International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(1): 2173-2178

Received: 01-11-2018
Accepted: 05-12-2018

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Reviews on agronomical and functional aspect of quinoa

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Abstract
Quinoa (*Chenopodium quinoa* Willd) 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) [69]. 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) [25]. 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) [69, 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, 16]. The family *Chenopodiaceae* is composed of herbs and shrubs, or rarely small trees that usually grow in alkaline soil. The plants are usually scruffy 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) [14]. 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

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

(***Source***: Valencia-Chamorro, 2003) [65].

Cultivation, Yield and Production

Table 2: Details of quinoa crop

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

(Jacobsen and Stolen, 1993; Jacobsen, 2003; Valencia-Chamorro 2003; Fuentes and Bhargava 2011; Bazile *et al.,* 2013) [30, 65, 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 qt/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) [52].

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].

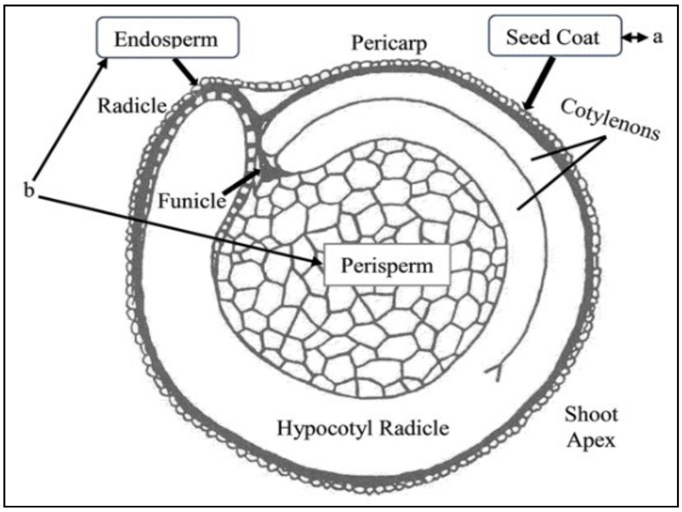

Fig 1: Seeds structure of quinoa (a-Source of polyphenols, saponin and starch; b- Source protein and lipids) (Prego *et al.,* 1998) [50]

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) [44] 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 (Improta and Kellems, 2001; Filho, 2017) [28, 18].

Quinoa grain is an important food source for human consumption in the Andean region and has immense industrial value (Fuentes and Bhargava, 2011) [19]. It is highly nutritive and is being used to make flour, soup, breakfast, noodles, pastries, dark chocolate (Schumacher *et al.,* 2010) [58], bread (Gewehr *et al.,* 2016, Alencar *et al.,* 2017) [24, 3] and alcohol also rarely reported medicinal purposes (Mujica, 1994) [41]. 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) [51] 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) [20]. 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 hence can be used as nutraceutical and functional food ingredient (Arneja *et al.,* 2015) [4]. The starch of *C.* quinoa is highly suitable for emulsion food products (Ahamed *et al.,* 1998) [2]. In Peru and Bolivia, quinoa flakes, tortillas, pancakes and puffed grains are produced commercially (Popenoe *et al.,* 1989) [48].

The highly nutritious quinoa flour could be used to supplement protein deficient wheat flour or corn meal commonly used for human consumption, is used in making value added product such as bread (Turkut *et al.,* 2016) [64], biscuits (Thejasri *et al.,* 2017) [62], extruded blends (Coulter and Lorenz, 1991; Gearhart and Rosentrater, 2014) [15, 34], and gluten-free bakery and pasta products (Gao *et al.,* 2018) [22]. Lorenz *et al*., (1990) studied on the effect of quinoa-wheat flour blends (5/95, 10/90, 20/80, 30/70) in breads, cakes and cookies and reported that the Breads and Cake with 5% and 10% quinoa flour were of good quality and acceptable. Cookie spread and cookie appearance was improved with a quinoa/low-spread flour blend by using 2% lecithin. Lorusso *et al.,* (2017) [35] prepared pasta by replacing 20% of semolina with native and fermented quinoa flour and found that free amino acids, total phenols, and the antioxidant activity of pasta prepared with fermented quinoa flour were up to twice as high than the other types of pasta. Makdoud and Rosentrater (2017) [38] studied on development and testing of gluten free pasta based on rice, quinoa and amaranth flours by using extrusion processing and carried out the best pasta formulation was 10% amaranth flour, 40% quinoa flour, and 50% rice flour, with 18% eggs whites and 39% water. Srujana (2017) [60] prepared ladoo (sweet) and chapathies (unleavened Indian flat bread) products with germinated quinoa flour ranging from 25, 50, 75 and 100% and sensory data indicated that the ladoo and chapathi with up to 25% of germinated quinoa flour were acceptable. Quinoa could be effectively utilized in the beverage industry for the preparation of malted drink formulations. Another study showed increase in the level of insulin-like growth factor-1 (IGF-1) in the plasma of children who consumed a supplementary portion of an infant food prepared by drum drying a pre-cooked slurry of quinoa flour (Ruales *et al.,* 2002) [56].

Nutritional Disadvantages

Quinoa also contains a high amount of health-beneficial phytochemicals including saponins, phytosterols, and phytoecdysteroids. Phytic acid and saponins are the main disadvantageous factors in quinoa (Valencia-Chamorro, 2003) [65]. 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) [65].

Saponin

At least 20 different types of saponin have been identified in quinoa (Kuljanabhagavad *et al*., 2008) [32]. 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-demosidic. The most common monosaccharides are D-glucose, D-galactose, Dglucuronic acid, D-galacturonic acid, L-rhamnose, Larabinose, D-xylose and D-fructose. Four aglycones have been identified in quinoa saponins: oleonolic 231 acid, phytolaccagenic acid, hederagenin (Ridout *et al*., 1991; Ng *et al*., 1994; Ahamed *et al*., 1998) [53, 45, 2]. Some authors count serjanic acid as the fourth aglycone (Madl *et al*., 2006) [37], while others consider it to be spergulagenic acid (Kuljanabhagavad and Wink, 2009) [33]. 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 suggests they may even be beneficial in human diet (Schlick and Bubenheim, 1996; Aguilar *et al*., 1979; Galwey *et al*., 1990; Chauhan *et al*., 1992) [57, 1, 21, 12].

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% (Guclu-Ustundag and Mazza, 2007) [26]. 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) [39]. The only real proxy for determining if a type of quinoa may be classified as "sweet" is its organoleptic acceptabilsity 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) [66] 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) [31] 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

1. Agiular RH, Guevara L, Alvary JO. A new procedure for the quantative determination of saponins and its application to several types of perivian quinoa. Acta Quent. Venez. 1979; 30:167.
2. Ahamed NT, Singhal RS, Kulkarni PR, Pal M. A lesser-known grain, *Chenopodium quinoa*: Review of the chemical composition of its edible parts. Food and Nutrition Bulletin. 1998; 19(1):61-70.
3. Alencar NMM, Morais EC, Steel CJ, Bolini HMA. Sensory characterisation of gluten-free bread with addition of quinoa, amaranth flour and sweeteners as an alternative for coeliac patients. International Journal of Food Science & Technology. 2017; 52(4):872-879.
4. Arneja I, Tanwar B, Chauhan A. Nutritional Composition and Health Benefits of Golden Grain of 21 st Century, Quinoa (Chenopodium quinoa willd.): A Review. Pakistan journal of Nutrition. 2015; 14(12):1034.
5. Bazile D, Fuentes F, Mujica A. Historical Perspectives and Domestication. In. A. Bhargava and S. Srivastava, ed. Quinoa: Botany, Production and Uses. CABI Publisher, Wallingford, UK. 2013; 16:35.
6. Bazile D, Bertero HD, Nieto C. State of the art report on quinoa around the world in 2013, 2015.
7. Belton P, Taylor J. Pseudocereals and Less Common Cereals. Germany: Springer-Verlag Berlin Heidelberg, 2002, 93-116.
8. Benson L. Manual of the orders and families of dicotyledons. Plant classification (chapter 10). New Delhi: Oxford and IBH, 1957, 109-325
9. Brenes E, Crespo F, Madrigal K. El cluster de quinoa en Bolivia: Diagnostico competitivo y recomendaciones! estrategicas. (The quinoa! cluster: competitive diagnosis and strategic recommendations). Documento Proyecto andino de competitividad, Instituto centroamericano de administracion de Empresas INCAE, 2001, 54.
10. Burlingame B, Charrondiere UR, Dernini S, Stadlmayr B, Mondovi S. Food biodiversity and sustainable diets: Implications of applications for food production and processing. In J.I. Boye and Y. Arcand (Eds.), Green technologies in food production and processing, 2012, 643-657. Boston, MA: Springer US. Dated on 8-07-2016 Retrieved from http://www.springerlink.com/index/10.1007/978-1-4614-1587-9_24.
11. Casini P. Possibilita di introdurre la quinoa negli ambient mediterranei. Informatore Agrario. 2002; 27:29-32.
12. Chauhan GS, Eskin NAM, Tkachuk R. Nutrients and Antinutrients in quinoa seed. Cereal Chemistry. 1992; 69(1):85-88.
13. Chavan SM, Chen P, Shih Y, Huang H, Cheng H. Diosgenin, a Steroidal Saponin, Inhibits Migration and Invasion of Human Prostate Cancer PC-3 Cells by Reducing Matrix Metalloproteinases Expression. Plosone. 2011; 6:1-10
14. Coral LLT, Cusimamani EF. An Andean ancient crop, Chenopodium quinoa Willd: A review. Agricultura Tropica et Subtropica. 2014; 47(4):142-146.
15. Coulter LA, Lorenz K. Extruded corn grits-quinoa blends. Journal of food processing and preservation. 1991; 15(4):231-242.
16. Cusack D. Quinoa: grain of the Incas. Ecologist. 1984; 14:21-31.

17. Food and Agriculture Organization (FAO), Assessment of the international year of quinoa. 2013. Hundred and forty ninth session. CL 149/10. Rome, Italy.
18. Filho AMM, Pirozi MR, Borges JTDS, Pinheiro, Sant'Ana HM, Chaves JBP *et al*. Quinoa: Nutritional, functional, and Antinutritional aspects. Critical reviews in food science and nutrition. 2017; 57(8):1618-1630.
19. Fuentes FF, Bhargava A. Morphological analysis of quinoa germ plasm grown under lowland desert conditions. Journal of Agronomy and Crop Science. 2011; 197:124-134.
20. Galwey NW. Exploited Plants-Quinoa. Biologist. 1989; 36(5):267-274.
21. Galwey NW, Leakey CLA, Price KR, Fenwick GR. Chemical composition and nutritional characteristics of quinoa (*Chenopodium quinoa* Willd.). Food Science and Nutritional. 1990; 42:245-261.
22. Gao Y, Janes ME, Chaiya B, Brennan MA, Brennan CS, Prinyawiwatkul W. Gluten-free bakery and pasta products: prevalence and quality improvement. International Journal of Food Science & Technology. 2018; 53(1):19-32.
23. Gearhart C, Rosentrater KA. Extrusion processing of amaranth and quinoa. *Montreal, Quebec Canada,* American Society of Agricultural and Biological Engineers, 2014.
24. Gewehr MF, Pagno CH, Danelli D, Melo LMD, Flôres SH, Jong EVD. Evaluation of the functionality of bread loaves prepared with quinoa flakes through biological tests. Brazilian Journal of Pharmaceutical Sciences. 2016; 52(2):337-346.
25. Gordillo-Bastidas E, Díaz-Rizzolo DA, Roura E, Massanés T, Gomis R. Quinoa (Chenopodium quinoa Willd), from nutritional value to potential health benefits: an integrative review. J Nutr. Food Sci. 2016; 6(497):10-4172.
26. Guclu-Ustundag O, Mazza G. Saponins: properties, applications and processing. Critical Reviews in Food Science and Nutrition. 2007; 47:231-258.
27. Hostettmann K, Marston A. Saponins: Chemistry and Pharmacology of Natural Products. Cambridge University Press, Cambridge, UK, 1995.
28. Improta F, Kellems RO. Comparison of raw, washed and polished quinoa (*Chenopodium quinoa* Willd.) to wheat, sorghum or maize based diets on growth and survival of broiler chicks. Livestock research for rural development. 2001; 13(1):10.
29. Instituto Nacional de Estadística – INE. 2013. Comercio Exterior de Bolivia. (Available at http://apps.ine.gob.bo/comex/Main) (Accessed on 1 July 2013)
30. Jacobsen SE, Stolen O. Quinoa- morphology, phenology and prospects for its production as a new crop in Europe. Euro. J Agron. 1993; 2(1):19-29.
31. Johnson DL, Ward SM. In: Janick, J., Simon, J.E. (Eds.), Quinoa. New Crops. Wiley, New York, 1993, 222-227.
32. Kuljanabhagavad T, Thongpasuk P, Chamulitrat W, Wink M. Triterpene saponins from Chenopodium quinoa Willd. Phytochemistry. 2008; 69:1919-26.
33. Kuljanabhagavad T, Wink M. Biological activities and chemistry of saponins from *Chenopodium quinoa* Willd. Phytochemistry Reviews. 2009; 8:473-490.
34. Lorenz K, Coulter L. Quinoa flour in baked products. Plant Foods for Human Nutrition. 1991; 41(3):213-223.
35. Lorusso A, Verni M, Montemurro M, Coda R, Gobbetti M, Rizzello CG. Use of fermented quinoa flour for pasta making and evaluation of the technological and nutritional features. LWT-Food Science and Technology, 2017; 78:215-221.
36. Ludena Urquizo FE, García Torres SM, Tolonen T, Jaakkola M, Pena-Niebuhr MG, Wright A *et al*. Development of a fermented quinoa-based beverage. Food science & nutrition. 2017; 5(3):602-608.
37. Madl T, Sterk H, Mittelbach M. Tandem Mass Spectrometric Analysis of a Complex Triterpene Saponin Mixture of *Chenopodium quinoa*. American Society for Mass Spectrometry. 2006; 17(6):795-806.
38. Makdoud S, Rosentrater KA. Development and Testing of Gluten-Free Pasta Based on Rice, Quinoa and Amaranth Flours. Journal of Food Research, 2017, 6(4).
39. Mastebroek HD, Limburg H, Gilles T, Marvin HJP. Occurrence of sapogenins in leaves and seeds of quinoa (*Chenopodium quinoa* Willd.). J Sci. Food Agr. 2000; 80(1):152-156.
40. Mosblech NAS. Central Andean vegetation response to rapid paleoclimate changes. Florida Institute of Technology, 2012.
41. Mujica A. Andean grains and legumes. In: Hernando Bermujo, J.E., Leon, J. (Eds.), Neglected Crops: 1492 from a Different Perspective. FAO, Rome, Italy. 1994; 26:131-148.
42. Mujica SE, Jacobsen J, Ezquierdo JP, Marathee. Resultados de la Prueba Americana y Europes de la Quinua FAO, UNA-Puno, CIP. 51, 2001.
43. Nascimento AC, Mota C, Coelho I, Gueifão S, Santos M, Matos AS *et al*. Characterisation of nutrient profile of quinoa, amaranth, and purple corn consumed in the north of Argentina: Proximates, minerals and trace elements. Food Chemistry. 2014; 148:420-426.
44. Navruz-Varli S, Sanlier N. Nutritional and health benefits of quinoa. Journal of Cereal Science. 2016; 69:371-376.
45. Ng KG, Price KR, Fenwick GR. A TLC method for the analysis of quinoa saponins. Food Chemistry. 1994; 49(3):311-315.
46. Nieto C, Soria M. Procesamiento de quinua en Ecuador. 94 p. Proyecto 3P-85-0213. *Informe final de labores.* INIAPUTA- CIID. Quito, 1991.
47. Oshodi AA, Ogungbenle HN, Oladimeji MO. Chemical composition, nutritionally valuable minerals and functional properties of benniseed (*Sesamum radiatum*), pearl millet (*Pennisetum typhoides*) and quinoa (*Chenopodium quinoa*) flours. Int. J Food Sci. Nutr. 1999; 50(5):325-331.
48. Popenoe H, King SR, Leon J, Kalinowski LS. Lost Crops of the Incas. In: Vietmeyer, N.D. (Ed.), Little Known Plants of the Andes with Promise for Worldwide Cultivation. National Academy Press, Washington, 1989.
49. Prado FE, Gallardo M, González JA. Presence of saponin-bodies in pericarp cells of *Chenopodium quinoa* Willd. (quinoa). Biocell. 1996; 20(3):259-264.
50. Prego I, Maldonado S, Otegui M. Seed structure and localization of reserves in Chenopodium quinoa. Ann. Bot. 1998; 82(4):481-488.
51. Priyanka M, Suneetha J, Maheswari KU, Suneetha KB, Kumari BA. Development and evaluation of quinoa based snack items. Journal of Pharmacognosy and Phytochemistry. 2017; 6(4):831-833.

52. Rakeshkumar. Rajasthan farmers try out quinoa cultivation. The article published by Gulf News People on dated 30 November, 2016.
53. Ridout CL, Price KR, Du Pont MS, Parker ML, Fenwick GR. Quinoa saponins-analysis and preliminary investigations into the effects of reduction by processing. J Sci. Food Agric. 1991; 54:165-76.
54. Ruales J, Nair BM. Content of fat, vitamins and minerals in quinoa (*Chenopodium quinoa* Willd.) seeds. Food Chemistry. 1993. 48:131-136.
55. Ruales J, Nair BM. Nutritional quality of the protein in quinoa (Chenopodium quinoa Willd.) seeds. Plant Foods Hum. Nutrition. 1992; 42:1-11.
56. Ruales J, Grijalva YD, Lopez-Jaramillo P, Nair BM. The nutritional quality of an infant food from quinoa and its effect on the plasma level of insulin-like growth factor-1 (IGF-1) in undernourished children. International journal of food sciences and nutrition. 2002; 53(2):143-154.
57. Schlick G, Bubenheim DL. Quinoa candidate crop for NASA's controlled ecological life support systems J. Janick (Ed.), Progress in New Crops, ASHS Press, Arlington, VA, 1996.
58. Schumacher AB, Brandelli A, Macedo FC, Pieta L, Klug TV, de Jong EV. Chemical and sensory evaluation of dark chocolate with addition of quinoa. Journal of food science and technology. 2010; 47(2):202-206.
59. Sharma V, Chandra S, Dwivedi P, Parturkar M. Quinoa (*Chenopodium quinoa* Willd.): a nutritional healthy grain. International Journal of Advanced Research, 2015; 3(9):725-736.
60. Srujana MNS, Kumari BA, Maheswari KU, Devi KS, Suneetha WJ. Sensory Quality Characteristics of Gluten-Free Products Prepared with Germinated Quinoa. Int. J. Curr. Microbiol. App. Sci. 2017; 6(8):3507-3514.
61. Stikic R, Glamoclija D, Demin M, Vucelic-Radovic B, Jovanovic Z, Milojkovic-Opsenica D *et al*. Agronomical and nutritional evaluation of quinoa seeds as an ingredient in bread formulations. Journal of Cereal Science. 2012; 55(2):132-138.
62. Thejasri V, Hymavathi TV, Roberts TP, Anusha B, Devi SS. Sensory, Physico-Chemical and Nutritional Properties of Gluten Free Biscuits Formulated with Quinoa Foxtail Millet and Hydrocolloids. Int. J Curr. Microbiol. App. Sci. 2017; 6(8):1710-1721.
63. Trease GE, Evans WC. The pharmacological action of plant drugs. In: Pharmacognosy. 12th ed. London: Ballière Tindall/English Language Book Society, 1983, 147-54.
64. Turkut GM, Cakmak H, Kumcuoglu S, Tavman S. Effect of quinoa flour on gluten-free bread batter rheology and bread quality. Journal of Cereal Science. 2016; 69:174-181.
65. Valencia-Chamorro SA. Quinoa. In: Caballero B.: Encyclopedia of Food Science and Nutrition. Academic Press, Amsterdam. 2003; 8:4895-4902.
66. Vega-Gálvez A, Miranda M, Vergara J, Uribe E, Puente L, Martínez EA. 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.
67. Vilche C, Gely M, Santalla E. Physical properties of quinoa seeds. Bio systems Engineering. 2003; 86(1):59-65.
68. Yang MH. Steroidal sapogenins from plants of Dioscorea. Chin Trad Herb Drugs. 1981; 12:41-48.
69. Zurita-Silva A, Fuentes F, Zamora P, Jacobsen SE, Schwember AR. Breeding quinoa (*Chenopodium quinoa* Willd.): potential and perspectives. Molecular Breeding, 2014; 34(1):13-30.