Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT

SCHOLARLY, PEER REVIEWED

Volume 24 No. 7
July 2024

PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2024; 24(7): 26837-26857 https://doi.org/10.18697/ajfand.132.24095

Date	Submitted	Accepted	Published
	27th September 2023	12th June 2024	27th July 2024

POTENTIAL CONTRIBUTION OF KENYAN-GROWN QUINOA IN IMPROVING MACRONUTRIENT AND MICRONUTRIENT INTAKE IN CHILDREN AGED 2-6 YEARS IN KENYA

Thuku LN[1]*, Ngala S[1], Kaindi DWM[1] and W Kogi- Makau[1]

Linet Njeri Thuku

*Corresponding author email: linethuku@gmail.com

[1]University of Nairobi, Department of Food Science Nutrition and Technology, Nairobi, Kenya

ABSTRACT

The triple burden of malnutrition is a problem that is being fought against at global, continental, regional and national levels. When consumed in adequate quantities, healthy diets are important in reversing the menace of malnutrition. In Kenya, grains are an important source of energy and micronutrients. Even though they contribute most energy and micronutrients, a huge Recommended Daily Allowance deficit still exists. Incorporating ancient grains such as quinoa which are nutrient-rich and can survive in harsh climatic zones into the diets, can boost the efforts made towards the fight against malnutrition. Though quinoa adaptation trials have been conducted in Kenya, expanded data on the nutrient content are yet to be compiled. Between May 2022 and August 2022, four varieties of quinoa; Cherry Vanilla, Titicaca, Brilliant Bright Red and Biobio were grown at the University of Nairobi, Upper Kabete campus field station. The harvests of the four varieties were separately analyzed to determine and compare the content levels of macronutrients (carbohydrates, crude protein, fats) and micro-nutrients (manganese, magnesium, potassium, calcium, iron, copper and zinc). The four varieties were significantly different in all the analyzed elements except moisture content. Cherry vanilla had the highest level of crude protein (25.1±0.3g/100g) and fat (11.46±0.184g/100g) but the lowest level of carbohydrates (42.5±0.4%). Titicaca had the highest amounts of; manganese (21.9±0.06g/100g), potassium (511.9±0.03mg/100g), iron (11.5± 0.07mg/100g) and zinc (14.1±0.0mg/100g). Biobio variety exhibited the highest amount of magnesium (73.9±0.1mg/100g). In conclusion, the different varieties of quinoa significantly differ in their levels of macro and micronutrients. The Kenyan-grown quinoa has the potential to contribute to increased dietary intake of both macronutrients and micronutrients of children aged 2-6 years old. The Kenyan-grown quinoa contains levels of micronutrients in higher amounts compared to maize, rice and wheat - the commonly consumed cereals in Kenya. On this basis, the study recommends that the growing and consumption of quinoa should be promoted in Kenya and introduced into the diets of children aged 2-6 years of age in Kenya. Quinoa-based products for children aged 2-6 years should be developed. Climate zone-oriented agronomic trials on quinoa farming should be conducted.

Key words: Quinoa, varieties, Cherry Vanilla, BBR, Titicaca, Biobio, micronutrients, macronutrients

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 7
July 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

INTRODUCTION

Over the past three decades, significant effort has been made to battle the triple burden of malnutrition which encompasses undernutrition, overnutrition and micronutrient deficiency. According to the Joint Child Malnutrition Estimates of 2020, globally, 149 million children under the age of five were stunted, 45 million were wasted, and 39 million were overweight. Among the under-fives, Africa has a stunting prevalence of 29.1% and Kenya stands at 18%. Stunting prevalence in some counties in Kenya is higher than 30% (Kilifi 37%, West Pokot 33.5%, and Samburu 31%), while the wasting rate might be as low as 1% [1].

According to UNICEF 2019, at least 50% of under-fives worldwide experience vitamin and mineral deficiency [2]. Iodine, vitamin A, zinc, and iron deficiency are the most significant in public health globally. This is because micronutrient inadequacies significantly impede the healthy development of individuals and populations at large, particularly among children and pregnant women in developing countries [3]. Comparing the results from two micronutrient surveys, 1999 and 2011, the micronutrient status of the Kenyan population has significantly improved. This is with the exception of zinc deficiency, whose prevalence rose in all categories as follows: Among the children, the prevalence rate rose to 82% from 50% in 1999. In adults, a rise of 16.3% in women and 28.8% in men was recorded [4]. Though the government has set up various strategies to curb undernutrition and micronutrient deficiencies, climate change is a setback to the progress made. Low crop production, food insecurity, and inadequate consumption of diets of high nutrient quality and diversity due to climate change (among other factors) have reduced the impact of the government's efforts [5].

According to the Kenya Micronutrient Survey in 2011 [4], whole grains are an important source of all micronutrients studied in the survey. They are the leading source of iron, zinc and dietary energy, whereas milk and dairy products are the leading source of calcium. Although they contribute the most, a large deficit in achieving Recommended Daily Allowances (RDAs) still exists [4]. Worth noting is the fact that although the diets of preschool children are primarily cereal-based, maize, rice and wheat, which are the most common cereals, contain low amounts of protein, vitamins and minerals [6, 7]. This situation raises the need to utilize ancient crops such as quinoa, known to withstand harsh climatic conditions and well-endowed with both macro- and micronutrients.

Quinoa is a pseudo-grain whose origin can be traced to the South American Andes region (5000BC-3000BC). It is well endowed with a wide variety of nutrients that include; protein, lipids, fiber, vitamins (B6, pantothenic acid, biotin, vitamin A and folate) and minerals (iron, calcium, zinc, and potassium among others) as well as beneficial Phyto-chemicals (saponins, and phytosterols). Quinoa has a rich balance of the essential amino acids [8]. Quinoa exhibits tolerance in extreme conditions such as high levels of salinity [9], and a wide range of cultivation altitudes, from sea level to 4000m high [10]. In the South American Andes region, different quinoa cultivars are adapted to a wide range of climates and ecological zones. The potential for successful growing of quinoa in African countries, including Kenya is high considering that the climatic conditions are similar; temperature range of 17˚C-25˚C and rainfall as low as 500mm [11].

Quinoa was first grown in Kenya in the late 1930s (1935-1939), to assess its ability to adapt to the local environments. The trials were done in different areas: Kitale, Kapenguria, Kiambu, and Scott Agricultural Laboratories [12]. Between 1999 and 2000, a second study was carried out in Kenya as a fragment of an international multi-environmental trial. The study aimed to determine how twenty-four (24) ascensions of quinoa would adapt to and their yield under Kenyan conditions [13]. In 2015, FAO successfully conducted adaptation trials of 10 quinoa varieties in four (4) Eastern African countries; Ethiopia, Kenya, Uganda and Zambia. In Kenya, the trials were done in Embu, Karuangi and Mitunguu/Tunyai. The report detailed the agronomical characteristics and amino acid composition of the 10 quinoa genotypes, among which were Cherry vanilla, Brilliant Bright Red (BBR), Biobio and Titicaca [14]. Additionally, the report stated that the nutrient content varies with soil nutrient status, climatic conditions and type of ascensions [14]. Based on the previous experiments done on quinoa in Kenya, this study acknowledges the information generated and produced on the agronomical characteristics and adaptability of the grain in Kenya by The Food and Agriculture Organization (FAO) [14]. To contribute to the body of knowledge, this study's objective is to determine the wide-ranging nutritional content (macronutrients, calcium, iron and zinc) of four different ascensions (Cherry Vanilla, Biobio, BBR and Titicaca) grown in Kenya in May 2022-August 2022, and establish its potential nutrient contribution to the diets of children aged 2-6 years in Kenya.

MATERIALS AND METHODS

The field experiments were conducted at the University of Nairobi, Faculty of Agriculture, Kabete Field Station in Kenya, from May 2022 to August 2022. Kabete is located at latitude 1˚ 15_S and longitude 36˚44_E, and an altitude of 1930m above sea level with a temperature range of 13°C-23^{0}C and annual rainfall of 970mm [14].

A randomized block design was used during planting; the four quinoa varieties; Cherry Vanilla, Biobio, BBR and Titicaca were planted each on a different block 2m by 12.5m [15]. A sunflower guard row was planted all around the study site to shield the quinoa grain from being eaten by birds. The experimental plot was prepared by plowing and cross-plowing two times and followed by laddering until a good tilth was obtained. All the weeds and stubbles were collected and removed from the land. The land was leveled after breaking the clods into crumbly soil. Using a stick, planting rows were lightly drilled.

Before planting, the seeds were mixed with sand, 200g of sand with 200g of seed in a ratio of 1:1 [16]. A handful of organic (chicken) manure was broadcasted with sowing. The four varieties of quinoa, Cherry Vanilla, Biobio, BBR and Titicaca were broadcasted along the planting rows on 21st May 2022 in different blocks by hand, with planting spacing of 1m by 12.5m between blocks and 15cm between rows. The sunflower guard rows were planted on the same day as the quinoa seeds at a spacing of 1m all round.

Since it was the rainy season, supplemental irrigation was done once a week, using the sprinkler method for 3 consecutive hours for the first 2 months [14]. The crop was harvested after three months and later put in the greenhouse for one and a half weeks to facilitate drying. Greenhouse drying was the best option since the crop was harvested in the rainy season, in addition to the fact that it is shown to improve the quality of the products, compared to sun-dried products and reduce the time used in drying [17].

Laboratory Analysis

A hundred grams of each variety in raw form were randomly weighed and ground for laboratory analysis to determine their proximate and mineral composition [18]. In proximate composition analysis, seven parameters were assessed, namely: moisture, fiber, ash, protein, fat, carbohydrate and energy.

The moisture content was determined using the air oven method. Five (5) grams of each quinoa variety were accurately weighed in a dish of known weight and put in an air oven maintained at 105˚C for four hours (4 hours). The samples were cooled in a desiccator, weighed and returned to the oven for drying for another thirty (30) minutes, after which, the samples were again cooled and weighed. The latter and former steps were repeated thrice when the moisture content was agreed within 0.05%. The moisture content of the four varieties was calculated in percentage (%) [18].

The fiber content of the four quinoa varieties was determined using acid/base digestion. Three grams (3g) of each of the four quinoa varieties were weighed into separate graduated 600ml beakers. A small amount (15ml) of boiling distilled water and 25ml of 2.04N Sulphuric acid were added into the beaker. Boiling distilled water was then added into the beaker to make up a volume of 200ml. This volume was maintained while boiling for thirty minutes (30) minutes on a hot plate. The contents of the beaker were filtered using a Buchner funnel that was slightly packed with glass wool. The residue was washed three times with boiling distilled water and later transferred back to the beaker. Fifteen milliliters (15ml) and 25ml of 1.78N Potassium hydroxide solution were added into the beaker. The volume was topped up to 200ml with boiling distilled water and was maintained while boiling for thirty (30) minutes on a hot plate. The contents in the beaker were filtered using glass wool. The residue was washed three times with boiling distilled water and three times with small amounts of ethanol, after which the residue in the glass wool was transferred to a porcelain dish and dried at 105˚C in an air oven for two hours. The contents were then cooled in a desiccator, weighed to obtain $W_{1,\text{ and}}$ then with the dish ignited to 550˚C to constant weight. The contents of the dish were cooled in desiccators and weighed to obtain $W_{2.}$ The crude fiber content of the four quinoa varieties was calculated in % [18].

The ash content of the four quinoa varieties was determined using the muffle furnace method. Three grams (3g) of the sample were weighed into a porcelain crucible. The ashing process started with a low flame (bunsen burner) and then continued in a muffle oven at 500˚C-600˚C until a light gray ash of constant weight was obtained. The percentage (%) ash content of the four samples was calculated as the weight of the sample before drying/weight of the sample after drying x 100 [18].

The Kjeldahl distillation method was used to determine the crude protein content of the four quinoa varieties under study. Half a gram (0.5g) of each of the four quinoa varieties was weighed in a nitrogen-free filter paper which was carefully folded and placed in a kjeldahl flask. One (1) Kjeldahl catalyst tablet and 10ml of concentrated Sulphuric acid were added into the flask. The mixture was heated in a block digestor inside a fume cupboard until a clear solution was obtained. The solution was left to cool to room temperature, after which the digesting tube was three-quarters (¾) filled with distilled water. Then 3 drops of methyl red and some amount of 40% NaOH were added into the digesting tube and the tube was fixed in the distillation unit. The solution was distilled and the nitrogen trapped in 25ml of 0.1N HCl contained in a 300ml flask. The distillate was back titrated with 0.1N NaOH solution till the solution changed colour. The crude protein was calculated using a conversion factor of 6.25.

The fat content of the four quinoa varieties was determined using the Soxhlet Extraction method. Four grams (4g) of each of the four varieties was weighed (W_1) into an extraction thimble. The sample was covered with cotton wool and the thimble was placed into a Soxhlet extractor. A tarred flat-bottomed flask with 200ml of petroleum Ether was then placed on a heating mantle and connected to the Soxhlet extractor. The extraction continued for eight (8) hours, after which the

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 7
July 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

solvent was evaporated in a rotary evaporator. The residue was dried in an air oven at 105˚C for one (1) hour, cooled in a desiccator and weighed (W_2). The crude fat content of the four quinoa varieties was calculated as follows: W_1-W_2/W_1 X100 [18]

The percentage proportion of carbohydrates in the four quinoa varieties was obtained by difference method, 100 – (% protein+ % total fat+% total ash + % water). The total energy value was obtained via calculation using the Atwater factors by multiplying the total grams of fat by nine, total grams of carbohydrates by four and total grams of protein by four and summing up the outputs [18].

To determine the mineral composition of the four different quinoa varieties, the matrix of the sample was changed from solid to liquid using a combination of the dry ash method and acid digestion. Two grams (2g) of each of the four varieties was weighed into a porcelain dish and heated at 550^{0}c for four (4) hours in a muffle furnace. The ash obtained was digested using 20% HCl. The contents were filtered into a 50ml volumetric flask and topped up to the mark using distilled deionized water. The target minerals (calcium, iron, and zinc), were analyzed using atomic absorption spectrophotometer (Buck Scientific Model 210 VGP).

Data analysis

All determinations were done in duplicates and the results were expressed as mean ± standard deviation. The data were analyzed using SPSS 20 software. To test the significant difference in nutrient content level among the four Kenyan-grown quinoa varieties, ANOVA was applied at a 5% level of significance.

RESULTS AND DISCUSSION

Macronutrients

The mean energy level of the four quinoa varieties grown in Kenya per 100g was 350.1±16.4 kcal, with Cherry Vanilla having the highest energy level at 373.5±0.1 kcal and Titicaca the lowest at 331.6±0.1kcal. There was a significant difference among the four varieties *(p=0.000)*. The moisture content of the four varieties ranged from 10.3% to 10.7%, with a mean of 10.4±0.2%. Titicaca had the lowest percentage (10.3±0.0%) whereas BBR had the highest percentage (10.7± 0.2%). There was no significant difference in moisture content in the four varieties (*p =0.195).* This could be attributed to the fact that all four ascensions were dried using the same method and for an equal duration.

The mean ash content of the four quinoa varieties was 3.74±1g/100g with Titicaca having the highest ash content (5.2±0.3g/100g) and BBR had the least ash content at 2.5±0.1g/100g. The other two varieties, Cherry vanilla (3.7±0.2g/100g) and Biobio (3.6±0.1g/100g) had relatively close ash content levels. There was a

ajfand Since 2001
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 7
July 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

significant difference (*p =0.000)* in ash content among the four varieties of quinoa (Table 1).

The percentage of fiber in the four varieties ranged from 6.1 to 6.9g/100g with a mean fiber content of 6.7±0.4g/100g. BBR variety had the highest level of fiber content (6.9±0.9g/100g) whereas Biobio had the least (6.05±0.1g/100g) and a significant difference existed among the four varieties, *(p=0.000)* (Table 1).

The four varieties of quinoa exhibited significantly different amounts (p=0.000) of protein per 100g with a mean crude protein of 18.2±6.2g/100g. Cherry vanilla had the highest level of crude protein (25.1g/100g), followed by BBR (21.1±0.1g/100g) while Titicaca had the lowest amount of protein (9.3g/100g). Besides Cherry Vanilla, whose protein levels were higher, the other varieties' protein levels are within range of the protein values in quinoa as reported by Jancurova *et al*. [19] of 8-22% while Biobio, BBR and Titicaca had protein levels higher than the protein values in new quinoa ascensions grown in Egypt of 13.1-16.7% reported by Barakat and 14-15.5% in four ascensions from the Agronomical experimentation Center of Altiplano University Peru reported by Repo-Carrasco-Valencia & Serna [19, 20, 21]. The protein content of quinoa is reported to be higher than other cereals such as barley (11%), rice (7.5%) and corn (13.4%) and is similar to protein content in wheat (15.4%) [22]. In Kenya, the most commonly consumed cereals contain a protein content of 7-12g/100g [23]. According to the Kenya Food Composition Tables, maize, rice and wheat have lower protein content levels than quinoa (Table 1). In comparison to the protein content of quinoa grown in Kenya, quinoa is a more promising pseudo cereal with a higher protein content and especially the Cherry vanilla variety. If consumed in considerable amounts, it has the potential to adequately contribute to the protein needs of children aged 2-6 years who need it for the growth and development of their body.

The mean fat content of the four quinoa varieties is 6.7±3.1g/100g with Cherry Vanilla and Titicaca having the highest and lowest fat content levels of 11.5±0.2g/100g and 4.7±0.1g/100g, respectively. There was a statistically significant difference among the four varieties (p=0.000) (Table 1). Apart from Cherry Vanilla, whose fat content was higher by about 2%, the fat level of the other varieties lies within the range of fat levels in different cultivars of quinoa grown in different regions in the world of 4% - 9.5% as reported by Angeli *et al.* [24]. Quinoa is reported to have a higher fat content than other cereals such as maize but lower than soya bean [24]. Quinoa oil is also reported to contain high levels of essential fatty acids and more than three-quarters of the total fatty acids are polyunsaturated fatty acids [25]. Dietary unsaturated fatty acids are associated with numerous health benefits such as improved insulin sensitivity, reduced risks from suffering from diabetes, cancer and cardiovascular diseases [26]. Fat in the body acts as a

https://doi.org/10.18697/ajfand.132.24095

source of energy as well as helps in the absorption of fat-soluble vitamins; vitamins A, D, E and K when consumed in the same meal. The fat content level of the cereals commonly consumed by children aged 2- 6 years is lower than that of Kenyan-grown quinoa. Cherry vanilla and BBR contain close to 2.5 and 1.5 times the fat level in maize, respectively (Table 1). If adopted into the Kenyan children's diets quinoa is a great source of oils.

The mean carbohydrate level of the four varieties is 54.2±8.5g/100g, with values ranging from the lowest in Cherry vanilla at 42.5g/100g and highest in Titicaca at 64.1 g/100g. The carbohydrate levels of the four varieties were significantly different (p=0.000) (Table 1). The carbohydrate (CHO) content of three of the varieties, except for Cherry vanilla, fell within the ranges of 52% - 69% dm [25], and 49% and 68% [24] of different quinoa varieties grown in different regions in the world as reported in the reviews. When compared to the CHO ranges of 64% - 74% dm reported by Abugoch, the CHO values of three varieties, except for Titicaca are lower [27]. Quinoa also contains dietary fiber, a type of carbohydrate. This makes quinoa a great whole grain for children aged 2-6 years since it will release energy slowly, over a longer time and cause satiety over a longer period [23].

Micronutrients

Cereals originating from the Andean region, including quinoa, are well endowed with iron, manganese, zinc and copper compared to rice. In particular, the content of phosphorus and magnesium can meet up to 55% of a consumer's Dietary Recommended Intake [28].

The level of manganese in the four quinoa varieties ranges between 8.56mg/100g and 22.0 mg/100g with a mean content of 15.1±6.6mg/100g. Titicaca and BBR contain the highest and lowest amounts of manganese, respectively. There was a significant difference, (p=0.000) in manganese content among the four quinoa varieties (Table 2). In this study, the values of manganese were much higher than those reported in the USDA database of 2.02mg/100g [29]. In the human body including that of children 2-6 years, manganese plays an important role in intracellular activities, as it functions as a co-factor for certain enzymes. It plays crucial roles in body processes and systems such as digestion, production of energy, immune system and regulation of neuronal activities [30]. Though manganese deficiency is rare, its Adequate Intake (AI) in children aged two to six years is 0.5 -1.0 mg/day [31] The quantities of manganese contained in Kenyan-grown quinoa can meet over and beyond the Adequate Intake (AI) of manganese for children making it a good source of manganese.

https://doi.org/10.18697/ajfand.132.24095

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 7
July 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

The amount of magnesium in the four quinoa varieties ranged from the lowest content of 29.2 mg/100g in BBR to the highest content in Biobio at 73.9 mg/100g and a mean content value of 43.0±19.2mg/100g among the four varieties. The content levels of magnesium in the four varieties were significantly different, (p=0.000) (Table 2). The levels of magnesium reported in this study are lower than those reported by Koziol at 249.6mg/100g but quite similar to the value (26mg/100g) reported by Ruales & Nair [32, 33]. Compared to other cereals such as wheat and corn, quinoa is reported to contain higher levels of magnesium [34]. In comparison to rice and wheat, all Kenyan grown quinoa contains higher amounts of magnesium than rice and except for Biobio whose levels are higher, the levels are similar to wheat (Table 2). Moreover, if consumed, the levels can contribute 17-31% of the Adequate Intake levels for children aged 2-6 years old [31].

The mean potassium content of the four varieties is 435.2±77.8mg/100g. Titicaca had the highest content level of potassium (511.9± 0.03 mg/100g) whereas, Cherry Vanilla had the lowest amount (347.6±0.1mg/100g). The content level of potassium in the four varieties was significantly different, (p=0.000) (Table 2). The content levels of potassium in all four quinoa varieties in this study were lower than those reported by USDA of 551mg/100g [29]. Notably, the potassium levels are higher in quinoa than in other staple cereals consumed in Kenya. The Kenyan grown quinoa if incorporated into the diets of children aged 2-6 years would contribute close to 50% of the Adequate Intake (AI) of potassium (Table 2).

The mean level content of calcium of the four varieties was 6.99±3.71mg/100g, and a range between 1.34 mg/100g to 10.81 mg/100g, with Biobio and Cherry Vanilla having the least and most quantities, respectively. There is a significant difference in calcium levels in the four quinoa varieties under study (*p=0.000*) (Table 2). The amounts of calcium reported in this study are lower compared to those reported in a review of 148.7mg/100g [35], and 26mg/100g reported in a study on quinoa Russian selection grown in the South of Russia [36]. It is documented in the literature that quinoa contains calcium at levels higher than the other commonly consumed cereals such as maize, rice and wheat [34]. Notably, the calcium content in the four Kenyan-grown quinoa varieties is quite low, this could be attributed to the soil type and soil composition of the region where the experiments were done [34]. Based on the obtained results, the Kenyan-grown quinoa would contribute at 0.3-1.8% of the RDA of calcium (Table 2).

The mean iron content of the four quinoa varieties is 8.7±2.4mg/100g. Compared to the other varieties, Titicaca and BBR had the highest 11.47mg/100g and lowest 5.25 mg/100g iron content, respectively. The four quinoa varieties had significantly different iron content (p=0.000) (Table 2). The levels of iron of the four varieties fall within the range of results (1.4 mg/100g -16.8mg/100g) reported in a review conducted by Vega-Galvez *et al.* [34] and considerably higher than the results reported by Ruales & Nair of 0.4mg/100g [33]. In both studies, the experiments were done using raw quinoa grains. The iron content of Titicaca grown in Kenya is lower than that of the same variety grown in Iran at 43 mg/100g [37]. Iron plays crucial roles in the human body. Such roles include; carrying oxygen from the lungs to other body organs, serving as a transport medium for electrons and being a crucial part of the enzyme systems in numerous tissues [38]. Results from this study show that all the varieties contain higher iron levels than common staples in Kenya; maize, wheat and rice (Table 2). Except for BBR, the amounts of iron in the other three varieties in 100g are sufficient to meet the RDA of iron in children aged 2-6 years of 7-10 mg/day [39]. Nevertheless, it is worthwhile noting that the method used in analyzing iron content in this study is limited; this is because iron is volatilized at high temperatures leading to some unaccounted-for loss.

Of the four varieties, Cherry Vanilla had the highest amounts of copper (1.86mg/100g) and Titicaca had the lowest amount (0.83mg/100g). The four quinoa varieties with a mean copper content of 1.1±0.46 mg/100g had significantly different copper levels (p=0.000). Compared to Kozioł [32] who reported copper levels of 5.1mg/100g, this study's results of copper were lower in quantity but quite similar to the results reported by Ruales & Nair of 1.0mg/100g and higher than the results reported by USDA of 0.48mg/100g [29, 33]. Nevertheless, the amounts of copper in the four Kenyan-grown quinoa varieties are sufficient to meet the Recommended Daily Intake (RDI), of children aged two to six years whose requirements range from 0.3 to 0.4 mg per day [40]**.** Among other functions, though required in small quantities, copper plays a role in brain development, maintenance of the nervous and immune systems and activation of genes.

The content level of zinc in the four varieties ranged between 8.79mg/100g to 14.1mg/100g. Titicaca had the highest zinc content level (14.11mg/100g) followed by Biobio (13.98mg/100g), Cherry vanilla (11.64mg/100g) and BBR with the lowest zinc levels of 8.79mg/100g. The mean content of zinc was 12.1±2.31mg/100g. The levels of zinc in the four varieties were significantly different (p=0.000). (Table 2). The zinc levels in the four Kenyan-grown varieties are within the range of 2.75-4.8mg/100g as reported in a review by Vega-Galvez *et al*. [34, 37]. Titicaca grown in Kenya had higher zinc content compared to the same variety grown in Iran (> 0.001g/100g) [37]. A 100g of all four varieties, provides sufficient quantities of zinc required to meet the Recommended Dietary Intake (RDI) for children aged 2-6 years of 3-5mg/day.

Mineral and nutrient content is anticipated to vary with various factors such as soil nutrient status, climatic conditions and type of ascensions [14]. In comparison to quinoa grown in seven regions in Chile, South America [North Ancovinto, Cancosa, Centre Cahuil, Faro, South Regalona and Villarrica], the quinoa grown in Kenya contained higher content levels of manganese, iron and zinc; similar content levels of copper and lower content levels of magnesium, calcium and potassium.

Comparison in nutrient profile and utilization of quinoa and local non-cereal foods

Though a *pseudo*-cereal, quinoa's micronutrient composition is comparable to local nutrient-rich vegetables, such as cowpeas leaves whose consumption is limited by seasonality challenges. A study conducted in Kitui and Taita Taveta Counties in Kenya reported that during the surplus season, all households consumed cowpeas they had produced, but during the drought period majority of these same households had no cowpea leaves to consume or they had to source them from elsewhere. Advocacy for the consumption of cowpea leaves over the seeds is higher, since the leaves are richer in vitamins, antioxidants and minerals [41]. Once well stored and observed, grains such as quinoa can have a shelf-life over a long period such as several months. Considering the fact that both quinoa and cowpea are drought tolerant crops, quinoa has an upper hand since it can be stored for longer hence available for consumption over a long time. In terms of utilization, quinoa grain can be boiled or fried. Additionally, when ground into flour, it can be used to develop numerous products such as chapati, mandazi, and stiff porridge (Ugali) among other products [14].

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

The different varieties of quinoa significantly differ in their levels of macro and micronutrients. Cherry Vanilla variety has the highest content of protein and fat while as Titicaca and Biobio has the highest content level of carbohydrates and fiber, respectively. In respect to levels of micronutrients, out of the seven micronutrients analyzed in this study (manganese, magnesium, potassium, calcium, iron, copper and zinc) Titicaca has the highest level of four (4) (manganese, potassium, iron, zinc). The Kenyan-grown quinoa has the potential to contribute to increased dietary intake of both macronutrients and micronutrients of children aged 2-6 years old. Except Titicaca, the other three four quinoa varieties contain higher protein levels than maize, rice and wheat, the commonly consumed staple cereals in Kenya.

The Kenyan-grown quinoa contains levels of micronutrients in higher amounts compared to maize, rice and wheat the commonly consumed cereals in Kenya. The levels of copper, manganese and zinc in the four quinoa varieties are sufficient to meet the nutrient requirements in children aged 2-6 years. Except for BBR, whose iron content can meet slightly over 50% of the recommended daily intake, the iron levels in Cherry Vanilla, Titicaca and Biobio are sufficient to meet the recommended daily intake of children aged 2-6 years. The levels of potassium in all the four varieties are able to meet slightly less than 50% of the RDA of the target population. None of the varieties contain adequate calcium levels in 100g to meet the Recommended Daily Allowance (RDA) of 500-600mg/day for children aged 2-6 years although their consumption would contribute to the dietary intake.

On this basis, the study recommends that; the growing and consumption of quinoa should be promoted in Kenya and introduced into the diets of children aged 2-6 years of age in Kenya; Quinoa-based products for children aged 2-6 years should be developed; and Climate zone-oriented agronomical trials on quinoa farming should be conducted.

Funding
The authors sincerely appreciate the FoodLAND Project, under the sponsorship of the European Union's Horizon 2020 research and innovation program under a grant agreement (GA no 862802).

Conflict of Interest
The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 7
July 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 1: Proximate composition of the four different quinoa varieties grown in Kenya (on dry weight basis) compared to Kenya's staple cereals (Maize, rice and wheat)

Variety of Quinoa	Moisture %	Fiber %	Ash %	Protein %	Fat %	Carbohydrates %	Energy Kcal
Cherry Vanilla	10.4±0.6	6.9±0.0	3.7±0.2	25.1±0.3	11.5±0.2	42.5±0.4	373.5±0.1
BBR	10.7± 0.2	6.9±0.8	2.5±0.1	21.1±0.1	6.5±0.2	52.3±0.1	352.1±1.5
Titicaca	10.3±0.0	6.9±0.1	5.2±0.3	9.3±0.0	4.2±0.0	64.1±0.1	331.6±0.1
Biobio	10.4±0.2	6.1±0.0	3.6±0.1	17.0±0.1	4.7±0.1	57.9±0.2	343.4±0.86
Maize	**13.6**[7]	**9.4**[7]	**1.2**[7]	**7.94**[7]	**4.5**[7]	**63.4**[7]	**345**[7]
Rice	**12.2**[7]	**0.2**[7]	**0.2**[7]	**2.6**[7]	**0.3**[7]	**26.2**[7]	**503**[7]
Wheat	**12.2**[7]	**11.2**[7]	**0.7**[7]	**11.2**[7]	**1.6**[7]	**70.7**[7]	**349**[7]
The results are expressed as mean± standard deviation (SD)							

ajfand Since 2001 AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 7
July 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 2: Mineral composition of the four different quinoa varieties grown in Kenya in comparison to Kenya's staple cereals (Maize, rice and wheat)

Variety of Quinoa	Manganese (mg/100g)	Magnesium (mg/100g)	Potassium (mg/100g)	Calcium (mg/100g)	Iron (mg/100g)	Copper (mg/100g)	Zinc (mg/100g)
Cherry Vanilla	9.45±0.04	33.5±0.08	347.6±0.1	10.81±0.01	9.5±0.1	1.86±0.06	11.6±0.01
BBR	8.59±0.03	29.2±0.05	502.02±0.12	7.96±0.1	5.25±0.05	0.94±0.01	8.79±0.08
Titicaca	21.97±0.06	35.4±0.07	511.9±0.03	7.86±0.06	11.47± 0.07	0.83±0.02	14.1±0.01
Biobio	20.5±0.15	73.9±0.12	379.03±0.13	1.34±0.0	8.59±0.11	0.86±0.01	13.98±0.193
Maize	5.0	75[7]	226[7]	24[7]	2.6[7]	0.2	1.88[7]
Rice	1.1	23[7]	59[7]	21[7]	0.9[7]	0.1	1.32[7]
Wheat	0.7	31[7]	129[7]	35[7]	5.6[7]	0.1	0.87[7]
RDA/RNI /AI	0.5-1.0mg/day [31]	170-230mg/day[31]	800-1100mg/day [31]	500-600mg/day	7-10mg/day[39]	0.7-1.0mg/day [31]	3-5mg/day[39]
% contribution of 100g quinoa to RDA/RDI in 100g	>100%	17-31%	43.4% - 46.5%	0.3-1.8%	75%-114.7%	118.6%-186%	282- 293%
Mean, SD	151.15±65.5 15.1±6.6	430.01±192.5 43.±19.2	4351.5±778 435.1±77.8	69.95±37.1 7.0 ±3.7	87.0±24.0 8.7±2.4	11.21±4.6 1.1±0.46	121.32±23.1 12.1±2.31

The results are expressed as mean± standard deviation (SD)

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 7
July 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374


Titicaca Variety


Biobio Variety


Cherry Vanilla


Brilliant Bright Red (BBR)


Sunflower Guard Rows

Harvested Quinoa grains

REFERENCES

1. **Kenya National Bureau of Statistics Nairobi.** Kenya Demographic and Health Survey 2022 Key Indicators Report 2023. [Online]. www.DHSprogram.com

2. **UNICEF.** The State of the World's Children 2019: Children, food and nutrition - UNICEF DATA. [Online]. https://data.unicef.org/resources/state-of-the-worlds-children-2019/ *Accessed: Oct. 26, 2021.*

3. **WHO.** Nutrition interventions. World Health Organization. 2017. [Online]. http://www.who.int/elena/intervention/en/ *Accessed: Oct. 26, 2021.*

4. **Ministry of Health.** The Kenya National Micronutrient Survey. 2011.

5. **WFP**. Climate Crisis and Malnutrition: a case for acting now. World Food Program. 2021.

6. **Ronoh AK, Mercy Were G, Wakhu-Wamunga F and JB Wamunga** Food Consumption Patterns among Pre-School Children 3 - 5 Years Old in Mateka, Western Kenya. *Food Nutr Sci*. 2017; **08(08):** 801–811. https://doi.org/10.4236/fns.2017.88057

7. **FAO/Government of Kenya**. Kenya Food Composition Tables. 2018. [Online]. Available: http://www.fao.org/3/I9120EN/i9120en.pdf *Accessed: May 01, 2024.*

8. **Intelli A, Beenu T and C Ambika** A Review Nutritional Composition and Health Benefits of Golden Grain of 21st Century, Quinoa (Chenopodium quinoa willd.). *Pakistan Journal of Nutrition*. 2015; **14(12):** 1034–1040. https://doi.org/10.3923/pjn.2015.1034.1040

9. **Gómez-Pando L R, Álvarez-Castro R and AE La Barra** Effect of Salt Stress on Peruvian Germplasm of Chenopodium quinoa Willd.: A Promising Crop. *J Agron Crop Sci*. 2010; **196(5)**; 391–396. https://doi.org/10.1111/J.1439-037X.2010. 00429.X

10. **Tanwar B, Goyal A, Irshaan S, Kumar V, Sihag MK, Patel A and I Kaur** Quinoa. *Whole Grains and Their Bioactives: Composition and Health*. (2019); 269–305. https://doi.org/10.1002/9781119129486.CH10

11. **Jean P and CWM Dorst** Factors influencing climate Britannica. https://www.britannica.com/place/South-America/Factors-influencing-climate *Accessed February 17, 2022.*

12. **Elmer LA** Quinua (Chenopodium Quinoa) *The East African Agricultural*. 1942. **8(1);** 21–23. https://doi.org/10.1080/03670074.1942.11664212

13. **Bertero HD, De La Vega AJ, Correa G, Jacobsen SE and A Mujica** Genotype and genotype-by-environment interaction effects for grain yield and grain size of quinoa (Chenopodium quinoa Willd.) as revealed by pattern analysis of international multi-environment trials *Field Crops Res*. 2004; **89(2-3);** 299–318. https://doi.org/10.1016/j.fcr.2004.02.006

14. **FAO.** *Prospects for quinoa adaptation and utilization in Eastern and Southern Africa*. 2021. https://doi.org/10.4060/cb2351en

15. **David Chaney** Common Research Designs for Farmers - SARE. https://www.sare.org/publications/how-to-conduct-research-on-your-farm-or-ranch/basics-of-experimental-design/common-research-designs-for-farmers/ *Accessed August 29, 2023.*

16. **Moses FAM, Mathew A, Clare M, Mercy L, Berhanu F, Susan W, Regina K, Otim AO, Eric K, Christopher M, Didier B and MI Mohamud** Prospects for quinoa adaptation and utilization in Eastern and Southern Africa. In Prospects for quinoa adaptation and utilization in Eastern and Southern Africa. FAO, 2021. https://doi.org/10.4060/cb2351en

17. **Sahdev RK** Open Sun and Greenhouse Drying of Agricultural and Food Products: A Review. *International Journal of Engineering Research & Technology*. 2014; **3(3**): 1053-1066. https://doi.org/10.17577/IJERTV3IS030902

18. **AOAC Official Method of Analysis** (2005). https://idoc.pub/documents/aoac-official-method-of-analysis-2005-aoac-992-23-3no768y9k5ld *Accessed July 25, 2023.*

19. **Jancurová M, Minarovičová L and A Dandár** Quinoa: A Review. *Czech Journal of Food Sciences*. 2009; **27(2):** 71–79. https://doi.org/10.17221/32/2008-CJFS

20. **Barakat H, Khalifa I and D Petko** Chemical composition and nutritional value of seeds from new quinoa accessions, cultivated in Egypt. *Bulgarian Chemical Communications*. 2017. **49 (Special Issue D)**; 231-238.

21. **Repo-Carrasco-Valencia RAM and LA Serna** Quinoa (*Chenopodium quinoa,* Willd.) as a source of dietary fiber and other functional components. *SciELO Brasil Food Science and. Technology*. 2011; **31(1).** https://www.scielo.br/j/cta/a/64zr4jJ7KCB8kZgZyQ3Hs6Q/abstract/?lang=en *Accessed August 20, 2022.*

22. **Abugoch LE, Romero N, Tapia CA, Silva J and M Rivera** Study of some physicochemical and functional properties of quinoa (chenopodium quinoa willd) protein isolates. *Journal of agricultural and food chemistry.* 2008; **56(12):** 4745–4750. https://doi.org/10.1021/JF703689U

23. **National Guidelines for Healthy Diets and Physical Activity.** 2017. www.nutritionhealth.or.ke *Accessed August 20, 2022.*

24. **Angeli V, Silva P, Crispim MD, Khan M, Hamar A, Khajehei F, Graeff-Hönninger S and C Piatti** Quinoa (*Chenopodium quinoa* Willd.): An Overview of the Potentials of the 'Golden Grain' and Socio-Economic and Environmental Aspects of Its Cultivation and Marketization, 2020; **Vol. 9**: 216. https://doi.org/10.3390/foods9020216

25. **Filho AMM, Pirozi MR, Borges JTDS, Pinheiro Sant'Ana HM, Chaves JBP and JSDR Coimbra** Quinoa: Nutritional, functional, and antinutritional aspects. *Critical reviews in food science and nutrition.*2017; **57(8):** 1618–1630. https://doi.org/10.1080/10408398.2014.1001811

26. **Lunn J and HE Theobald**The health effects of dietary unsaturated fatty acids. *Nutrition Bulletin.* 2006; **31(3)**: 178–224 https://doi.org/10.1111/J.1467-3010.2006. 00571.X

27. **Abugoch James LE** Quinoa (*Chenopodium quinoa* Willd.): composition, chemistry, nutritional and functional properties. *Advances in food and nutrition research.* 2009; **58:** 1–31. https://doi.org/10.1016/S1043-4526(09)58001-1

28. **Nascimento AC, Mota C, Coelho I, Gueifão S, Santos M, Matos AS, Gimenez A, Lobo M, Samman N and I Castanheira** Characterization of nutrient profile of quinoa (*Chenopodium quinoa*), amaranth (*Amaranthus caudatus*), and purple corn (*Zea mays* L.) consumed in the North of Argentina: proximate, minerals and trace elements. *Food Chemistry.* 2014. **148**; 420–426. https://doi.org/10.1016/j.foodchem.2013.09.155

29. **USDA FoodData Central**. https://fdc.nal.usda.gov/fdc-app.html#/food-details/2512372/nutrients *Accessed September 25, 2023.*

30. **Chen P, Bornhorst J and M Aschner** Manganese metabolism in humans Front. *Biosci (Landmark Ed)*. 2018; **23(9);** 1655–1679. https://doi.org/10.2741/4665

31. **European Food Safety Authority.** Dietary Reference Values for nutrients Summary report. December. 2017. https://doi.org/10.2903/sp.efsa.2017.e15121

32. **Kozioł MJ** Chemical composition and nutritional evaluation of quinoa (*Chenopodium quinoa* Willd.). *Journal of Food Composition and Analysis* 1992; **5(1):** 35–68. https://doi.org/10.1016/0889-1575(92)90006-6

33. **Jenny Ruales and BM Nair** Nutritional quality of the protein in quinoa (*Chenopodium quinoa*, Willd) seeds Plant. *Foods for Human Nutrition 1992;* **42(1)**: 1–11. https://doi.org/10.1007/BF02196067

34. **Vega-Gálvez A, Miranda M, Vergara J, Uribe E, Puente L and EA Martínez** Nutrition facts and functional potential of quinoa (*Chenopodium quinoa* willd.), an ancient Andean grain: a review. *Journal of the science of food and agriculture 2010*; **90(15)**: 2541–2547. https://doi.org/10.1002/JSFA.4158

35. **Iqbal MA** An Assessment of Quinoa (*Chenopodium quinoa* Willd.) Potential as a Grain Crop on Marginal Lands in Pakistan. *American-Eurasian J. Agric. & Environ. Sci*. 2015; **15(1):** 16-23 https://doi.org/10.5829/idosi.aejaes.2015.15.1.12474

36. **Leushkina EV** Study of the chemical composition of quinoa of Russian selection grown in the South of Russia *IOP Conf. Ser.: Earth Environ. Sci.* 2021. https://iopscience.iop.org/article/10.1088/1755-1315/640/2/022004/meta *Accessed August 20, 2022.*

37. **Sekhavatizadeh S** Nutritional, antioxidant properties and polyphenol content of quinoa (*Chenopodium quinoa* Willd) cultivated in Iran *Journal on Food, Agriculture and Society*. 2021; **9(2).** Retrieved from http://www.thefutureoffoodjournal.com/index.php/FOFJ/article/view/336 *Accessed April 10, 2023.*

38. **Gupta CP** Role of Iron (Fe) in Body. *Journal of Applied Chemistry*.2014 **7(11):** 38–46 www.iosrjournals.org *Accessed April 10, 2023.*

39. **Trumbo P, Yates AA, Schlicker S, and M Poos** Dietary reference intakes: vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc. *Journal of the American Dietetic Association.*2001; **101(3):** 294–301. https://doi.org/10.1016/S0002-8223(01)00078-5

40. **National Academy of Sciences.** Dietary Reference Intakes (DRIs): Recommended Dietary Allowances and Adequate Intakes, Elements, Food and Nutrition Board, National Academies. March 2019.