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Review

Nutritional constituents of pseudo cereals and their potential use in food systems: A review

Nisar Ahmad Mir, Charanjit Singh Riar, Sukhcharn Singh*

Department of Food Engineering & Technology, Sant Longowal Institute of Engineering & Technology, Longowal, Punjab, 148106, India

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ABSTRACT

Consumers are more focused to adopt healthy life styles and appropriate nutritional habits. From the variety of plants which can be potentially used for human nutrition, today fewer and fewer species are used due to elevated risk of health related problems. Results from a number of recent studies have highlighted the need for an improvement in the nutritional quality of cereal based gluten free products. In order to meet the demands of the growing population new food stuffs are being continuously investigated with the aim to improve the diet and conduce to a better health state. At present attention of researchers is more focused towards the exploitation of alternative crops or underutilized species for multifarious uses. Interest in the pseudo cereals has aroused considerably due to their excellent nutritional, phenolic and phytochemical profile and their use in development of gluten free products. Moreover, the amino acid profile and nutritional properties like essential amino acid index, biological value, protein efficiency ratio and nutritional index of pseudo cereals are higher as compared to conventional cereals like wheat rice and maize. Recent studies have indicated that phenolics present in pseudo cereals have several health benefits like prevention and reduction of oxidative stress, anti-cancer, anti-diabetic, anti-inflammatory, anti-hypertensive and prevention of cardiovascular diseases. Therefore, commercialization of these pseudo cereals would help to combat various health related issues, and also the availability of palatable pseudo cereal containing gluten-free products would represent advance towards ensuring an adequate intake of nutrients in subjects with celiac disease.

1. Introduction

The greatest threat to the survival of humanity is the ever-increasing gap between population growth and food supply. FAO, in its annual report "The State of Food Insecurity in the World 2017", estimates that the number of chronically undernourished people in the world is estimated to have increased to 515 million, up from 777 million in 2015 although still down from about 900 million in 2000 (Kline et al., 2017). From the nutritional point of view, the usefulness or functionality of any grain as human food depends primarily on the quantity and quality of protein. Proteins are an important group of bio-macromolecules that are involved in the physiological functions. Natural vegetable proteins are useful materials owing to their safeness, high biocompatibility, nutritional value and low cost. Hence, finding new vegetable proteins rich in essential amino acids is important for food and pharmaceutical industries (Bergamo, Maurano, Mazzarella, Gianfrani, & Rossi, 2011). The grain functionality principally depends on the genetic makeup and impact of environmental factors on its principal components like carbohydrates, proteins, vitamins, minerals and phenolic phytochemicals. Due to this reason many cereals crops may be either rich in one component or may be deficient in other compound. In order to overcome this condition, much attention has been centered on the exploitation and utilization of unusual food plants, such as Andean pseudo cereals. There is a considerable interest in Andean pseudo cereals for their nutritional potential, phytochemical content and their use in gluten free products. This new plant species has a more important role in the development and diversification of agricultural products and food. Therefore, the development of novel foods from such plant species having multitude of health benefits can offer an excellent opportunity to improve the public health; hence such foods are gaining importance from the scientific community, consumers, and food manufacturers (Gul, Singh, & Jabeen, 2016). Whole pseudo cereal grains such as buckwheat, amaranth and quinoa are also rich in a wide range of compounds e. g flavonoids, phenolic acids, trace elements, fatty acids and vitamins with known effects on human health like prevention and reduction of many degenerative diseases (Gorinstein et al., 2002; Kalinova & Dadakova, 2009; Li & Zhang, 2001; Tomotake et al., 2007). It has been observed that consumption of whole grains have been

* Corresponding author.
E-mail address: sukh_72@hotmail.com (S. Singh).

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associated with reduced incidence of diseases such as cancer (Chan, Wang, & Holly, 2007; Slavin, 2004), cardiovascular disease (Jacobs & Gallaher, 2004; Mellen, Walsh, & Herrington, 2008), high blood pressure (Behall, Scholfield, & Hallfrisch, 2006; Flint et al., 2009) and diabetes (Lutsey et al., 2007; Qi & Hu, 2007; Rave, Roggen, Dellweg, Heise, & tom Dieck, 2007). Despite their high quality protein, amino acids, phytochemicals and minerals, commercialization of these products is still quite limited due to research gap regarding their nutritional composition and also lack of recent technologies about their processing and utilization. Therefore technology portfolio should be continued and expanded to valorize the knowledge about the processing technologies to achieve attractive functional properties and nutritive value.

Pseudo cereals are underutilized crops, they are gluten free, high in proteins and contains myriad of essential nutrients, they also contain saponins which are having many agro pharmocological and industrial applications (Valcárcel-Yamani, & da Silva Lannes, 2012). In addition the saponins have hemolytic and antilipemic activity and also have the capacity to lower cholesterol level in blood serum. This property of saponins might be considered its most important positive characteristic and also no negative effects of the saponins have been found on the digestibility of proteins (Repo-Carrasco, Espinoza, & Jacobsen, 2003). So keeping in view the importance of above mentioned properties this review article will open new horizons towards the utilization of different underutilized pseudo cereals, their potential health benefits and nutritional properties for the development of novel and functional foods.

2. Historical background

Amaranth and quinoa were two of the major crops for the Pre-Colombian cultures in Latin America. After the Spanish conquest, amaranth and quinoa consumption and cultivation was suppressed and thereafter only continued in a small scale. Recently, the recognition of their nutritional and functional properties has increased consumers interest in them and consequently their cultivation has improved. The production of quinoa is estimated at 39,000 MT in Bolivia, 929 MT in Ecuador and 28,649 MT in Peru in the year 2005 (FAOSTAT, 2007). However, until today amaranth and quinoa cultivation is still low. Amaranth is not even listed in the FAO statistics on production data. However, an appreciable commercial cultivation of amaranth for human nutrition does take place. Besides Latin American countries, it is produced in the USA, China and Europe. Middle Asia has been considered as the origin center for buckwheat and it was then transferred to Central and Eastern Europe by nomadic people. Within 13th century buckwheat reached some importance in Germany, Austria and Italy, which was however lost due to cultivation of other cereals. Today buckwheat celebrates a come-back due to the demand of gluten-free diet and the worldwide production reaches 2.5 Mha providing 2 MT of buckwheat. In 2005, China produced 800,000 MT, followed by Russia (605,640 MT) and Ukraine (274,700 MT) (FAOSTAT, 2007). In Europe, 72,096 MT were produced in Poland, 124,217 MT in France and little in Hungary, Slovenia, Latvia and Lithuania. Japan is the main importer of buckwheat. The differences in production of pseudo cereals may be due to different geographical conditions and different farming practices which significantly affects the production and yield of pseudo cereal crops.

Amaranth and quinoa were considered as the major food crops in the Aztec, Mayan and Incan civilizations. However, their production and use declined significantly due to the conquest of the Spanish cultures which lead to the collapse of Indian cultures (Bressani, 2003; Schoenlechner, Siebenhandl, & Berghofer, 2008). In the past decade quinoa has been introduced in Europe, North America, Asia and Africa with high yields (Abugoch, 2009). Nowadays quinoa production is in a process of expansion in different geographic areas of the world due to its extraordinary adaptability. In Asia, studies in the Himalayas and the plains of Northern India have shown that the crop can successfully produce high yields with agricultural potential for other countries with similar agro-climatic conditions (Bhargava, Shukla, & Ohri, 2006; FAO, 2011). In addition quinoa seeds have been cultivated in Japan showing a higher content of bioactive compounds compared to other cereals and pseudo cereals (Hirose, Fujita, Ishii, & Ueno, 2010).

3. Characteristics of pseudo cereals

According to the American Heritage Dictionary of English language, “a pseudo cereal is defined as any plant that does not belong to the grass family but produces fruits and seeds used as flour for bread and other staple foods”. The three best pseudo cereals known so far are grain amaranth (*Amaranth caudatus, Amaranth cruentus, Amaranth hypochondriacus*; family Amaranthceae), quinoa (*Chenopodium quinoa* sub sp. quinoa; Chenopodiaceae), and buckwheat (*Fagopyrum esculentum*; Polygonaceae). They are dicotyledonous plants as opposed to many cereals like wheat, rice and barley which are monocotyledonous. Their seeds resemble in function and composition to that of true cereals that is why they are referred to as pseudo cereals (Alvarez-Jubete, Arendt, & Gallagher, 2010a). Quinoa (*Chenopodium quinoa Willd*) is a native to Andean region of South America. The crop is well adapted to an altitude of 2000–4000 m. The weedy *Chenopodium album* plant is known as pig weed in English while as its popular Hindi name is “Bathua” (Jan, Saxena, & Singh, 2016). It is also frost resistant and can be grown in areas with low rainfall of 300–400 mm. It has small seeds with diameter ranging from 1 to 2.5 mm. Quinoa according to sowing density can grow upto the height of 1–3 m. The roots can reach a depth of up to 30 cm if sown deep in the soil. The seeds can germinate very fast i,e in a few hours after being exposed to moisture. Its stem is cylindrical having 3.5 cm diameter and the stem can be either as a straight stem or branched and its color is variable. Depending upon the variety it changes its color from white, yellow or light brown to red. Its leaves are shaped like a goose foot and flowers are incomplete and do not have petals. The grain is enveloped in two layered pericarp which contains saponins. The saponins are bitter substances and must be removed before consumption.

Buckwheat (*Fagopyrum esculentum Monch*) has originated from Chinese gene center. In Japan after rice it is considered as one of the most important grain crop. It likes warm climates, low requirements of humus and can be produced on almost all types of soils except sand. Highly nutritious crop and ranks among plants with highest protein content. It has the potential for the prevention of Type-II diabetes and reduction of cholesterol.

Amaranth has a huge biodiversity and among all the species *Amaranth caudatus*, *Amaranth hypochodriacus* and *Amaranth cruentus* are mainly cultivated for their seeds (Kaur, Singh, & Rana, 2010). It was neglected from the food table for many decades and after the arrival of the Spanish conquistadors in Latin America as it was used in ceremonial dishes associated with human sacrifices by the Aztecs (Rastogi & Shukla, 2013). The seeds are lenticular in shape and diameter ranging from 1 to 1.5 mm and weighing 0.6–1.3 mg per seed (Bressani, 2003). Nature has provided this seed with a lot of characteristics like high tolerance to arid conditions and poor soils, resistance to drought, heat and pests and its ability to such environments where conventional cereal crops cannot thrive well.

4. Celiac disease

Celiac disease (CD) is an autoimmune disease characterized by life-long intolerance to the ingestion of gluten a term used to encompass prolamins (specific storage ethanol-soluble proteins) in cereals (Kagnoff, 2005). The pathogenesis of CD involves interactions between genetic susceptibility (HLA-DQ2 and HLA-DQ8 alleles), environmental exposure (gluten intake), and an immunological response that causes typical small intestinal mucosal injury characterized by complete loss of