Reviews on agronomical and functional aspect of quinoa

Sagar M Chavan, NK Jain, Vishal Kumar, SK Jain, C Agarwal, N Wadhawan, Arun Kumar and AK Mehta

Abstract
Quinoa (Chenopodium quinoa Wild) is a pseudo-grain cultivated and consumed by humans as a dietary staple in South America. The grains have higher nutritive value than traditional cereals, present a rich source of a variety of minerals, vitamins and higher contents of most essential amino acids, especially lysine which reveals its potential for a valuable ingredient in the preparation of highly nutritious food. It is nutraceutical properties and functional food that aims at lowering the risk of various diseases. The high genetic variability and premises properties of quinoa make it potential to be grown worldwide, even it has been declared “The International Year of the Quinoa” (IYQ) by the United Nations in the year 2013. In recent years, consumer demand for quinoa in the developed world has grown steadily. The aim of this review was to identify agronomical, functional and nutritional knowledge of quinoa in front of Indian people, to disseminate knowledge about quinoa worldwide. Quinoa has the potential to become an important industrial and food crop of the 21st century.

Keywords: Agronomical aspects, functional aspects, quinoa, Chenopodium quinoa willd

Introduction
Quinoa is a grain with intrinsic outstanding characteristics in respective of nutritional quality, genetic variability, adaptability to adverse climate and soil conditions, and low production cost constitutes quinoa as a strategic crop with potential contributor to food security and sovereignty (Zurita-Silva et al., 2014) [66]. Its grains have higher nutritive value than traditional cereals, present a rich source of a variety of minerals, vitamins and higher contents of most essential amino acids, especially lysine which reveals its potential for a valuable ingredient in the preparation of highly nutritious food and also its nutraceutical properties and are an excellent example of 'functional food' that aims at lowering the risk of various diseases (Vega-Gálvez et al., 2010) [66]. Quinoa is easy to cook, has versatility in preparation, and could be cultivated in different environments (Gordillo-Bastidas et al., 2016) [23]. The high genetic variability and premises properties of quinoa make it potential to be grown worldwide, even it has been declared “The International Year of the Quinoa” (IYQ) by the United Nations in the year 2013 (Zurita-Silva et al., 2014; Nascimenta, 2014) [66, 43]. In recent years, consumer demand for quinoa in the developed world has grown steadily.

Agronomic Aspects of Chenopodium
Quinoa is a dicotyledonous plant and is botanically classified in subclass as dicotyledoneae, group as thalamiﬂorae, order as caryophyllales, family as chenopodiaceae, genus as chenopodium and species as quinoa (Benson, 1957; Cusack, 1984) [8, 66]. The family Chenopodiaceae is composed of herbs and shrubs, or rarely small trees that usually grow in alkaline soil. The plants are usually scurfy because of their external cells that dry into white flakes. The leaves are simple, sometimes more or less succulent or reduced to small scales, and usually alternate but rarely opposite. There are no stipules and the flowers are bisexual or rarely unisexual (Trease and Evans, 1983) [63]. Some species are restricted to wet, salty, or alkaline soil, such as that of coastal marshes or alkaline plains and desert areas. Some of the more important genera are Chenopodium (goosefoot, pigweed, or lamb’s quarters), Kochia (red sage), and Salsola (Benson, 1957) [8]. Quinoa is still an “underutilized” crop, annual broad-leaved plant, 1-2 m tall with deep penetrating roots which can be cultivated from sea level upto an altitude of 3800 m (Coral and cusimamani, 2014) [49]. General category of quinoa crop in five ecotypes presented in Table 1 and details of quinoa crop are presented in Table 2.
Table 1: General categories of quinoa crop

<table>
<thead>
<tr>
<th>Ecotype</th>
<th>Location</th>
<th>Growth altitude (m)</th>
<th>Varieties</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea-level</td>
<td>South of Chile</td>
<td>&lt; 500</td>
<td>Chilean varieties</td>
<td>Unbranched, long day plants, yellow, bitter seeds</td>
</tr>
<tr>
<td>Valley</td>
<td>Andean valley</td>
<td>2000–4000</td>
<td>Blanca de Junin, Rosada de Juni, Amarilla de Matangani, Dulce de Quitopamba, Dulce de Lazio</td>
<td>Big plants, branched, short growth period</td>
</tr>
<tr>
<td>Subtropical</td>
<td>Subtropical area of Bolivia (Yungas)</td>
<td>2500–3000</td>
<td>-</td>
<td>Plants with intense green color that turns orange as they mature, small seeds, white or orange</td>
</tr>
<tr>
<td>Salar</td>
<td>Bolivian Salares</td>
<td>3700–3800</td>
<td>Real</td>
<td>Plants adapted to salty and alkaline soils, bitter seeds, high saponin content</td>
</tr>
<tr>
<td>Antiplanic</td>
<td>Area around Lake Titicaca</td>
<td>3500–4000</td>
<td>Cheweca, Kancolla, Blanca de Juli</td>
<td>Short plants with straight stems, short growth period, resistant to frost</td>
</tr>
</tbody>
</table>

(Source: Valencia-Chamorro, 2003) [5].

Cultivation, Yield and Production

Table 2: Details of quinoa crop

<table>
<thead>
<tr>
<th>Details</th>
<th>-</th>
<th>Particular</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>-</td>
<td>Quinoa</td>
</tr>
<tr>
<td>Scientific Name</td>
<td>-</td>
<td>Chenopodium quinoa wild.</td>
</tr>
<tr>
<td>Origin</td>
<td>-</td>
<td>Andes region of South America</td>
</tr>
<tr>
<td>Climate</td>
<td>-</td>
<td>desert, warm and dry, cold and dry, temperate and rainy, temperate with high relative humidity</td>
</tr>
<tr>
<td>Temperature</td>
<td>-</td>
<td>15–20°C, withstands temperature extremes ranging from 38°C to -8°C.</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>-</td>
<td>40% to 88%</td>
</tr>
<tr>
<td>Sowing season</td>
<td>-</td>
<td>1st week of November to 1st week of December</td>
</tr>
<tr>
<td>Soil</td>
<td>-</td>
<td>loam soil</td>
</tr>
<tr>
<td>Seed rate</td>
<td>-</td>
<td>2 kg/acre</td>
</tr>
<tr>
<td>Spacing</td>
<td>-</td>
<td>Row 20-25 cm (in rows, groups, mixed, broadcast)</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>-</td>
<td>Neem cake, Vermi compost, NPK- 20:20:15</td>
</tr>
<tr>
<td>Rainfall requirement</td>
<td>-</td>
<td>250-300 mm</td>
</tr>
<tr>
<td>Maturity days</td>
<td>-</td>
<td>100-120</td>
</tr>
</tbody>
</table>

(Jacobsen and Stolen, 1993; Jacobsen, 2003; Valencia-Chamorro 2003; Fuentes and Bhargava 2011; Bazile et al., 2013) [30, 45, 19, 5]

International: Countries in Europe, 2/3rd of the area planted to quinoa are in Bolivia (63%), 1/3rd in Peru (36%) and just 1% in Ecuador. The crop yield per square meter reaches 50 grams in Bolivia, 100 grams in Peru and 75 grams in Ecuador. Between the year 2005 and 2012, the demand for Bolivian quinoa was increased by 1120%, 207% and 361% in United States of America, France and Germany respectively. A total of 25,660 tonnes were exported, for a total value of USD 78.9 million at a price of USD 3075/tonne (Mosblech, 2012) [40]. Total quinoa production also increased significantly from 23,240 tonnes in 2000 to 44,260 tonnes in 2012 (INE, 2013) [29]. In 2014, 192.5 tons of quinoa was produced in the world among these three South American countries were the top producers, Peru (114.3 tons) was the largest, second leading was Bolivia (77.4 tons) and Ecuador ranked third (0.8 tons) of quinoa (Bazile et al., 2015). Bolivia and Peru are the biggest exporters with 88% of the worldwide production, followed by the United States of America with 6% (Brenes et al., 2001) [9].

Many European countries are members in the project entitled ‘Quinoa-A multipurpose crop for EC’s agriculture diversification’ which was approved in 1993. The American and European test of quinoa have yielded a good result and demonstrate the potential of quinoa as a grain fodder crop (Mujica et al., 2001; Casini, 2002; Jacobsen, 2003) [42, 11].

National

In India, the cultivation of quinoa was initiated in Andhra Pradesh. One of recent project “Project Anantha” by Andhra Pradesh was sought to push quinoa, with its lower water intake, as an alternative crop in the dry terrain of Anantapur district. (Burlingame et al., 2012) [10]. Recently, the farmers have started quinoa cultivation on contract basis or through government support in the state like as Andhra Pradesh, Telangana and Rajasthan. In the 2015-16, rabi (winter) season, quinoa was sown in 50 hectares at Bhilwara and Chittorgarh districts of Southern Rajasthan. The production was observed as 18 q/ha. However, research on quinoa crop production and their strategies has in the progressing in India. Therefore, the data on yield and production are lacking. Government of Rajasthan has providing the quinoa crop seed to tribal community living in Dungarpur district under Tribal Sub Plan (TSP) scheme to increase their income, livelihood and standard of living and also, to encourage them to shift from traditional crops such as wheat and maize to a more remunerative quinoa (Rakeshkumar, 2016) [32].

Seed Structure

The edible seeds of quinoa are small, round and flat (disc-shape), about 2 mm in diameter and 0.5 mm in thickness, colors can range from white to grey and black, or can be yellow and red. The physical properties of quinoa seeds as a function of moisture content (4.6 to 25.8% db) were determined by Vilche et al., (2003) [67] and as moisture content (5-15%, wb) by Chavan et al., (2018). Seed structure of quinoa shows in Fig. 1. The major anatomical parts of the grain are the pericarp, the perisperm and the embryo (Mastebroek et al., 2000) [39]. The outer layer of the seed is made up of a two-layered pericarp, with the seed coat below that perisperm, embryo and endosperm are the three areas where reserve food is stored in quinoa seed (Prego et al., 1998, Belton, 2002) [50, 7].
Uses of Quinoa

Quinoa is gluten-free, high in protein, fibre, magnesium, B-vitamins, iron, potassium, calcium, phosphorus, lipids, vitamin E and various beneficial antioxidants (Navruz-Varli and Sanlier, 2016) and one of the few plant foods that contain all nine essential amino acids. Nutritional quality of quinoa grain is very good, ranging the proximate composition of quinoa from 10 to 18, 4.5 to 7.5, 65 to 75, 1.4 to 3.8 and 2.1 to 7% for protein, crude fat, carbohydrates, ash and crude fibre, respectively. Quinoa also appears to be a good source of vitamin E, which is substantially higher than other grain crops (Improt and Kellens, 2001; Filho, 2017). Quinoa grain is an important food source for human consumption in the Andean region and has immense industrial value (Fuentes and Bhargava, 2011). It is highly nutritious and is being used to make flour, soup, breakfast, noodles, pastries, dark chocolate (Schumacher et al., 2010), bread (Gewehr et al., 2016, Alencar et al., 2017) and alcohol also rarely reported medicinal purposes (Mujica, 1994). Stikic et al., (2011) reported the study of bread supplemented with quinoa seeds could enable the development of a range of new baking products with enhanced nutritional value. Priyanka (2017) developed quinoa based snack items like porridge, salad and payasam. It can be fermented to make beer, beverage (Ludena, 2016) or used to feed livestock (Galwey, 1989). It is sold either as whole grain that is cooked as rice or in combination dishes. Texture of cooked quinoa was significantly influenced by protein content, flour viscosity, quinoa cooking quality, amylose content and starch enthalpy. Gluten free grain quinoa has been found to exhibit anti oxidative, anti hypertensive, anti diabetic properties and is being used to make flour, soup, porridge, salad and payasam.

Quinoa from 10 to 18, 4.5 to 7.5, 65 to 75, 1.4 to 3.8 and 2.1 to 7% for protein, crude fat, carbohydrates, ash and crude fibre, respectively. Quinoa also appears to be a good source of vitamin E, which is substantially higher than other grain crops (Improt and Kellens, 2001; Filho, 2017). Quinoa grain is an important food source for human consumption in the Andean region and has immense industrial value (Fuentes and Bhargava, 2011). It is highly nutritious and is being used to make flour, soup, breakfast, noodles, pastries, dark chocolate (Schumacher et al., 2010), bread (Gewehr et al., 2016, Alencar et al., 2017) and alcohol also rarely reported medicinal purposes (Mujica, 1994). Stikic et al., (2011) reported the study of bread supplemented with quinoa seeds could enable the development of a range of new baking products with enhanced nutritional value. Priyanka (2017) developed quinoa based snack items like porridge, salad and payasam. It can be fermented to make beer, beverage (Ludena, 2016) or used to feed livestock (Galwey, 1989). It is sold either as whole grain that is cooked as rice or in combination dishes. Texture of cooked quinoa was significantly influenced by protein content, flour viscosity, quinoa cooking quality, amylose content and starch enthalpy. Gluten free grain quinoa has been found to exhibit anti oxidative, anti hypertensive, anti diabetic properties and is being used to make flour, soup, porridge, salad and payasam.

Nutritional Disadvantages

Quinoa also contains a high amount of health-beneficial phytochemicals including saponins, phytosterols, and phytocoeysteroids. Phytic acid and saponin are the main disadvantageous factors in quinoa (Valencia-Chamorro, 2003). For quinoa processing, removal of saponin is the main avenue, the nutritional, functional and uses of saponin is described below.

Phytic acid

In cereals, phytic acid is located in the germ. In quinoa seeds, phytic acid is located in the external layers as well as in the endosperm. It has been reported that the mean (value) phytic acid concentration, was 1.18 g/100 g in five varieties of quinoa (Valencia-Chamorro, 2003). Saponin

At least 20 different types of saponin have been identified in quinoa (Kuljanabhagavad et al., 2008). These chemical compounds include various monosaccharide units that are attached via a glycosidic bond to a triterpene skeleton, known as an aglycone or sapogenin. Depending on the number of saccharide chains in the structure, classified as mono, di- or tri-demiosidic. The most common monosaccharides are D-glucose, D-galactose, Dglucuronic acid, D-galacturonic acid, L-rhamnose, Larabinose, D-xylene and D-fructose. Four aglycones have been identified in quinoa saponins: oleonolic 231 acid, phytolacca genetic, hederagenin (Ridout et al., 1991; Ng et al., 1994; Ahamad et al., 1998) and some authors count serjanic acid as the fourth aglycone (Madl et al., 2006), while others consider it to be spergulagenic acid (Kuljanabhagavad and Wink, 2009). Saponins are plant glycosides that impart a bitter taste and tend to foam in aqueous solutions, considered to be highly toxic, nevertheless, those present in foodstuffs are non-toxic and suggest they may even be beneficial in human diet (Schlick and Bubenheim, 1996; Aguilar et al., 1979; Galwey et al., 1990; Chauhan et al., 1992).
Saponins in the quinoa seed are located in the first external coat of the episperm, which is itself made up of four layers which include perianth, pericarp, a seed coat layer, and a cuticle like structure (Prado et al., 1996; Jiménez et al., 2010) [49]. Saponin content also differs in different growing stages, low saponin is found in the branching stage and high in the blooming stage. In current characterizations, various quinoa varieties and ecotypes are designated as saponin content in “bitter” grains is 1–3%, in “sweet” grains 0.0–0.1%, and in “semi-sweet” grains 0.1–1% (Gcuel-Ustundag and Mazza, 2007) [50]. Other authors believe that a variety or ecotype may be considered “sweet” if the saponin content is 20–40 mg/100 g dry weight and “bitter” if the saponin content is > 470 mg/100 g dry weight (Mastebroek et al., 2000) [59]. The only real proxy for determining if a type of quinoa may be classified as “sweet” is its organoleptic acceptability for human consumption, which varies between 0.06 and 0.12% (Nieto and Soria, 1991) [46]. However, because saponins may impart a bitter taste, saponins are removed either by the wet method (water washing or alkali washing and rubbing) (Vega Galvez et al., 2010) [60] or by dry method, i.e. toasting and subsequent rubbing of the grains (mechanical abrasion) (Schlick and Bubenheim, 1996; Bazile et al., 2015) [57, 6]. Coulter and Lorenz (1990) have demonstrated that the protein quality of a saponin-free quinoa has shown better growth response than white rice, maize or wheat.

Application of saponins
Saponins have immense industrial importance and are used in the preparation of soaps, detergents, shampoos, beer, fire extinguishers and photography, cosmetic and pharmaceutical industries (Johnson and Ward, 1993) [51] and other industrial applications (Yang et al., 1981; Chen et al., 2011; Hostettmann and Marston, 1995) [68, 13, 27] as, for example, preservatives, flavour modifiers (due to their chemical properties and abilities as foaming agents) and agents for cholesterol removal from dairy products. Despite all these health benefits, quinoa is not widely consumed due to several reasons, such as high import costs of the grain and lack of knowledge regarding its benefits among the consumers. More studies are required to increase knowledge about this “pseudo-cereal”, to demonstrate its functional and nutritional benefits, and to study its anti-nutritional effects. Since, it presents high commercial value and excellent nutritional quality, prepared to investigate its basic compounds and health effects.

Conclusion
The outstanding agronomical and functional properties of quinoa have been reviewed. The aim of this paper is to disseminate knowledge about quinoa worldwide. This systematic review has identified that the Management strategies of quinoa cultivation among the farmers as well as the consumers and consumption of quinoa may lead to comparatively lower weight gain, an improved lipid profile, saponin content and potential antioxidant effects with a particular focus on interest in quinoa as a food source and a steady uptake of it in the diet. The identification of health benefits in a human population would encourage further investment in quinoa and galvanise public perception that it is a desirable food that could be consumed as part of a balanced diet. Bitter seed coat saponins while probably slowing speed to quinoa recovery, might now is helpful for its ‘take-off’ among farmers for a broader range of consumers worldwide.

References


