Quinoa: A potential crop for food and nutritional security in Tanzania

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Abstract

A rapid population growth rate couples with a diverse climate change, both associated to food and nutrition insecurity in Tanzania, calls upon a need to adopt and utilize more nutritious and stress tolerant food crop varieties. Quinoa a native and ancient food crop of the South American has recently been recognised as a super food globally due to its wide range of geographical adaptability, stress tolerance and high nutritional value. Quinoa starch content is 78% which is low as compared to common cereal such as maize, rice wheat and sorghum commonly used as staple food in Tanzania. This leads to its lower glycaemic index hence wide range of consumers. Quinoa is high in protein content (23%), the protein is complete and gluten free unlike other plant sources. Also, quinoa seeds are rich in Fat (10%), dietary fibre (3.8%) and ash content (3.8%). The seeds are rich in essential minerals such as Fe (1487), Ca (132) and Zn (44) all in mg/100g dry weight. Processing of quinoa seeds can either follow a dry or a wet processing. As food quinoa, can be used as a rice replacements or added in other food recipes. Its seed flour can be used in a variety of confectioneries formulations. Non-food applications includes the use of saponin in making hair shampoo and detergents, while the straws and other parts of the plant can be used for fuel and animal feeds. Therefore, quinoa is a potential crop in Tanzania not only for food and nutrition security but also as a source of income through both local and export markets.

Key words: Quinoa, Food security, Nutrition, Climate change, adaptability, Agriculture

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1. Introduction

Tanzania population growth rate is approximately 3% , and the current population is expected to double by 2050 (Brinda, Andrés, & Enemark, 2014). Food production to meet future demand requires expansion of the farming land, intensification of the current production technology to increase yield and use of improved storage facilities to ensure sustainable food availability (Lang, 2010). Also, according to Joyceline and Fanny (2014), Tanzania malnutrition rate is 4.9% where by, chronic malnutrition is at 35% due to limited access to nutritious food (UNICEF, 2015). This is because majority of Tanzanians depend on common cereals such as; rice, maize, sorghum, wheat and tuber crops such as; cassava and potatoes as their main staple food (Rosalind S. Gibson & Christine Hotz, 2001; Houston, 1994). All these staple food are rich in macronutrients but poor in essential micronutrients leading to nutrition insecurity (Ranum, Peña Rosas, & Garcia Casal, 2014). On the other hand, as a current situation globally, Tanzania is experiencing a diverse climate change whereby, several parts of the country are suffering from drought, unreliable rainfall patterns, soil erosion, soil fertility degradation, temperature extremes, plant diseases and pests infestation (Kinabo, 2004; Lema & Majule, 2009; Mongi, Majule, & Lyimo, 2010; Schlenker & Lobell, 2010). All these facts, raise a concern whether traditional agricultural practices and local cereal crops species which are vulnerable to climate change, have the capacity to meet future food demand for the fast growing population (Brinda et al., 2014). Therefore, there is an urgent need to identify and adopt nutritious and stress tolerant food crop as alternative staple crops for sustainable food production and as a mitigation strategy to climate change especially in marginal areas of Tanzania.

Quinoa (*Chenopodium quinoa Willd*) has been reported to be a potential crop for food and nutrition security, it can serve to eradicate hunger, malnutrition and poverty globally (Sven-Erik Jacobsen, 2003a; S-E Jacobsen, Mujica, & Jensen, 2003; Sven-Erik Jacobsen, Sørensen, Pedersen, & Weiner, 2013). It is an ancient and native food crop for the Andeans people in South America forming an important part of their meal (Peiretti, Gai, & Tassone, 2013). Quinoa is a pseudocereal belonging to the *Chenopodiceae* family, genus *Chenopodium* (Lamothe, Srichuwong, Reuhs, & Hamaker, 2015). Based on colour unprocessed quinoa seed colour varies from white, black to red (Jancurova, Minarovicova, & Dandar, 2009; Nowak, Du, & Charrondière, 2015). It has been referred to as mother crop due to nutritional potentials and adaptability to a wide range of geographical condition (Repo-Carrasco-Valencia, Encina, Binaghi, Greco, & Ronayne de Ferrer, 2010). Although quinoa is not a true cereals, it's seeds can be milled into flour and be used in the same way like other cereals crops such as maize and rice (Ramos Diaz et al., 2013). According to Ferreira, Pallone, and Poppi (2015), Peru, Bolivia, Colombia and Ecuador are the major producers of quinoa globally. Bolivia and Peru are the major exporters of quinoa contributing to over 85% of quinoa in the global market (Abugoch James, 2009; Dallagnol, Pescuma, De Valdez, & Rollán, 2013; Inglett, Chen, & Liu, 2015).

Quinoa seeds are highly nutritious, contains not only carotenoids and vitamin C but also, rich in minerals such as Ca, Fe, Mn, Mg, Cu, and K compared to common cereals such as rice, maize, wheat and barley (Lazarte, Carlsson, Almgren, Sandberg, & Granfeldt, 2015). Unlike common cereals, quinoa seeds have a balanced protein profile same as milk protein and high quality fatty acids composition same as that of soybean oil (Ferreira et al., 2015). While quinoa seeds are gluten free, they are also claimed to be protective against allergy, acute inflammation and cardiovascular diseases because they contain phenolic compounds and other protective antioxidants (Graf et al., 2014; Nascimento et al., 2014). The Food and Agriculture Organisation (FAO) mention quinoa as a potential crop for future food security due to its nutritive value and diverse adaptability to harsh weather (Sven-Erik Jacobsen, 2003b). Coupled with that, the United Nations (UN) declared 2013 as the international year of quinoa as a mitigation to fight global food and nutritional insecurity (Nowak et al., 2015).

Quinoa has recently interested other nations including, United states, Canada, Europe, China, Australia, China and Japan (Escuredo, González Martín, Wells Moncada, Fischer, & Hernández Hierro, 2014). Although quinoa is unpopular in Africa, it has been introduced since 1990s in Kenya and in 2010s in Malawi on research bases (Maliro & Guwela, 2015). No cultivation trials have been conducted in Tanzania to test for adaptability, productivity and consumer acceptability of quinoa. Maize, rice, sorghum and cassava commonly used as staple food in Tanzania, are less nutritive and have limited adaptability as compared to quinoa (Schoenlechner, Wendner, Siebenhandl-Ehn, & Berghofer, 2010). At the same time, micronutrient deficiencies (hidden hugger) are increasingly high in Tanzania (Macro, 2011; Robinson & Nyagaya, 2014). Therefore, agricultural researchers in Tanzania should focus on introducing healthy and stress tolerant such as quinoa as a mitigation to food insecurity, poverty and climate change threats. This work narrates the potentials of quinoa to Tanzanian communities. It aims at advocating the adoption and utilization of quinoa as a best and sustainable source of nutrients than fortification programs which are popular today.

2. Nutritional potentials of Quinoa

2.1 Carbohydrates

Quinoa carbohydrate content varies from 66% to 78% which is less compared to cereals commonly used as staple food in Tanzania such as maize (81.1%) and rice (80.4%) **(Table 1)**. Quinoa starch is ideal for diabetics, obese and those with cardiovascular diseases due to its low glycaemic index (Bhargava, Shukla, & Ohri, 2006; Inglett et al., 2015; Jancurova et al., 2009). Also, quinoa starch finds a lot of application in the food industry because of its unique properties (Araujo-Farro, Podadera, Sobral, & Menegalli, 2010; Gely & Santalla, 2007; Inglett et al., 2015). Its starch granules are smaller up to 3.0µm as compared to maize which is up to 23µm and wheat which is up to 40µm, the property which favours its easy dispersion in food (Rayner, Timgren, Sjöö, & Dejmek, 2012; Valencia-Chamorro, 2004). Opaque nature of quinoa starch makes it more useful in emulsion foods, while it's resistive nature to retrogradation makes it useful for frozen food (Bhargava et al., 2006). Conversely, quinoa starch have non-food applications in industries as biodegradable filler in light polyethylene (Bhargava et al., 2006).

2.2 Proteins

Quinoa seeds contain protein up to 16.5% which is high as compared to common cereals such as rice (8%), wheat (14%), and barley (11%) **(Table 1)**. Since quinoa is gluten free, it is widely used in food recipes for a range of consumers including the celiac and vegetarians (Abugoch, Tapia, Villamán, Yazdani-Pedram, & Díaz-Dosque, 2011; Harra, Lemm, Smith, & Gee, 2011). Major proteins in quinoa are albumin and globulin which forms 77% and less than 7% prolamins (Jancurova et al., 2009). Quinoa protein has a balanced amino acid profile such that, it contains histidine and lysine which are uncommon in plant source (Escuredo et al., 2014; Repo-Carrasco-Valencia et al., 2010). Quinoa could be a better alternative for protein source especially in rural communities in Tanzania and other developing countries since its protein matches milk casein protein which is expensive (Comai et al., 2007; Rosalind S Gibson & Christine Hotz, 2001).

2.3 Fats

Depending on variety, quinoa seeds contains fat up to 10% which is higher than in other cereals (Valencia-Chamorro, 2004). Fatty acids composition in quinoa fat is quite similar to that in soybean oil, containing essential fatty acids; linoleic, oleic and palmitic (Peiretti et al., 2013). Quinoa oil contains vitamin E, a natural antioxidants, therefore it is stable to rancidity and have a long shelf life (Bhargava, Shukla, & Ohri, 2007). If incorporated in Tanzanian meals, it can be a good source of fat as opposed to common cereals. Also, Quinoa could be a better raw material for high quality edible oil extraction than corn (maize) for export markets (Peiretti et al., 2013; Tang et al., 2015).

2.4 Fibres

Quinoa seeds are a good source of dietary fibre rich in xyloglucans and pectic substances (Lamothe et al., 2015). Depending on variety, quinoa contains up to 3.8% fibre **(Table 1)** (Alvarez-Jubete, Arendt, & Gallagher, 2010; Jancurova et al., 2009; Miranda et al., 2012; Schoenlechner et al., 2010).

Table 1: Proximate composition of quinoa and other cereals (g per 100g dry weight)

	Quinoa	Maize	Rice	Wheat
Protein	16.5	9.4	7.6	14.3
Fat	6.3	4.7	2.2	2.3
Fibre	3.8	7.3	6.4	2.8
Ash	3.8	1.2	3.4	2.2
Carbohydrate	69.0	74.3	80.4	78.4

(Jancurova et al., 2009; Nuss & Tanumihardjo, 2010)

2.5 Minerals and Vitamins

Quinoa contains over 3.5% ash which is higher than that in common cereals such as rice (0.5%), wheat (1.8%) and maize (1.7%) (Konishi, Hirano, Tsuboi, & Wada, 2004; Miranda et al., 2012). For instance; quinoa is rich in minerals; calcium, magnesium, iron and copper and vitamins; ascorbic acid and β-carotene (Jancurova et al., 2009; Lazarte et al., 2015). It is a potential crop for Tanzanian communities to fight hidden hunger especially for women at reproductive age, pregnancy, children and other vulnerable groups (Sven-Erik Jacobsen et al., 2013; James & Matemu, 2016; Shekhar, 2013). Use of crops rich in nutrients such as quinoa could be a sustainable approach to fight hidden hunger rather than fortification programs which are sophisticated (depends on industries and distribution systems), donor dependant and may not reach people in remote areas (Shekhar, 2013). Schoenlechner et al. (2010), mentioned that pseudo cereals such as quinoa are rich source of folate which is an important vitamin during pregnancy. In addition quinoa attracts different communities around the world because it is claimed to be protective against non-communicable diseases such as cancer and diabetes mellitus type II (Gómez-Caravaca, Iafelice, Verardo, Marconi, & Caboni, 2014).

Table 2: Some mineral composition of quinoa and other cereals (mg/kg dry wt.)

	Quinoa	Maize	Rice	Wheat
Ca	1487	7	65	503
Mg	2496	127	735	1694
K	9267	287	1183	5783
P	3837	210	1378	4677
Fe	132	2.71	7	38
Cu	51	0.3	2	7
Zn	44	2.2	6	47

(Jancurova et al., 2009; Nuss & Tanumihardjo, 2010)

3. Quinoa agronomic practises

Quinoa has a broad genetic diversity such that, over 150 species are cultivated around the world (Valencia-Chamorro, 2004). Most of species can adapt to a wide range of soil pH (6.00 to 8.5), salinity, frost (S. E. Jacobsen et al., 2007) and areas where annual rainfall is bellow 300mm (Miranda et al., 2014; Repo-Carrasco-Valencia et al., 2010). Quinoa can be grown from sea level up to over 3700m altitude and from cold (bellow 0ºC) to above 34ºC temperatures (Bhargava et al., 2007; Valencia-Chamorro, 2004). Quinoa grows up to 205 meters tall and takes about 6 months to reach maximum maturity (S. E. Jacobsen et al., 2007; Lamothe et al., 2015; Valencia-Chamorro, 2004; Vilche, Gely, & Santalla, 2003). Based on its versatility quinoa can be introduced and perform well in various parts of Tanzania. For instance; it can be an alternative crop to areas with low annual rainfall such as Central Tanzania, Mara and Same. According to Maliro and Guwela (2015), quinoa cultivation trial performed well in Kenya in 1990s and Malawi in 2010s under varying environment.

Downy mildew diseases caused by *Peronospora farinose* is highly reported to affect quinoa production worldwide (Danielsen, Bonifacio, & Ames, 2003; Stikic et al., 2012). Other disease includes; rhizotomies damping off, fusarium wilt, seed rot, damping off, leaf spot and brown stalk rot (Danielsen et al., 2003; Jancurova et al., 2009). Up to 20% yield loss due to diseases and pest infestation has been reported in Peru, Ecuador, Bolivia and Colombia (Danielsen et al., 2003).

4. Processing

Quinoa seeds outer layer is bitter; it is normally removed before human consumption because it impairs on the seeds palatability (Jancurova et al., 2009; Kuljanabhagavad, Thongphasuk, Chamulitrat, & Wink, 2008; Valencia-Chamorro, 2004). The external coating can be removed by abrasive de-hulling in alkaline water (wet process), followed by washing in water before drying (Jancurova et al., 2009). The drying processes should be immediate after washing to avoid seed germination and fungal growth (Pappier, Fernández Pinto, Larumbe, & Vaamonde, 2008; Valencia-Chamorro, 2004). This method is recommended for commercial application (Miranda et al., 2011).

The second method involves scrubbing and polishing (dry process) of quinoa seeds without water application hence the seeds does not pass through the drying process (Pappier et al., 2008; Valencia-Chamorro, 2004). This method is less expensive compared to the later because it does not use resources such as water and heat energy, yet, it does not contaminate the environment (Miranda et al., 2011; Valencia-Chamorro, 2004). Dry processing is feasible for household applications (Valencia-Chamorro, 2004).

5. Uses and application

Quinoa seeds are popularly used as a rice replacement, whereby processed seeds are boiled and served as rice (Lamothe et al., 2015; Miranda et al., 2011; Valencia-Chamorro, 2004). Also, the seeds can be used as a toping in various food recipes such as salad and soup (Jancurova et al., 2009; Lundberg-Hallén & Öhrvik, 2015). Quinoa seeds flour finds a wide range of application in the food industry (Inglett et al., 2015). For instance, it can be used at different proportions along with other ingredients to make cakes, noddles, biscuits, bread and be extruded to make various food snacks (Elgeti et al., 2014; Inglett et al., 2015). According to Iglesias-Puig, Monedero, and Haros (2015), a proportion of quinoa flour improves bread quality. Coupled with that, quinoa seeds can be fermented to a good quality temple (Harra et al., 2011; Valencia-Chamorro, 2004), also can be brewed into a gluten free beer (Collar & Angioloni, 2014; Deželak et al., 2014).

Medina, Skurtys, and Aguilera (2010), mentioned that, quinoa fits as a component in baby's food formulations because it contains all nutrients necessary for baby health. For example, it can be mixed in porridge formulations which is popular food for kids under 5 years and lactating mothers in Tanzania. Shekhar (2013), reported that, Fe and Zn deficiency has led to prevalence of maternal mortality and stunting in developing countries respectively. Application of quinoa in different food formulations in Tanzania could be a sustainable solution to fight hidden hunger. Utilization of quinoa food products could be an additional effort to food fortification and micronutrients supplement programs to fight malnutrition in Tanzania.

According to Valencia-Chamorro (2003), quinoa plant leaves can be served as raw salad or cooked same as other vegetables. Also the leaves can be processed into other products such as, tonics, puddings and syrups (Jancurova et al., 2009). Vidueiros et al. (2015), concluded that, the whole quinoa plant can be processed into a nutritious broiler feed at proportion of 150g/kg of a feed.

Saponin which is processed out of the quinoa seed pericarp, is potential components for a number of non-food industrial applications (Gómez-Caravaca et al., 2014; Harra et al., 2011; Świeca, Sęczyk, Gawlik-Dziki, & Dziki, 2014). It is used as component in making hair shampoo, detergents, dye, fungicides and fire extinguisher chemicals (Araujo-Farro et al., 2010; Gómez-Caravaca et al., 2014; Stuardo & San Martin, 2008). Apart from being a source of nutritious food, quinoa is a potential crop for Tanzanians as a source of income to contribute for poverty alleviation.

6. Conclusions

The current and future food demand to feed the rapid growing population in Tanzania, requires adoption of nutritious and stress tolerant food crop varieties such as quinoa. Quinoa is a potential source of food and income due to its wide range of adaptability and high demand especially in export markets. Inclusion of quinoa in dietary patterns, infants and pregnancy food formulations could be a sustainable approach to fight food and nutrition insecurity in Tanzania rather than sophisticated fortification and supplementation programs. Due to its wide geographic adaptability and successful trials in different parts of the world including Kenya and Malawi, quinoa can also be cultivated and adopted successful in Tanzania. However, community awareness and technical support is required for a successful adoption of quinoa.

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