Food Science and Quality Management
ISSN 2224-6088 (Paper) ISSN 2225-0557 (Online)
Vol.123, 2024

DETERMINATION OF THE NUTRITIONAL VALUE OF YAM TUBERS (DIOSCOREA ALATA L., VARIETE IKIVUZA), A NEGLECTED VARIETY FOUND IN BURUNDI

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Abstract
Knowledge of the nutritional value of a diversity of food crops can play a large role in the food and nutritional security of populations. The present study was carried out to determine the nutritional value of yam tubers (*ikivuza* variety) a neglected variety found in Burundi. To achieve this, yam tubers were collected to undergo physicochemical laboratory analyzes for macronutrient and mineral salt contents. For yam tubers, the overall average macronutrient contents varied from 7.8%, respectively; 0.45% for proteins and fat, while the average contents of mineral elements were respectively 1051.7 mg/kg; 335.5 mg/kg; 5826 mg/kg; 26.29 mg/kg; 9.46 mg/kg and 7.67 mg/kg; for phosphorus, magnesium, potassium, iron, copper and zinc. All these results show that these crops contain a significant proportion of nutrients and their valorization would be a sustainable way to fight against food insecurity.
Keywords: Burundi, Yam, Nutritional value
DOI: 10.7176/FSQM/123-07
Publication date: October 30th 2024

1. Introduction

Burundi is a landlocked country in the heart of Africa's Great Lakes region, between the Nile Basin to the east and the Congo River Basin to the west, which flows into Lake Tanganyika. Burundi's economy is dominated by small-scale, essentially rain-fed subsistence farming, practised by over 90% of the total population and occupying 50% of the country's surface area, with an average income of US$200 (World Bank,2023). This low level of income could be explained by under-exploited or rather neglected food resources and ignorance on the part of the population. Neglected or under-utilized crops offer considerable potential for increasing food production, ensuring food security for the population, covering healthcare needs and contributing to the effort to reduce poverty (Kahane et al., 2013; Mayes et al., 2012). Agronomic research is generally based on a small number of so-called major crops (rice, wheat, maize, cassava), which increasingly form the basis of global food security (ISABU, 2012). Some other crops remain neglected not only by research or extension services, but also by the population, who do not grow and/or consume them due to prejudice or poor taste. It is therefore timely to find ways of adding value to these neglected and under-utilized food crops in Africa in general, and in Burundi in particular.

Among the neglected or under-utilized food crops in Burundi is the yam. This tuberous plant has long been cultivated in Burundi, but is currently neglected on a small scale, and its consumption is only accepted by a small proportion of the population. Its nutritional value has not yet been studied in Burundi. The overall aim of this study was to determine the nutritional potential of Dioscorea alata yam tubers, ikivuza variety, with a view to their future valorization.

2.Materials and methods

2.1. Plant material

In this study, tubers of yam Dioscorea alata L., variety ikivuza, harvested in the experimental fields of the University of Burundi in Gitega and Bujumbura were used. They were analyzed for nutrient content in the laboratory. Figure 1 shows the tuber samples used in this study.

Figure 1. Yam tubers used for nutrient analysis (tubers harvested in Gitega and Bujumbura on the left and right respectively), photos taken in July 2022.

2.2. Methodology

In this study, tubers harvested from experimental fields set up on the Zege university campus in Gitega and the Mutanga university campus in Bujumbura were used. In each of the two fields, three tubers were peeled and then cut into two pieces. One part was cooked, while the other was kept raw.

The Bujumbura yam growing field was located at the Mutanga university campus, at 03° 22' 39" south latitude and 029° 23' 03.5" east longitude. This site is located in the Imbo natural region, a region known for being the hottest in Burundi and one of the least rainfed in Burundi. In fact, the average annual temperature in this region is between 23 and 24°C, while the average annual rainfall is between 800 and 950 mm. The climate of the Imbo region is of type (AW4)S according to Köppen's classification.

The Gitega yam-growing field was established on the university campus, located at 03° 24' 2" south latitude and 029° 55' 32" longitude and situated in the Kirimiro natural region in the central plateaus. Gitega's climate is of

the (CW3)S type according to Köppen's classification. The average daily temperature is 20°C, while the annual rainfall is 1130 mm.

After grinding, the samples were analyzed at the Laboratoire d'Analyse des Sols et des Produits Agro-Alimentaires (LASPA) of the Institut des Sciences Agronomiques du Burundi (ISABU). Analyses were carried out for water, ash, fat, total protein, carbohydrates and mineral elements (potassium, calcium, sodium, copper, magnesium, manganese, zinc, phosphorus and iron). The analysis methods used are those in force at LASPA. As a reminder, water content is determined by the oven-drying method. Ash is obtained by incinerating a test sample at 550°C. Fat is extracted by ether soxlet. Total protein is determined using the Kjeldahl reference method. The carbohydrate content is obtained by the difference between the dry sample weight and the sum of the protein, lipid and ash weights. Spectrophotometric and colorimetric determination of minerals was carried out after sample mineralization. Sample grindings were solubilized by acid etching on a sand bath, using concentrated nitric acid and hydrogen peroxide. Potassium, calcium, sodium, copper, magnesium, manganese and zinc were determined by atomic absorption spectrophotometry, and phosphorus and iron by colorimetry.

2.3. Statistical analysis

The experiments were conducted in triplicate and the results were expressed as mean with standard deviation. Statistical analysis of the data was performed using SPSS Package Program. Statistical significance was taken at 95% confidence interval when $p<0.05$. When Analysis of Variance (ANOVA) revealed a significant effect ($p<0.05$), the data means were compared by the least significant difference (Duncan's Multiple Range test) test.

3. RESULTS AND DISCUSSION

3.1. Dry matter, total ash, protein and fat contents

The average dry matter, total ash and macronutrient (protein and fat) contents of fresh and cooked tubers harvested in Bujumbura and Gitega are shown in Table 1.

The overall aveage dry matter content was 38.92±4.82%. Dry matter ranged from36.5±3.3% to 41.6±4.5%,with the highest content in fresh tubers that were harvested in Gitega and the lowest in cooked tubers harvested in Bujumbura.ANOVA analysis of these resultats showed there was no significant difference between tubers harvested in two regions (Gitega and Bujumbura) and between fresh ans cokked tubers for this parameter ($P > 0.05$).Overall these results are significantly higher then those obtained by Behera et al.(2009) from yam whose results ranged from 24.91% to 33.33%.

In the yam tubers analyzed in this study, the overall mean total ash content was 4.57±3.05. The average total ash content ranged from 7.98±4.94% to 2.92±0.81% for Gitega and Bujumbura respectively. The highest content was found in cooked yam tubers from Gitega, while the lowest content was found in cooked yam tubers from Bujumbura.

Furthermore, the Duncan test shows that the mean total ash contents of the two regions (Gitega and Bujumbura) do not differ significantly ($P > 0.05$). These results are lower than those found by Tchiègang et al (2009), which ranged from 4.53% to 5.43%.

The overall average protein content of all samples analyzed was 7.8% DM. This value confirms that yam tubers are the best sources of protein compared with other tubers commonly consumed in Burundi, such as cassava (1.3%) and sweet potato (1.7%) (FAO, 2001). The protein contents found through this study confirm that yam is an important source of protein, since it covers the WHO recommendations for daily protein consumption of 0.6g/kg/dr for adult men and women (pellet, 1990) and 1.52g/kg/dr for pregnant women (Stephens et al., 2014). Comparing tubers harvested in the two study regions for their levels of this nutrient by Duncan's test, we note that there is no significant difference ($p > 0.05$) between samples harvested in the two locations. Similarly, the effect of cooking on protein content was only observed in tubers harvested in Bujumbura ($p<0.05$). This content is very close to that found by Elenga et al. (2016) in yam porridge, which was 7.01%. It is clearly higher than that found in Madagascar in cooked tubers of the Dioscorea alata variety, which was 4.1% (Jeannoda et al., 2007).

The average fat content (FC) of the yam tubers analyzed ranged from 0.21±0.08% to 0.68±0.14%, while the overall average for this variable was 0.45% for both regions. The latter is comparable to the 0.4% fat content of Dioscorea alata tubers from Madagascar (Ranaivosoa et al., 2010). These results confirm that yam is a high-energy, low-fat food (Attaie et al., 1997). Comparing the two regions of tuber origin using Duncan's test, we found that there was a significant difference ($P < 0.05$) between the samples analyzed from one region to another. This means that tubers harvested in Gitega are richer in lipids than those from Bujumbura.

Table 1. Average dry matter, total ash, protein and fat contents of yam tubers (% DM).

Sample	DM%	AC%	Proteins	FC
BC	37,6 ± 6,97^{a}	2,92 ± 0,81^{a}	4,18±0,79^{b}	0,22±0,09^{b}
BF	36,5±3,29^{a}	2,98±0,14^{a}	9,06±2,2^{a}	0,21±0,08^{b}
GC	40±4,9^{a}	7,98±4,9^{a}	6,81±2,08^{ab}	0,66±0,18^{a}
GF	41,56±4,48^{a}	4,39±0,49^{a}	11,09±1,31^{a}	0,68±0,14^{a}
Global average	**38,92±4,82**	**4,57±3,05**	**7,8±3,1**	**0,45±0,26**

Where BC is cooked tuber harvested in Bujumbura; BF: raw tuber harvested in Bujumbura; GC: cooked tuber harvested in Gitega; GF: raw tuber harvested in Gitega. Values are means ± standard deviations. Means followed by the same superscript letter in the same column are not significantly different ($P < 0.05$) at the 5% threshold.

3.2. Mineral content

The mineral element contents (P, Mg, K, Fe, Cu and Zn) of the samples analyzed in this study are shown in Table 2.

3.2.1. Phosphorus content

The overall average phosphorus content obtained was 1051.7 mg/kg DM (Table2). This value does not differ greatly from that found by other research, notably that of Akin-Idowu et al. (2009), who found an average

phosphorus content for yam tubers of 1331.3mg/kg. The recommended dietary allowance for phosphorus is 800mg/d (Potier et al., 2003). The content found in tubers is therefore suitable for human consumption.

3.2.2. Magnesium content

The overall mean Mg content of the samples is 335.5 mg/kg DM (Table 2), a value close to the results found 478.3 mg/kg DM by Wu et al. (2016). Thus, the values recorded are suitable for the recommended magnesium intakes of 80 to 410 mg/d for a child and 420 to 460 mg/d for an adult (Szekely ,2009; CSS, 2009).

3.2.3. Teneur en potassium/ Potassium content

The results of potassium analysis in yam samples (Table 2) show that the tubers analyzed have an overall mean potassium content of 5826±2581.48 mg/kg. Such values are higher than those found in yam tubers 475±1475 mg/kg by Polycarpe et al. (2012). Compared with cassava roots, which contain 271mg potassium (Salvador et al. (2014), yam tubers are considerably richer in this mineral. For this element, Duncan's test at the 5% threshold reveals no significant difference between the two sample categories. The recommended daily intake for potassium is 800 to 5000 mg/d for children and 3000 to 4000 mg/d for adults (Szekely, 2009; CSS, 2009). Yam is therefore a good source of potassium.

3.2.4. Iron content

The overall mean iron content of the samples was 26.29±11.69 mg/kg DM (Table 2). These results are comparable to those found 15.18 to 30.86 mg/kg by researchers such as Oko and Famurewa (2015). Because of the wide dispersion of values within sample categories, Duncan's test at the 5% threshold shows no significant difference between these categories ($p>0.05$). Daily iron requirements for men and women are 1mg and 2mg respectively (Valdiguie, 1995). Yam is therefore a good source of iron and can contribute to consumers' well-being in terms of meeting their iron requirements.

3.3.4. Copper content

The average copper content of the yam tuber sample categories analyzed was 9.46±5.13mg/kg DM. These results are lower than those of Baah et al (2009), who found an average copper content of 12.3 to 15.7 mg/kg in yam tubers. However, given the needs of the human organism, yams can be a good source of copper, as the recommended dietary intake of copper is 1.5 to 3.0 mg per day for adults (Pettersson and Rasmussen, 1999).

3.2.5. Zinc content

The average zinc content of yam tuber samples was 7.67±4.85mg/kg DM (Table 2). This value differs markedly from the results found by other authors, notably Sohore (2011), who recorded average zinc contents ranging from 1 to 2.4mg/kg in yam tubers. Yam can therefore be a source of zinc to cover nutritional needs, as daily requirements are 1.6 to 3.6 mg/d for children and 4 to 5 mg/d for adults (Ekissi et al., 2020).however, for a pregnant woman, daily requirements are estimated at 14 mg, an increase of 4 mg over the normal requirements of an adult woman (Costello & Osrin, 2003).

Table 2: Average mineral content of yam tubers (mg/kg DM)

Sample	P	Mg	K	Cu	Zn	Fe
BC	880 ±233^{bc}	472 ± 122^{a}	4897,33 ± 1785^{a}	7,24±2,19^{ab}	9,41±6,5^{a}	24,13±14,1^{a}
BF	1563,66±168,5^{a}	456,33±0,08^{a}	6644,33±4833^{a}	15,24±8,12^{a}	9,36±3,68^{a}	35,8±13^{a}
GC	637,66±116,7^{c}	91,93±30,8^{b}	4369±331^{a}	6,58±0,5^{b}	4,66±2,16^{a}	16,76±2,11^{a}
GF	1125,66±268,18^{b}	320,33±101,01^{ab}	7394,66±903,27^{a}	8,77±1,83^{ab}	8,58±4,67^{a}	28,46±9,66^{a}
Global average	1051,75±397,97	335,15±192,06	5826±2581,48	9,46±5,13	7,67±4,85	26,29±11,69

Where BC is cooked tuber harvested in Bujumbura; BF: raw tuber harvested in Bujumbura; GC: cooked tuber harvested in Gitega; GF: raw tuber harvested in Gitega. Values are means ± standard deviations. Means followed by the same superscript letter in the same column are not significantly different ($P < 0.05$) at the 5% threshold.

4. Conclusion

Although the cultivation and consumption of yam, Dioscorea alata, Ikivuza variety is neglected in Burundi, the present study has just demonstrated its nutritional value. It is a good source of proteins and has the recommended quantities of minerals (potassium, phosphorus, iron, magnesium, zinc and copper). Its consumption could help meet human nutritional needs, combat food insecurity and correct certain micronutrient deficiencies. Given its high level of micronutrients and productive capacity, this crop should be developed and popularized in rural areas, where it can play an important role in household food security.

5. Acknowledgements

The authors express their gratitude to the University of Burundi for funding this study through the project “Increasing Agricultural Productivity through Intensification of Traditional Crops Currently Neglected in Burundi, Domestication, and Valuation of Their by-products for human and animal consumption (IDOVA)”.

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