20 mg/100g) were previously reported [31]; while 17.3–34.5 mg/100 g which confirm the present findings were also reported in similar studies [21]. Vitamin A analysis on different processed sweet potato roots revealed that they ranged between 8699 IU/100 g and 15740 IU/100 g [21] which are in agreement with 10,880 IU/100g obtained in the present study. Orange carrots contain vitamin C in appreciable amounts. The present study found 6.76 mg/100 g of vitamin C. Previous studies reported 8 mg/100g [27] which is in accordance with the result of the present study. These variations may be due to the carrots' origins and the analytical methods. Orange coloured carrots are rich in carotene, a precursor of vitamin A. The vitamin A content of 1100 IU/100 g reported in a similar study [27] is less than the present finding, which was 6,413.1 IU/100g.

Vitamin A is essential for normal vision, maintaining the integrity of epithelial tissues and for a wide variety of other metabolic functions, while vitamin C plays an important role in the manufacturing of collagen, which is a connective tissue that holds bones together. It is used to maintain the integrity of the membranes by protecting molecules such as proteins, lipids, carbohydrates and nucleic acids from damage by free radicals, reactive oxygen species and reactive nitrogen species that are generated during normal metabolism and through exposure to toxic pollutants. It also modulates the absorption, transport and storage of iron [11].

CONCLUSION

Based on the findings of this study, red kidney beans grown in Rwanda are a good source of protein and carbohydrate. Sweet potato roots were rich in carbohydrates and vitamin A. Amaranth leaves were a good source of protein, ash, calcium, iron and vitamin C, while carrots contained appreciable amounts of fiber, calcium, and vitamin A. All samples were low in fat and the low moisture content indicates that they can be stored for a long time. The staple crops in Rwanda analysed could be used to develop composite flours for soup mixes to overcome micronutrient deficiencies, allow dietary diversity and reduce postharvest losses. This study further recommends the

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development of a Rwandan food composition database in order to ease complete diet formulation.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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Table 1: Proximate composition of red kidney beans, sweet potato roots, amaranth leaves and carrots

Sample name	Protein (%) dwb	Carbohydrate (%)	Fat (%) dwb	Fiber (%) dwb	Moisture (%)	Ash (%) dwb	Energy (kcal/100 g) dwb
Red kidney beans	21.48^{a} ± 0.09	60.86^{a} ± 0.902	2.58^{a} ± 0.06	2.33^{a} ± 0.04	8.82^{a} ± 0.06	3.94^{a} ± 0.02	357.19^{a} ± 0.438
Sweet potato roots	6.66^{b} ± 0.05	79.13^{b} ± 0.012	1.68^{b} ± 0.01	2.68^{b} ± 0.02	8.74^{a} ± 0.04	1.11^{b} ± 0.05	363.65^{b} ± 0.153
Amaranth leaves	29.46^{c} ± 0.15	19.29^{c} ± 0.26	7.89^{c} ± 0.04	8.98^{c} ± 0.09	10.08^{b} ± 0.04	24.30^{c} ± 0.28	283.96^{c} ± 0.644
Carrot	13.8^{d} ± 0.08	57.38^{d} ± 0.23	2.08^{d} ± 0.04	9.63^{d} ± 0.14	8.88^{a} ± 0.01	5.16^{d} ± 0.02	322.89^{d} ± 0.123

Means followed by the same letter in a column are not significantly different at p≤ 0.05
Values are means of triplicate readings
dwb:*" dry weight basis"*

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Table 2: Mineral content of red kidney beans, sweet potato roots, amaranth leaves and carrots

Sample name	Calcium (mg/kg on dwb)	Zinc (mg/kg on dwb)	Iron (mg/kg on dwb)
Red kidney beans	146.4[a]	8.54[a]	21.36[a]
Sweet potato roots	182.7[a]	nd	nd
Amaranth leaves	26,290[b]	30.48[c]	219.1[b]
Carrots	1,247[c]	15.55[d]	8.81[a]

Means followed by the same superscript s in a column are not significantly different at p≤ 0.05. Values are means of triplicate readings
Nd: *"Not detected"*
dwb: "dry *weight basis"*

Table 3: Vitamin content of red kidney beans, sweet potato roots, amaranth leaves, carrot

Sample name	**Vitamin A (IU/100 g)**	**Vitamin C (mg/100g)**
Red kidney beans	768.0 ± 14.8	2.67 ± 0.30
Amaranth leaves	399.4 ± 10.9	330.3 ± 1.28
Sweet potato roots	10,880 ± 246.2	31.0 ± 0.42
Carrots	6,413 ± 188.3	6.76 ± 0.17

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