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Development of Nutritional and Biological Activity of Quinoa Seeds for Functional Food Products

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ABSTRACT

Quinoa (Chenopodium quinoa Wild., Amaranthaceous) is a stress-tolerant, grain-like food crop that for thousands of years has provided subsistence, nutrition, and medicine for indigenous Andean cultures. Quinoa includes a high content of photochemical that are good for wellbeing, including amino acids, fibre, polyunsaturated fatty acids, vitamins, minerals, spoons, phytosterols, phytoecdysteroids, phenolics, beta and lysine beanies. Numerous food products and nutraceutical products and processes have been produced from quinoa over the past 2 decades. In addition, 4 clinical studies have shown that supplementation with quinoa has significant, beneficial effects on human metabolic, cardiovascular, and gastrointestinal health. Within the research, agricultural and development sectors, however, vast challenges and opportunities remain to optimize the role of quinoa in promoting global human health and nutrition.

Keywords: *Biological Activity, Cereal Products, Dietary Supplements, Nutritional Quality, Quinoa*

INTRODUCTION

Malnutrition, a wide-mouthed demon, advancing on a staggering scale, is a global distress affecting one in nine people on earth (FAO, 2011). The International Food Policy Research Institute (IFPRI) Global Nutrition Report (GNR), 2015, a report card on the global nutrition scenario, provides a clear view of the triumph of malnutrition over ineffective global efforts to combat this demon. Though malnutrition affects the world, the rate of incidence in developed countries is abysmally large. In India, in partnership with UNICEF (2013-14), the Study Survey on Children (RSoC) recorded 29.4% of Indian children as underweight, 15% wasted and 38.7% stunted. The statistics portrayed malnutrition as "India's National Shame" (Dasgupta, 2015). The shrinkage of world food baskets is one of the key factors behind global malnutrition. The global food supply depends primarily on a few species of crops, called 'Major Crops.' Just 30 such crops meet almost 95 per cent of the world's food requirements. Dependence on 30 crops in the world population of 7.3 billion people (Population Reference Bureau, 2015) has created a significant imbalance between global food supply and global food demand, further contributing to food shortages and a worsening global malnutrition scenario.

There is also a great need to broaden the genetic diversity of plants in order to avoid reliance on only the main food crops. Researchers worldwide stress the need to concentrate and expand the use of those crops abandoned by science, technology and marketing systems, with growing interest in seeking new alternative sources. These crops are known as "Neglected and Underused Crops" (NUCS), also known as "Orphan Crops." Chenopodium quinoa, an underutilised pseudo-cereal crop belonging to the Chenopodiaceae family, is one such overlooked crop. Originating and originating originally in the Andean region of South America (Matiacevich et al., 2006), Chenopodium quinoa is an ancient crop with modern perspectives, with Peru and Bolivia being the main producers.

The genus Chenopodium belongs to the Amaranthaceae (APG II System, 2003) family of flowering plants and is classified into the Chenopodiaceae subfamily (formerly known as the goosefoot family), comprising approximately 250 species (Kadereit et al., 2005). Quinoa is an annual herb, 1 to 4 m tall, with erect cylindrical stems, green to pale yellow leaves, petal-free flowers and colourful (red, purple, yellow, black) seeds (James, 2009). The thirty-seventh session of the FAO General Conference adopted a resolution recommending the declaration of the year 2013 as the 'International Year of Quinoa.' The key amazing features of the Chenopodium quinoa crop, namely its extraordinary nutritional composition, flexibility to adapt to extreme environmental conditions and latent inherent ability to triumph over global hunger and malnutrition.

As estimated by USDA, 2013 reports on the proximate composition of quinoa, 13.2 percent moisture content, 14.12 percent protein, 6 percent fat, 2.3 percent ash, 64.8 percent carbohydrate and 7 percent fibre content. The protein content of quinoa is considered similar to that of milk protein, casein, when considering the nutritional aspect (Gordillo-Bastidas et al., 2016). It contains all the essential amino acids containing both lysine (5.4%) and methionine (2.1%), which gives it a special characteristic and makes it a complete food product (USDA, 2013). The ash content of quinoa is greater than that of traditional cereals such as wheat and rice (Miranda et al. 2012) and the fibre content is greater than that of maize and wheat (Miranda et al. 2012). (Repo-Carrasco-Valencia, 2010). The seeds are also high in minerals, vitamins and (Konishi et al., 2004). Quinoa seeds are also found to be abundant in bioactive compounds such as polyphenols (Hirose et al., 2010), isoflavones (Lutz, 2013) and to have good anti-oxidant properties (Pasko et al. 2010a). It was also known as an oil crop with a fatty acid composition corresponding to soybean oil (Comai et al., 2007). The presence of prolamine in non-quantifiable quantities gives it the added benefit of being a "gluten-free grain," making it ideal for patients with celiac disease to eat it (Zevallos et al., 2012).

Despite being nutritious, due to the presence of saponins, primarily in the hulls, the only downside of this grain is bitterness and specific astringency in its taste (GomezCaravaca et al., 2014). The variety can be graded as "sweet" (Saponin 0.1 percent) depending on the saponin content present in quinoa seeds (Mastebroek, 2000). Domestic or industrial processing will lower the content of saponin (Soetan and Oyewole, 2009) to make the grain more palatable and appropriate. The presence of nutrients and bioactive compounds also conveys quinoa's nutraceutical properties. It is understood that against various conditions such as hypertension, obesity, hypercholesterolemia, diabetes, etc., it has health potential (Jancurova et al. 2009; Arneja et al. 2015). The involvement of phytochemicals is responsible for their anti-oxidative, cardiovascular, antiallergic, anti-inflammatory, antiviral, and anti-carcinogenic activities (Hirose et al., 2010). (James, 2009). Often known to have the ability to help regulate appetite, Chenopodium quinoa (Berti et al., 2004). Speaking of the versatility of the crop to adapt to harsh environmental conditions, it is tolerant to challenging conditions such as soil salinity (pH 6.0 to 8.5), drought, frost, unfavourable temperatures (as low as -1 ⁇ C to 35 ⁇ C), etc.

The capacity to rise at an elevation of 4500 m above sea level (Jacobsen, 2011). Successful quinoa propagation in field trials at the hottest and driest location in the world, the Arabian Peninsula, also demonstrates its ability to adapt to adversity (Rao and Shahid 2012). Thus, the versatile features of this crop and its impeccable nutritional benefits cause quinoa cultivation to advance to different parts of the world from the borders of its Andean motherland. In addition to exemplary features, the rising demand for quinoa worldwide has also prompted farmers and researchers to cultivate quinoa worldwide. Quinoa has been successfully promoted in England (1970), Denmark, Europe (1993) and Kenya (Jacobsen, 2011) and has made its way to Asia with a strong interest in the crop, especially in the Indian subcontinent (Bhargava et al., 2006).

In Pakistan, Nepal and India, crop production is more widespread. India is a land with varied climatic regions (tropical wet, tropical dry, subtropical humid and mountains) and quinoa is a crop deeply known to be well adapted under unusual environmental conditions. Initially grown in the footsteps of Himlayan hills in India, the crop was successfully grown for the first time in 2013 under the Indian border (Bhargava et al., 2006). The project has greatly promoted the cultivation of quinoa among South India's various private companies. The quinoa craze and demand among Indians has increased much more than their demand for traditional staple crops and millets such as sorghum, pearl millet, finger millet, etc. Since most of the quinoa saponins are present in the outer layers (40-45 percent), grains undergo industrial processing, primarily the de-hulling or de-cortication process, to extract the outer layers of the grain after harvesting and prior to marketing. Dehulling is known to enhance the consistency of the grain by lowering the anti-nutrient content (Lestiene et al., 2007) and improving the grain's acceptance and palatability. Dehulling, in addition to these advantages, has also been reported to cause nutrient loss. The researchers therefore suggest using common conventional domestic processing methods (Pawar and Machewar, 2006; Hotz and Gibbson, 2007) such as soaking and germination for domestic grain processing to reduce the loss and increase the bioavailability of nutrients from grains (Hemlatha et al. 2006).

In deciding the nutritional and phytochemical composition of a crop, the grain variety, climatic conditions of the cultivation region and processing methods are considered to be significant influencing factors. After several studies revealing the nutritional and phytochemical composition of American quinoa (Pasko et al.,2010b; Repo Carrasco Valencia et al., 2010; Miranda et al., 2012 and 2013; Carciochi et al., 2014; Gomez-Caravaca et al., 2014 and Tang et al., 2015), Kenya (Mujica et al. 2001), Japan (Hirose et al. 2010) and Morocco (Marmouzi et al., 2015) have recently been studied for their seed qualities. Indian Chenopodium quinoa, which was recently introduced in India, has not been much explored for its nutritional composition and health benefits, as per the literature available. "Therefore, the objective of our study is to debit Chenopodium quinoa seeds by removing saponins through domestic processing methods and estimate the nutritional and biological activity of debittered Chenopodium quinoa seeds, grown in Andhra Pradesh's Anantapur district, under the "Anantha" project. In the light of the above discussion, the present study "Debit evaluation of nutritional and biological activity.

OBJECTIVES OF THE STUDY:

1) To evaluate the nutritional quality of Chenopodium quinoa seeds

2) To assess the cholesterolemic effect of Chenopodium quinoa seeds

3) To develop and analyze value added products from Chenopodium quinoa seeds

Crude protein

The protein content of quinoa is higher than the widely used grains, according to USDA 2015, (Table 2.1). The protein content of Quinoa ranges from 11.32 to 16.10 g/100gm (Miranda et al., 2012). In comparison to wheat, barley, corn and maize, quinoa (cystine, arginine, histidine) and globulin (chenopodine) are the main proteins with a protein content of 35 and 37%, respectively (James, 2009).

Furthermore, the presence in celiac patients of non-quantifiable levels of glutamic acid and prolamine (<7%) and irritant protein makes quinoa appropriate for consumption in patients with celiac disease (Zevallos et al., 2012). This also makes quinoa a suitable candidate for gluten-free functional food product formulations (Manikandan et al., 2013). It is also established that the protein content of food is inversely related to its glycemic index (Shin et al., 2013), so quinoa is also appropriate for inclusion in the list of low glycemic index foods as higher protein content contributes to fullness, delayed gastric emptying and decelerated digestion rate (Pineli et al., 2015). It has been found that the protein content of the quinoa protein is almost the same as the milk protein, casein (Vega-Galvez et al., 2010). The low sulphur amino acid content of globulins in albumins is well balanced by the amino acids rich in sulphur (Mardini Filho et al., 2015). Quinoa is considered to be an outstanding grain containing both methionine (40 to 100 mg/100 g) and lysine (510 to 640 mg/100 g), which in legumes and cereals, respectively, restrict amino acids (Gorenstein et al., 2004, Bhargava et al., 2007, Gesinski and Nowak, 2011). Quinoa, except for tryptophan, contains all the essential amino acids (Elsohaimy et al., 2016). The existence of a well-balanced composition of amino acids therefore makes quinoa protein a "complete protein" of high nutritional and biological value (Comai et al., 2007).

In addition to having special nutritional properties, quinoa's protein content is also responsible for its varied functional properties. It imparts functional food products produced from quinoa with properties such as foaming, structural and thermal stabilisation. The addition of quinoa protein to the chitin-derived film improved the tensile property and thermal stability of the film quinoa-chitosan (Araujo-Farro et al., 2010).

Crude fat

The fat content of quinoa varies from 4.6 to 5.7 g/100g (Miranda et al., 2013) and is stated to be similar to kaniwa, the Andean crop (Repo-Carrasco-Valencia et al., 2011). Quinoa fat's qualitative and quantitative characteristics render it ideal for use as an oil crop. The fat content is greater than that of traditional cereals (USDA, 2015) and is uniquely rich in essential fatty acids (Table 2.1). (James, 2009). It also contains fewer saturated fatty acids and plentiful unsaturated fatty acids consisting of mono and poly unsaturated fatty acids (Marmouzi et al., 2015). Quinoa fat is 25 to 29% oleic acid (MUFA), 59% linoleic acid (PUFA) and 12.3% palmitic acid,

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according to Marmouzi et al., 2015. (SFA). Quinoa's fatty acid profile is also stated to be similar to soy and maize (Borges et al., 2013). It is also known that higher levels of PUFA are beneficial for cardiovascular disorders and insulin sensitivity (Oliver et al., 2012). Furthermore, quinoa's ratio of ⁇ -6/ ⁇ -3 fatty acid (10:1/9:1) is higher than western diets (Marmouzi et al., 2015), which also shows quinoa as a beneficial grain for cardio vascular disorders. Quinoa fatty acids are followed by antioxidants, which function as a saviour against oxidative rancidity (Ng et al., 2007). Tocopherols play a major role among antioxidants in imparting antioxidant activity to quinoa (Tang et al., 2014). The presence of γ-tocopherlos (797 ppm) and alpha-tocopherols (721 pm) in food applications encourages the use of quinoa and increases the shelf life of quinoa oil (Repo-Carrasco-Valencia et al., 2011). The quinoa oil saponification index (192%) is lower than butter (242%) and coconut oil (250%), but comparable to cottonseed (193%) and soybean (190%) oil (Sundarrajan, 2014). The unsaponifiable oil fraction of quinoa comprises squalene and phytosterols, in addition to tocopherols. The presence of squalene (54 to 89 mg/100g), an organic compound also contained in shark liver oil, is known to provide quinoa seeds with cardio vascular protective capacity (Ryan et al., 2007). Graf et al., 2014, concluded that quinoa's phytoecdysteroid content is directly associated with its oil content. While little attention has been given to phytosterols in quinoa, quinoa grains are known to contain around 118 mg/100 g of phytosterols (Varli et al., 2016). The presence of phytosterols, primarily campesterol (16 mg/100g), stigmasterol (3.4 mg/100g) and β-sitosterol (64 mg/100g), imparts quinoa with anti-inflammatory and anti-carcinogenic and hypo-cholestrolemic capacity (Villacres et al., 2013). The phytosterol content of quinoa is greater than that of maize and millet (Ryan et al., 2007). Phytosterols are also considered to have a major effect on lowering cholesterol levels through competitive cholesterol absorption inhibition due to structural similarity with cholesterol (Graf et al., 2015).

Impact of processing on fat content In 2013, Kayembe et al. documented an increase in fat content after soybean germination, as affected by processing techniques such as soaking and germination, while Kajihausa et al. reported a decrease in fat content after sesame seed germination in 2014. During the process, the observed decrease may be due to cell growth. Seed growth due to water imbibition by soaking cells consumes the required fat energy, a major source of carbon in seeds, which can lead to a decrease in fat content after soaking (Rumiyati et al., 2012). Crop germination contributes to the synthesis of metabolites. This metabolic transition involves energy released by fatty acid oxidation, resulting in a reduction in the fat content of germinated seeds (Hahm et al., 2009).

RESEARCH METHODOLOGY

This paper refers to the research design of this study. It explains in detail the methods used to accomplish the specified research objectives.

MATERIALS

Sample collection

To conduct this study Indian white Chenopodium quinoa grains “Royal White”, grown under project “Anantha,” were procured from TSIPARD (Telangana State Institute of Panchayat Raj and Rural Development), Hyderabad, Telangana, India. The American white Chenopodium quinoa grains “Royal White”, imported from Bolivia, South America, were procured from Devshree grains and pulses, New Delhi, India.

Sample processing

To debitter the raw white Indian Chenopodium quinoa, the grains were subjected to domestic processing methods viz. soaking and germination to obtain embittered Chenopodium quinoa seeds. The industrially processed grains refer to the product as available in the market for consumer consumption after undergoing industrial processes for embittering of quinoa.

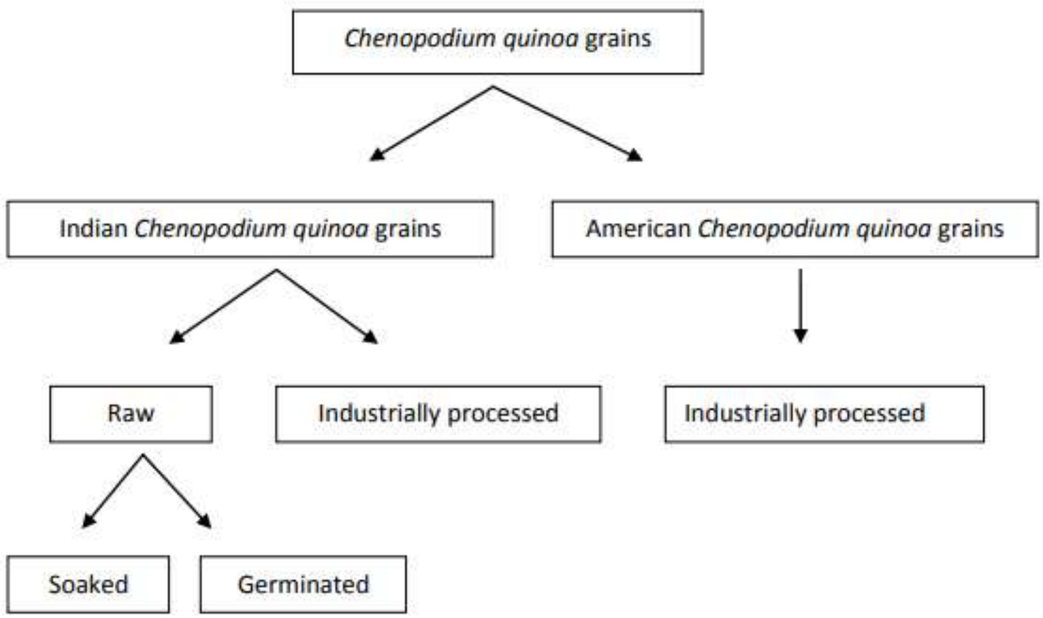

Figure 1.1: Processing of Chenopodium quinoa grains

DATA ANALYSIS

The raw seeds were reported to have a moisture content of 11.30±0.08 g/100g. The outcome was consistent with the values suggested by Nascimento et al., 2014. A important difference was observed ($p<0.05$) in the moisture content of untreated, domestically processed and industrially processed seeds. Soaking resulted in an 8.5 percent increase in moisture content, while germination resulted in a 17.5 percent decrease in moisture content. Desalegn, 2016, reported a similar pattern of variation in moisture content after soaking and germinating chickpea. The increase in moisture content after soaking may be attributable to dry seed water absorption, resulting in cell hydration and cell multiplication inside the seed (Nonogaki et al., 2010), although decreased germination moisture content may be due to the use of water in metabolite synthesis (Chung et al., 2014). Industrial quinoa production resulted in a decrease in moisture content by 8.5 percent. This can, during the process, be due to the removal of hulls. Chauhan, 1992, in quinoa hulls that account for about 8 percent of total seed weight, recorded 11.3 percent moisture content. Lower moisture content is an indication of longer shelf life of goods (Sanni et al., 2006). Thus, the findings show that germinated quinoa seeds have a stronger shelf life.

CONCLUSION

The Chenopodium quinoa seeds were assessed for their nutritional content towards the achievement of goal one. Proximate, nutritional, physiochemical and in vitro studies were carried out on the plants. (a) Indian Chenopodium quinoa seeds have been processed by domestic methods, namely soaking and germination, and have been evaluated for proximate, nutritional and physiochemical composition in comparison with raw and industrially processed seeds.

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