Go to TOC

Go to Section III

CHAPTER 18

Gluten-Free Autochthonous Foodstuff (South America and Other Countries)

María Alejandra García[1], Sonia Zulma Viña[1,2]

[1] Universidad Nacional de La Plata (UNLP) - Consejo Nacional de Investigaciones Científicas y Técnicas CONICET-La Plata, Centro de Investigación y Desarrollo en Criotecnología de Alimentos (CIDCA), Argentina.

[2] Universidad Nacional de La Plata, Facultad de Ciencias Agrarias y Forestales, Laboratorio de Investigación en Productos Agroindustriales (LIPA) - Curso Bioquímica y Fitoquímica, Argentina.

magarcia@quimica.unlp.edu.ar, soniavia@quimica.unlp.edu.ar

Doi: http://dx.doi.org/10.3926/oms.266

How to cite this chapter

García MA, Viña SZ. *Gluten-Free Autochthonous Foodstuff (South America and Other Countries).* In Arranz E, Fernández-Bañares F, Rosell CM, Rodrigo L, Peña AS, editors. *Advances in the Understanding of Gluten Related Pathology and the Evolution of Gluten-Free Foods.* Barcelona, Spain: OmniaScience; 2015. p. 605-644.

Abstract

The conservation and sustainable use of biodiversity for agriculture and nutrition have been extensively pointed out as crucial elements for food security and nutrition. Likewise, the relevance of learning from traditional foods and applying indigenous knowledge for the development and production of innovative gluten-free foods has been referred.

South and Central America have supplied a great quantity of plant foods for the sustenance of the humankind. Latin-America is by this time one of the World largest net food exporting area. However, its complete potential to expand agricultural production for regional consumption and global export has not yet been achieved. The region has a large number of skilled farmers that have preserved and transmitted their knowledge through generations.

Feeding a rapidly growing global population without expanding farming into environmentally susceptible areas and reducing the productive ability of the land already cultivated is a challenge that presents an elevated complexity level.

In a framework of a strong need for diet diversification, populations with special nutritional requirements, such as celiac patients, should be benefited with the offer of more balanced, rich and safe diet components. The possibility of learning to a great extent from traditional foods and spread on local and territorial knowledge for the development and production of innovative gluten-free foods appears as a promising alternative.

This chapter collects information about several plant species from the American continent that are more extensively used for the production of gluten-free foods (e. g. maize, potato, cassava, sweet potato, quinoa, amaranth, some legume grains) as well as other species that could potentially be developed with the same purpose, such as the Andean root and tuber crops: achira, ahipa, arracacha, maca, mashua, mauka, oca, ulluco, and yacon.

Keywords

Plant biodiversity and food, food sources from South and Central America, maize, potato, and cassava, andean root, tuber, and grain crops, innovative gluten-free products, family farming and food production.

1. Biodiversity and Food

The Food and Agriculture Organization of the United Nations (FAO) extensively works on the conservation and sustainable use of biodiversity for agriculture and nutrition[1], which is considered crucial for sustainable diets and for food security and nutrition.

Biodiversity is understood as the variability among living organisms from all sources, comprising terrestrial and aquatic ecosystems and the ecological complexes of which they are part. It includes diversity within species, between species and the diversity of the ecosystems[2].

According to Savard et al.[3], in the last decades biodiversity concerns have been in the head of conservation efforts worldwide[2]. The term 'biodiversity' transcends all levels of life, from genes to communities, and all spatial and temporal scales. Biodiversity concepts can give a helpful support for conservation efforts.

During history, human beings have adapted to the tasks of their local environments to produce food systems with appropriate cultural features that provide healthy diets. Nevertheless, nowadays nearly 900 million people in the world suffer chronic hunger, diverse kinds of malnutrition and they have deficient access to healthy food[4,5]. It has been pointed out that human healthiness relies on the health of the ecosystems that supports people live, which must be carefully protected. The biodiversity inherent to the ecosystems must be safeguarded since it contributes to varied, healthy and sustainable diets.

Unfortunately, there is a worldwide tendency towards dietary simplification and a loss of food biodiversity is verified due to a progressive reliance on a reduced number of varieties of staple food crops[1].

There are over 50,000 edible plants in the world. However, only three crops (rice, wheat and maize) provide 60% of the food energy supply from plant origin. A few hundred of plant species contribute significantly to food supplies. In particular, the *Poaceae* botanical family (the fifth-largest plant family) comprises more than 10,000 species but few of them have been broadly introduced into cultivation over the past 2,000 years.

It is a very well-known fact that crop genetic diversity is under growing pressure from urban development, disease, and climate change, while mono-cropping (agricultural practices relying on a few high-yielding species and varieties) expose food supply to considerable risks. Little genetic diversity makes crops susceptible to widespread diseases, as happened during the Irish Potato Famine, when the late blight pathogen wiped out entire crops of the dominant potato variety, and one million people starved to death[6].

According to Dini et al.[7], the food supply relying on relatively few crops has negatively affected the competitiveness of minor or heritage crops. They have been restricted to subsistence uses or subjected to a disappearance risk. The renewed interest in neglected and under-utilized species arises from their involvement in agricultural diversification and the enhancement in the use of land, their economic potential and the prospect for diet diversification. These plant species have been used by local populations for many centuries. Their innovation is thus related to the manner in which old and new uses are being readdressed[7].

There are several zones of the Earth that concentrate the major biological richness and they are frequently referred to as ‘mega-diverse regions’. Up-to 70% of the biological diversity of our planet is found in 17 countries, representing 10% of the total planet extension.

The American continent joins the highest number of mega-diverse countries (seven in total): Brazil, Colombia, Ecuador, USA, Mexico, Peru, and Venezuela. Five countries with these features are situated in Asia (China, Philippines, Indonesia, India, and Malaysia); three in Africa (Madagascar, Democratic Republic of the Congo, and South Africa); and two in Oceania (Australia and Papua New Guinea).

The unique characteristics that allow to an enormous number of species being originated in and inhabiting these countries are: 1) many of them are in the tropics, where environmental conditions (climate and soils) favor biodiversity; 2) the coexistence of islands and the continental portions allows to the development of endemic, distinctive flora and fauna; 3) these countries comprise extensive areas that can shelter a lot of biological species, from different origins. Likewise, the domestication of plants and animal by the indigenous communities gave rise to a huge natural richness.

Some of the main messages and conclusions of the Third International Symposium on Gluten-Free Foods and Beverages (GF13 Conference), held in Vienna (Austria) in June 2013 referred to the possibility of learning to a great extent from traditional foods and applying indigenous knowledge for the development and production of innovative gluten-free foods[8]. However, there is an urgent need to be caring of the local livelihood from which the whole mankind could achieve a very valuable knowledge.

Likewise, with the development of new food products and the emerging of genetically modified and other new grain varieties, it becomes necessary to stay alert and constantly communicate potential new risks for gluten intolerant individuals who make up on average 1% and in some areas a lot more than 6% of the general population[8].

Current trends show that the gluten-free (GF) foodstuff market is one of the most growing markets in the sector of food and beverages, considering its evolution in recent years as well as the prospective for the immediate future.

2. Gluten-Free Autochthonous Foodstuff from South and Central America

2.1. Maize

Maize (*Zea mays*) (also known as corn) is native to the western hemisphere, although its exact place of origin is not completely certain. Archeological data found from drill cores at Mexico City were identified as maize pollen grains considered to be 80,000 years old[9]. Likewise, corn cobs that were dated 5,600 years old by radiocarbon determination were found at the bat caves in New Mexico. Most historians accept that corn was domesticated in the Tehuacan Valley of Mexico and that the original wild forms have long been extinct[9].

Proofs suggest that cultivated maize developed through natural crossings, firstly with gamagrass to yield teosinte and then probably with back-crossing of teosinte to primitive maize to produce modern races.

Maize was an honored food in the Americas. Domesticated by farmers about 8,000 years ago, America's cultures ground maize into dough or boiled, broiled, or popped it over hot coals. For drinking preparation, maize was also combined with water and other ingredients such as honey, chocolate, and pepper[10].

Maize is cultivated throughout the world and the worldwide production in 2012 was 872,066,770 tonnes[11]. According to Singh et al.[12], the main producing countries are USA, China, Brazil, Argentina, India, France, and Indonesia. Different varieties of maize are grown such as *Z. mays* var. *amylacea* (floury corn; soft corn); *Z. mays* var. *indurata* (flint corn; Indian corn); *Z. mays* var. *indentata* (dent corn); *Z. mays* var. *saccharata* and *Z. mays* var. *rugosa* (sweet corn); *Z. mays* var. *everta* (mainly used for popcorn); *Z. mays* var. *ceratina* (waxy corn)[12]. Likewise, maize kernels with different colors are also available, ranging from white to yellow, red and purple. Blue-, purple- and red-pigmented maize show bioactive and antioxidant properties due to high anthocyanin and phenolic content.

The constituents of maize kernel are: the endosperm (82-83%), the germ or embryo (10-11%), the pericarp (5-6%) and the tip cap (0.8-1%). The tip cap is the remaining fibrous material that connects the maize grain to the corncob.

According to Singh et al.[12], the endosperm is composed of numerous cells, each one packed with starch granules embedded in a continuous matrix of proteins. Corn endosperm includes two distinct parts: floury and horny endosperm. Horny endosperm has tightly packed, smaller starch granules placed toward the periphery, meanwhile floury endosperm contains laxly packed starch granules surrounding the central fissure.

The major constituent of maize grain is starch, which reaches up to 88% of the endosperm. Simple sugars are also present, such as glucose, sucrose and fructose varying from 1-3% of the kernel[13]. In common maize, with either the dent or flint type of endosperm, amylose makes up 25-30% of the starch and amylopectin represents the remaining 70-75%. On the other hand, amylopectin constitutes practically 100% of the starch in waxy maize. An endosperm mutant called amylose-extender (ae) shows an increase in the amylose percentage of the starch to 50% and more[13].

Protein content in maize (mostly found in the endosperm, inside sub-cellular bodies or protein bodies which contain the storage proteins of the endosperm) ranges from 8 to 11% of the grain weight in common maize varieties.

At least four different protein fractions in corn kernels are mentioned[13]: albumins and globulins (about 12% percent of total nitrogen); prolamines (52% of the nitrogen in the kernel), being zeins the ones found in the largest concentration; glutelins; and a small amount of residual nitrogen (about 5%). A minimum of four main fractions of the zein storage proteins have been identified: α-, β-, γ- and δ-zein.

While most maize protein (75%) comes from the endosperm, the embryo concentrates the proteins with the best amino acid profile. Those proteins present about three times more albumin, twice as much globulin, and ten times less zein than the whole grain[14].

Concerning the amino acid content of maize proteins, the zein fraction was shown to be very low in lysine (usually less than 30 mg g^{-1} protein) and practically lacking in tryptophan content. Conversely, the albumin, globulin and glutelin fractions contain relatively high levels of lysine and tryptophan, but they are the minor fraction of maize proteins. Another important characteristic of the zein fractions is that they show high content of leucine, an amino acid concerned in isoleucine deficiency[13].

Veloso Naves et al.[14], evaluated the nutritional and protein quality of maize germ with pericarp in relation to the whole corn kernel. The authors pointed out that the germ fraction presented a good profile of essential amino acids with a lysine level of 57.2 mg g^{-1} protein, approximately 50% higher than that of whole corn. The level of lysine found in whole corn (37.9 mg g^{-1} protein) was also higher than the values reported in the literature for common corn, which varied from 26 to 30 mg g^{-1} protein. The non-essential or conditionally essential amino acid contents of the germ were higher than those of whole corn, mainly due to aspartic acid, arginine and glycine levels[14].

2.2. Potato and Other Andean Root and Tuber (R&T) Crops

Potato (*Solanum tuberosum* L.) is the fourth most important world food crop, after wheat, rice, and maize. Since the sixteenth century, the diversity and adaptability of this tuber crop has made it spreading from South America, in the high Andes, to diverse altitudes in temperate regions of the world. Lately, potato production has been increasing most rapidly in the warm, humid, tropical Asian lowlands during the dry season[15]. In accordance with the International Potato Center, organism that was founded in 1971 in Lima (Peru), more than a billion people worldwide consume potato, and the global total crop production exceeds 300 million metric tons[6].

According to Kiple and Ornelas[16], potato was a subsistence crop on the highlands of all continents. In Europe, it was originally an anti-famine product but then became a basic dietary component. Potato has also developed as a vegetable or co-staple crop in Asia and Africa.

Potato is a critical produce in terms of food security in the face of population growth and increased hunger rates. For example, China, the largest consumer of potatoes in the world, expects to increase potato production to meet about 50% of the food demand for the next 20 years[6].

Potato was probably domesticated between 10,000 and 7,000 years ago in Peru and Bolivia, in the region of the Titicaca Lake. Cultivated potatoes include thousands of varieties that differ in size, shape, color, and other sensory characteristics. Potato originated in the South American Andes, but its core area of wild genetic diversity extends from Venezuela, Colombia, Ecuador, Peru, Bolivia, Argentina, and Chile across the Pampa and Chaco regions of Argentina, Uruguay, Paraguay, and southern Brazil[16]. Towards the North, it reaches Central America, Mexico, and the southwest of the United States. More than 200 wild potato species can be found in this broad habitat, covering high mountains and uplands, valleys, subtropical forests, drier semiarid basins between elevations, and littoral valleys[16].

According to Rodríguez-Sandoval et al.[17], potato flour contains good quality edible grade protein, dietary fiber, several macronutrients and trace elements, vitamins and negligible fat[18]. It has been positioned as a value-added thickener and color and/or flavor improver. Potato flour can be incorporated in sauces, gravy, bakery and extruded products, manufactured snacks, and in soup mixes[17].

Dini et al.[7], have pointed out that potato flour is probably the oldest commercial processed potato product, widely used in bakery. Small proportions of added potato flour allow retaining the freshness of bread, giving a characteristic flavor and improving toasting qualities. In bread making, potato products can be blended with wheat flour as starch and native or precooked flour.

Potato flour, when used for bread baking, is known to reduce staling and to improve toasting properties. Because of its adequate mineral content (potassium, magnesium and phosphorus) potato behaves like a very good yeast food. Potato flour is also used in the preparation of flat bread[19], such as ‘lefse’ and ‘potetlefse’ (Scandinavian potato flat breads).

Potato flour is produced in large quantities in USA and several European countries. The Netherlands, Germany, the United States, and Belgium are the main exporting countries and exported together 0.27 million tons of potato flour in 2007[19].

Rodríguez-Sandoval et al.[17], have studied the effect of quinoa and potato flours on the thermo-mechanical and bread making properties of wheat flour. From a techno-functional point of view, the authors have measured the moisture content (MC), water absorption index (WAI), water solubility index (WSI) and swelling power (SP) of the potato flour used in their assays. Results showed that this product presented slightly lower levels of moisture content (12.03±0.19%) together with the highest values of the other parameters in comparison with wheat and quinoa flour. Potato flour WAI was 4.48±0.11 g g^{-1}, meanwhile WSI and SP reached values of 7.45±0.72% and 4.84±0.12 g. g^{-1}, respectively. Authors have pointed out that higher WAI, WSI, and SP values of potato flour are possibly due to a higher content of phosphate groups on amylopectin, which resulted in repulsion between phosphate groups on adjacent chains, increasing hydration by weakening the extent of bonding within the crystalline domains.

Although chemical composition of potato flour depends on the variety and the region of provenance, carbohydrate content can vary between 79.0 and 87.3 g per 100 g. Crude protein ranges from 3.9 to 8.1 g/100 g, meanwhile crude fiber is within the range 1.3-2.9 g/100 g[19]. Total dietary fiber reaches 5.9 g/100 g of edible portion, according to USDA National Nutrient Database Reference[20]. Such as in other root and tuber derivate products, fat content is rather low: it can range between 0.3 and 1.3 g/100 g. Potato flour is a very good source of potassium (1000-1380 mg/100 g). Ascorbic acid content can range between 4-19 mg/100 g.

It has been mentioned that potato flour protein content is similar to that present in common cereals. Gahlawat and Sehgal[21] reported that the *in vitro* digestibility of potato flour protein was 73.3% and this value was significantly higher than that of raw potatoes. Potato tubers are a rich source of free asparagine (2010-4250 mg kg^{-1}).

Rodríguez Galdón et al.[22], determined the amino acid profile, amino acid score and total protein content in ten traditional potato cultivars from Tenerife (Bonita, Bonita negra, Azucena negra, Mora, Borralla, Terrenta, Colorada de baga, Negra, Peluca blanca and Palmera lagarteada). The authors have found significant differences among the potato cultivars in total protein content, and in the amino acids that were studied, except methionine. Apparently, the concentration of amino acids was not influenced by the production region. The chemical score of the potato protein varied considerably among the potato cultivars, ranging from 26.2 to 66.5%. Sulphur amino acids were the limiting amino acids for almost all the potato cultivars studied. Lysine was the limiting amino acid for the Borralla cultivar, and the second limiting amino acid in the rest of the potato cultivars analyzed.

It is worth noting that *Solanum tuberosum* is a cultivated tetraploid species of the series *Tuberosa*. This series includes two subspecies: the world-wide distributed *tuberosum* and the *andigena* (Juz. et Buk.) Hawkes subspecies. However, the last one (*andigena)* has received different taxonomic treatments. The subspecies *andigena* is cultivated at elevations of 2,500-4,300 m in the Andean highlands[23,24].

The *Andigenum* group comprises numerous potato landraces differing in growth habit, flower color as well as in tuber characteristics (distribution and depth of the eyes, shape, and skin and flesh color). In Argentina, these local varieties are grown in the northwest area (mostly in Jujuy, Salta and Catamarca provinces), in phytogeographical areas that correspond to the high mountain valleys and ''quebradas'' of the Puna and Prepuna[24]. Some potato varieties cultivated in Northern Argentina ('Tuni', 'Negra Ojosa', 'Colorada', 'Oca', 'Collareja', 'Runa', 'Moradita', 'Sani', 'Sallama', 'Santa María', 'Azul', 'Blanca', 'Malgacha') were historically selected by the Andean farmers mainly for their resistance to pests and diseases as well as for their nutritional value.

In order to rescue potato varieties with distinctive characteristics, several research projects are being conducted. In this sense, potato landraces are preserved *ex situ* at the Argentinean Potato Genebank of the Instituto Nacional de Tecnología Agropecuaria (INTA). In the 70's the Germplasm Bank was created in the Agricultural Experimental Station of Balcarce (INTA) in order to conserve, characterize and evaluate wild and cultivated potatoes. As a result of numerous germplasm collection trips and the conservation work in the medium and long term, the Bank has at present a collection of all wild species of the country as well as of those cultivated Andean varieties. According to Ispizúa et al.[24], the research group that works in Andean potatoes from northwestern Argentina have reported the intraspecific morphological variation and biochemical variability of potato storage proteins, among other achievements. The researchers Adriana Andreu (Biological Research Institute IIB, CONICET-UNMdP) and Andrea Clausen

(Genebank of the INTA) lead the Project "Treasures of the Andean Biodiversity: native potatoes and their value for the humanity", which promulgate the knowledge of these ancestral varieties and the creation of consciousness about the importance of its conservation, revaluing the phytogenetic patrimony.

Since these potato landraces possess valued agronomic characteristics (i.e. resistance to biotic and abiotic factors), they are frequently used by breeding programs from around the world. However, the agriculture in the Andean valleys of Argentina is nowadays threatened by various factors such as the loss of genetic diversity to reduce cultivation in the Andean potatoes due to the increasing number of different varieties that are planted. However, low cost technologies that can improve the situation are available, such as the choice of varieties with better agronomic and nutritional characteristics.

Referring to other Andean R&T crops, the CIP points out that nine native Andean R&T crops hold economic and nutritional relevance for subsistence farmers in the Andes. They are known by their Quechua aboriginal names: achira, ahipa, arracacha, maca, mashua, mauka, oca, ulluco, and yacon[6]. These crops are highly adapted to adverse environmental conditions: they grow at high altitudes, can surpass conditions of drought, tolerate freezing temperatures, and resist the exposure to ultraviolet radiation. Thus, from a productive point of view, they achieve good yields even with minimal or no inputs. Likewise, these crops show high vitamin, micronutrient, and starch content. Some of them have been mentioned as bearing various medicinal properties.

Achira, edible canna or Queensland arrowroot (*Canna edulis*) is a perennial plant that was a staple food for ancient Peruvians. There are 30-60 species in America and Asia, most of which produce fleshy, starchy rhizomes traditionally baked in earthen ovens, and also used to produce starchy flour for cooking breads and biscuits, and as a thickener in drinks and soups[6].

Achira cultivation has expanded to Asia, especially China, Vietnam, Taiwan, and Thailand, where its starch is used in the food industry for the production of ''noodles'' and employed as a thickening agent for sauces, condiments, dressings, and soups. Some authors have indicated that this plant has great potential for application in food because its roots are an interesting raw material for the extraction of starch and the development of edible films[25].

Achira rhizomes produce a high-value starch with large starch granules that enables it to be extracted simply and cost-effectively using homemade equipment. The particular composition of this starch makes it an important source of income for Andean communities, where in some villages it is the main cash crop[6]. For example, achira is achieving extensive recognition in Colombia, where there is an increasing demand for biscuits made from the root.

Achira flour consists mainly of starch, proteins, lipids, and fibers. Andrade-Mahecha et al.[25], have pointed out that the fiber content is directly related to the granule size. Fractions with larger mean diameter possessed higher dietary fiber content (ranging from 229.5-322.1 g/kg on a dry basis). These fiber values were higher than the ones of cassava and sweet potato flour. The protein content of achira flour varied between 40.6 and 45.4g/kg on a dry basis[25]. The lipid content of the flour samples ranged from 9.0 to 11.1 g/kg. Achira flour with the largest particle size (59.7 μm) showed the highest ash content (78.5 g/kg), while the highest starch content was found in the flour fraction with the smallest particle size. The authors have mentioned that the achira flour produced in the study can be considered as a functional ingredient for use in the food industry. The amylose content of the achira starch was 390.0 and 407.6 g/kg on a dry basis, for Brazilian and Colombian *Canna indica* starches, respectively[25].

Belonging to the *Fabaceae* (*Leguminosae*) botanical family, the genus *Pachyrhizus* (yam beans) is native to southern and central America. One of its distinctive characteristics is the production of storing tuberous roots. Thus, *Pachyrhizus* species could be developed as a new source of non-traditional flour and starch.

The main cultivated species are: *Pachyrhizus tuberosus*, the ‘‘Amazonian yam bean’’, mainly grown in Bolivia, Peru, Ecuador and Brazil; *Pachyrhizus erosus*, the ‘‘jacatupe’’ or ‘‘Mexican yam bean’’, found in Central America and the Caribbean; and *Pachyrhizus ahipa*, the ‘‘ahipa’’ or ‘‘Andean yam bean’’, from the Andes of Bolivia and northern Argentina[7].

Yam bean plants were cultivated by the ancient Mayans and Aztecs several centuries ago. The Mexican jıcama (*Pachyrhizus erosus*) has been rediscovered as a root crop of great economic significance. Its tuberous roots show, on a dry weight basis, 3-5 times the protein content of other root crops, such as potato. They are used as human food and for feeding livestock, because of their high energy content and digestibility. This species is currently cultivated in Mexico, Guatemala, El Salvador, and Honduras and it has also been introduced to different pan-tropical zones, with remarkable success in Southeast Asia[7].

Chemical analysis showed that *P. erosus* roots can provide potassium, sodium, phosphorus, calcium, and magnesium, as well as significant amounts of ascorbic acid. Other vitamins, such as thiamine, riboflavin, pyridoxine, niacin and folic acid, were also reported[26].

Concerning *P. ahipa*, this species was cultivated in the past by the Incan civilization although its production and use diminished significantly since the Conquest of America. Ahipa flour can be considered an alternative gluten-free product, appropriate for people with specific nutritional requirements. Compared to other R&T, ahipa flour has a more balanced composition from a nutritional point of view, supplying protein, fiber and minerals, such as potassium, calcium and iron.

Arracacha or Peruvian carrot (*Arracacia xanthorrhiza* Bancroft) belongs to the *Apiaceae* (*Umbelliferae*) botanical family. Three main varieties, with their distinctively yellow-, white-, and purple-colored roots are available[6].

According to Ribeiro et al.[27], the plant is originated in the tropical highlands of the Andes. It is usually grown at heights ranging from 1,500 to 2,500 m above sea level, at temperatures between 15 and 20°C, with an annual precipitation of about 1,400 mm. The edible parts of the plant are their storage roots (which may weigh up to 450 g and contain approximately 73% water), grouped around the central swollen rootstock and secondary cormels, from which shoots and leaves emerge.

The roots has to be roasted, boiled, baked or fried to be consumed and their characteristic taste resembles a blend of celery, carrot and parsnip. With a compact flesh that is richer in texture and taste than potato, the root can be used to garnish and flavor a range of dishes from soups to desserts. Young stems are used in salads or as a cooked vegetable, and the leaves are often fed to livestock[6].

Arracacha starch is easily digestible since the small size of its granules. Thus, it is good pureed or in soups for babies, the elderly, or people with disabilities. The processed roots are used as a thickener for baby food formula and instant soups[6].

Roots postharvest life is markedly short. They decay fast if stored at room temperature, being completely damaged within 12 days. The main factors causing postharvest losses are severe weight loss and *Rhizopus* and *Erwinia carotovora* attack. Since its tropical and subtropical origin, arracacha is sensitive to chilling injury when stored at low temperature, developing internal and external browning at 5°C[27].

Besides being an important food in the Andes, arracacha was introduced to Brazil early in the 20th century and it expanded in the Southern highlands, mainly in Minas Gerais state. Towards 2005, the two major arracacha clones grown in Brazil were Amarela de Carandaí and Roxa de Viçosa[27]. Brazilian crop improvement programs have succeeded in developing varieties that grow in seven months, which could benefit other farmers in the high Andes[6].

Maca (*Lepidium meyenii* Walp.) belongs to the *Brassicaceae* botanical family. It is an annual or biennial herbaceous plant. According to Wang et al.[28], it has been domesticated in the central Andes of Peru at elevations of 3,500-4,500 m above sea level, where it has been grown for at least 2,000 years ago. However, little is known about its origin.

The edible parts of maca are their subterranean hypocotyls, which are eaten fresh, or can be dried and stored for deferred consumption. Maca is also used as a folk medicine, especially to enhance sexual drive and female fertility in human beings and domesticated animals, to relieve rheumatism, ameliorate respiratory ailments, and as a laxative and antidepressant, among other properties[28].

Because of the initial scientific evidence for the substantiation of maca almost mythical properties, the crop has experienced a commercial boom. According to CIP[6] the root is processed to make flour for bread and biscuits, dried powder, and gelatinized capsules, most of them certified as organic products. Export volume reached over 700,000 kilograms in 2010.

According to Puoci et al.[29], the oral administration of a lipid extract of maca increased the sexual function of mice and rats[30]. Likewise, Sandoval et al.[31], reported on the capacity of this plant to scavenge free radicals and guard cells from oxidative stress.

Maca meal supplementation increased food intake, growth and feed utilization along with improving survival in rainbow trout juveniles[32]. This effect was attributed to the stimulation of growth hormone production. Maca has also been utilized to treat menopausal women since it was found to increase calcium content in the rats' femur[33] and, therefore, to alleviate the reduction of bone mineral density.

Maca chemical composition shows some interesting characteristics, mainly the high protein, unsaturated fatty acid and mineral contents. Water content of fresh maca roots is higher than 80%. On a dry basis, maca roots contain 8.87-11.6% protein, 1.09-2.2% total lipids, 54.6-60.0% carbohydrates, 8.23-9.08% fiber, 4.9-5.0% ash, and an energy content of 663 kJ/100 g. Carbohydrates are represented by sucrose (23.4%), glucose (1.55%), oligosaccharides (4.56%) and polysaccharides (30.4%)[28]. Maca roots contain seven essential amino acids representing 342.6-388.6 mg/g protein. These values are higher than those reported in potatoes and carrots.

The content of linoleic and oleic acids (unsaturated fatty acids) is 52.7-60.3% of total fatty acids. Besides, maca root powders are also abundant in minerals, being the contents of iron 16.6, manganese 0.8, copper 5.9, zinc 3.8, sodium 18.7, potassium 2050 and calcium 150 mg/100 g dry[28].

Recently, Puoci et al.[29], investigated the applicability of maca flour for the preparation of functional breads with improved biological properties. Different bread compositions (wheat-maca flour blends with 0, 5, 10, 15, 20% of substitution) were tested. They were characterized by specific *in vitro* tests to determine the antioxidant, anti-inflammatory activities, and the ability to reduce the sugar intake by performing enzymatic assays using α-amylase and α-glucosidase. Results revealed that the biological properties of maca flour were retained after the bread making process and that the analyzed breads were suitable as functional foods.

The International Potato Center points out that in terms of food security, oca (*Oxalis tuberosa* Molina), ulluco (*Ullucus tuberosus* Caldas) and añu or mashua (*Tropeolum tuberosum* Ruiz & Pavón) are the three most important Andean R&T crops. They adapt to altitudes between 2,000 and 3,800 meters above sea level and are associated with potato in the Andes of Peru and Bolivia. Cropping potato in combination with oca, ulluco, and mashua is a millennial tradition and this practice offers valuable supplementary nutrients to a diet based on potatoes. For example, oca has been mentioned as a food product high in protein, with a good balance of amino acids, supplying also high quantities of fiber and antioxidants.

Described in the records of the Spanish conquest, ceramic representations show that oca was a highly valued staple dating back to the pre-Colombian era. Because of its high yield and pleasant taste, oca is very popular in rural Andean cuisine. However, most oca production is still for home consumption. The tubers are traditionally boiled in soups or stews or also baked or roasted and often sun dried to sweeten before cooking[6].

Among the known Andean R&T crops, ulluco has been recognized as the most commercially viable. Since ulluco tubers present high water content, they are most suitable for boiling. Plant leaves are also edible and they have been mentioned as containing significant quantities of protein, calcium, and carotene[6].

Mashua tubers vary in color (usually white, yellow, red or purple) and shape. They contain high levels of isothiocyanates (glucosinolates), compounds known for their insecticidal and medicinal properties. This may explain the virtual absence of pests and diseases in the crop. This strong resistance is one reason why mashua is traditionally intercropped with other plants; farmers use it as a natural way to repel insects and pathogens.

Despite its high nutritional value, mashua is not widely commercialized. Because it is used in traditional medicine to regulate libido (the Incas reported its use to dampen sexual desire in campaigning armies), men are reluctant to eat it.

Campos et al.[34], have studied native potato (*Solanum sp.*), mashua, oca, and ulluco roots and tubers for their antioxidant capacity and associated secondary metabolites. Results showed that the antioxidant capacity in the crops studied ranged from 483 to 9800 µg trolox equivalents g^{-1}; phenolics ranged from 0.41 to 3.37 mg chlorogenic acid equivalents g^{-1}; anthocyanins varied from 0.08 to 2.05 mg cyanidin 3-glucoside g^{-1}; and carotenoid content was between 1-25 µg β-carotene g^{-1}. The content of bioactive compounds was high and variable between crops and within the genotypes studied. Generally, mashua tubers showed the highest antioxidant capacity and phenolic, anthocyanin and carotenoid content related to the other crops. Ulluco was the only crop that contained betalains in the acid form of betaxanthins (22-96 µg g^{-1}) and betacyanins (64 µg g^{-1}) with no presence of carotenoids or anthocyanins. It is worth mentioning that betalains are water-soluble nitrogen-containing pigments, comprising two structural groups: the red-violet betacyanins and the yellow-orange betaxanthins. Several works have demonstrated the potent antioxidant activity of betalains, which has been associated with protection against degenerative diseases[35].

Referring to yacon (*Smallanthus sonchifolius* (Poepp. et Endl.) H. Robinson), this ancient Andean crop has recently attracted worldwide interest due to its particular nutritional properties. Coll Aráoz et al.[36], have pointed out that yacon is a polyploid species (probably a hybrid), belonging to the *Asteraceae* botanical family, which has been classified as a semi-domesticated crop possibly based on a long time of cultivation in the Andean region[37].

Yacon underground system consists of two different types of reserve organs: the tuberous roots, i.e. the commercialized product; and the rhizophores, the organs of vegetative reproduction. The complete system accumulates fructans and other soluble carbohydrates, such as fructose, glucose and sucrose. The common name 'yacon' has its origin in the Quechua term 'yakku' (equivalent to 'watery' or 'tasteless'). Yacon is cultivated in the Andes from Colombia to northwestern Argentina at altitudes between 1,000 and 3,500 m above sea level. In the last two centuries the area of cultivation has shown a reduction, being cultivated for home consumption.

However, the unique carbohydrate composition of the roots has attracted the international interest since 40 to 70 % of the root dry matter corresponds to fructooligosaccharides (FOS, short polymers of fructose with a polymerization degree of 3-10 fructans which show low caloric value). Roots do not contain starch. Yacon roots also exhibit pharmacological properties such as antioxidant activity and beneficial effects on obesity and insulin resistance[36].

The tuberous root, which is eaten either raw or cooked, is sweet and crispy. Alternatively, yacon roots can be dehydrated and processed into a range of convenience products. They have been used in the production of beverages and bakery products according to their physicochemical properties[7].

2.3. Cassava

Cassava (*Manihot esculenta* Crantz) is a dicotyledonous perennial woody shrub that produces edible starchy roots. Cassava belongs to the *Euphorbiaceae* botanical family. Its roots fit into a class of food that basically provides energy in the human diet in the form of carbohydrates[38].

Cassava is believed to have its centre of origin in the Amazon region of South America[39], in central Brazil. However, there is no total consensus about the exact botanical origins of the progenitors of modern cultivated cassava[40,41].

According to Malandula Chipeta and Bokosi[41] the existence of cassava in Africa dates back to the 16th century, mainly in the West coast of Africa and later to East Africa all the way through Madagascar and Zanzibar carried by Portuguese navigators from Brazil. Further dissemination of cassava in Africa took place during the 20th century probably under the influence of colonial masters in which it was grown as reserve famine crop and due to its ability to counteract locust's attack[39]. At present, cassava is grown in all African countries.

Cassava was introduced to the Pacific sometime around 1,800 during the early years of European contact. It has become an important dietary staple and in some entities is produced in larger quantity than the traditional root crops of the area (taro, sweet potato, and yam). In the Pacific region, cassava is generally not produced on a large scale. It is grown in subsistence and home gardens, and is available in local markets.

Cassava flour is principally used in baking and confectionery products to substitute wheat flour at different proportions. Other food applications include the manufacture of weaning foods and pasta, and the production of starch used by the food, pharmaceutical, and chemical industries[7]. Cassava flour is widely used in the formulation of products destined to celiac patients. However, the very low protein content (1.0 % dry basis) and absence of gluten are considered disadvantageous for its exclusive use in food formulations, especially if the elasticity of the dough is essential for product quality[7].

According to the USDA National Nutrient Database for Standard Reference[20], 100 g of the edible portion of raw cassava (almost 60% water) provide 160 kcal of energy, 1.36 g of protein, 0.28 g of total fat, 38 g of total carbohydrates (calculated by difference), 1.8 g of total dietary fiber and 1.70 g of total sugars. The mineral content of 100 g of raw cassava corresponds to 16 mg of calcium, 0.27 mg of iron, 21 mg of magnesium, 27 mg of phosphorus, 271 mg of potassium, 14 mg of sodium and 0.34 mg of zinc[20]. Concerning ascorbic acid level, it has been reported to be 20.6 mg/100 g of edible portion; folate (dietary folate equivalent, DFE), 27 µg/100 g; and niacin, 854 µg/100 g.

2.4. Sweet Potato

Although wild forms of sweet potato (*Ipomoea batatas*) are not known to exist today, Central America and Peru are generally accepted as possible centers of origin for this crop, which belongs to the *Convolvulaceae* botanical family.

Sweet potato, native to tropical America, was brought to Spain by Christopher Columbus in 1492 and then introduced to African lands by the Portuguese. Nowadays, it is the third most important crop in seven eastern and central African countries, and fourth in six southern African countries. The highest consumer of sweet potato per capita is one of the African, Caribbean and Pacific Group of States (ACP) countries, the Solomon Islands in the South Pacific[42].

According to the Traditional Pacific Island Crops web site, sweet potato cultivation in the eastern and central Pacific predates European contact by several hundred years, possibly occurring as early as 1,000 CE. This movement of sweet potato from the Americas to the Pacific islands has been the focus of much debate.

Latest archaeological data indicates possible contacts between Polynesians and indigenous people in several locations along the western coast of America. Sweet potatoes may have been introduced into the Pacific as a result of this approximation and subsequently spread throughout Polynesia. Regardless of the means of dispersal, sweet potato remains as an important food crop all over the Pacific and in many other developing countries.

Sweet potato roots of different color (white to red, through yellow and violet, depending on the variety) are rich in starch and sugar. They can be used as human food, animal feed and for the production of alcohol and starch. Sweet potato roots can be consumed boiled, fried or roasted in an oven. The leaves of the plant are also edible (unlike those of the potato which are toxic) and are rich in proteins, vitamins and various minerals.

The International Potato Centre (CIP) keeps the largest bank of sweet potato genes in the world, represented by thousands of wild, traditional and improved varieties. Research works carried out at the beginning of the 20th century has shown that more than one hundred industrial products could be obtained from sweet potato, although their implementation is still to be developed. According to UNCTAD[42], studies have also shown that sweet potato can provide more than twice the carbohydrates than maize.

A program for improving sweet potato has been implemented consisting in crossing varieties obtained from the CIP and selected local varieties[42]. In France, CIRAD (Centre de Coopération Internationale en Recherche Agronomique pour le Développement) has identified a hybrid, since called "Africa" by producers for whom it has been a great success; it is sold on urban African markets. This material outstands for its shorter production cycle (12-16 weeks), better yield, high resistance to disease (leaf and stem scab), long post-harvest shelf life (4 weeks), very good taste and consumers' acceptance and high provitamin A content[42].

According to USDA National Nutrient Database for Standard Reference[20], 100 g of the edible portion of sweet potato provide 20 g of carbohydrates (obtained by difference), 4.2 g of sugars, 3 g of total dietary fiber, 1.6 g of protein and 0.05 g of total lipids. The mineral content of 100 g of sweet potato roots corresponds to 337 mg of potassium, 55 mg of sodium, 47 mg of phosphorus, 30 mg of calcium, and 25 mg of magnesium. The main microelements supplied are iron (0.61 mg/100 g) and zinc (0.30 mg/100 g)[20]. Concerning vitamin contents, ascorbic acid level has been reported to be 2.4 mg/100 g of edible portion; folate (dietary folate equivalent, DFE), 11 µg/100 g; and vitamin A (retinol activity equivalents, RAE), 709 µg/100 g.

Substitution levels above 10% of wheat flour with sweet-potato flour generally bring unacceptable characteristics of bread regarding the loaf volume, flavor, and texture[43].

Early works pointed out that the crude protein content of sweet potato (estimated as Kjeldahl nitrogen x 6.25) had been reported to range from 1.3 to 10% (on a dry basis)[44]. Likewise, significant genetic variability had been noted, thus the prospective for increasing protein content by breeding has been explored. Those early works indicated that sulfur-containing amino acids were the first limiting and lysine was the second limiting amino acid in sweet potato protein[44].

More recently, Sun et al.[45], have reported that the major storage protein in sweet potato root, which accounts approximately 80% of the total root protein called 'sporamin', has a molecular mass 25 kDa under reducing

SDS-PAGE conditions. However, under non-reducing SDS-PAGE conditions, molecular masses of 31 kDa and 22 kDa were reported (sporamin A and B, respectively)[45,46]. Although sweet potato protein amino acid profile and limiting amino acid vary with cultivar, the sweet potato essential amino acid distribution has been mentioned as nutritionally viable.

It is worth noting that sweet potato protein has a strong trypsin inhibitor activity, which could limit effective utilization for human or animal nutrition. Thus, to improve the nutritional value of these proteins, heat processing has been widely applied. In addition, thermal treatment also increases the *in vitro* protein digestibility of some plant products, such as soybean protein[47], probably due to deactivation of trypsin inhibitors.

2.5. Arrowroot

Arrowroot (*Marantha arundinacea*, belonging to the family *Maranthaceae*), also known as 'sagú' and 'uraro', is a perennial herbaceous plant with thick, fleshy roots. Considered as an introduced crop in the Philippines coming from tropical Latin America, the crop is grown specifically for its rhizomes for flour and starch production[48].

Arrowroot is an excellent source of starch (>85%) that has been lately used in the food industry for making biscuits and as a thickener and/or stabilizer. Arrowroot starch also found application in sizing textiles[49].

Hernández-Medina et al.[50], pointed out that in the Yucatan Peninsula (Mexico), the main R&T grown in the 'milpas' (Mesoamerican agro-ecosystem whose main productive components are maize, beans and squash) are of American origin. Four of these R&T were cultivated before the Conquest (makal *Xanthosoma yucatanensis*; sweet potato *Ipomoea batatas*; cassava *Manihot esculenta*; and jícama *Pachyrhizus erosus*) and the others (sagú *Marantha arundinacea* and potato *Solanum tuberosum*), although American, were introduced by the Spanish.

2.6. Andean Grains: Quinoa and Amaranth

Quinoa (*Chenopodium quinoa* Willd.) is an indigenous plant from the Andean region, cultivated by the Incas who called it ‘‘the mother grain’’ and considered it a sacred food. Quinoa dates more than 5,000 years ago[51]. In the Inca Empire quinoa occupied a place of prominence next only to maize[52]. However, after the Spanish conquest other crops, such as potato and barley, relegated quinoa to the background.

Mainly, quinoa is grown in the South American region (especially in and around the Andes), including countries like Ecuador, Peru, Chile and northern Argentina (Jujuy and Salta provinces)[53]. The worldwide production in 2012 was 82,510 tonnes and the harvested area was 102,745 ha[11]. Recently, there has been growing interest in a number of countries (especially in Europe), initiating introduction and research work on quinoa[54-56].

The proximate composition of quinoa varies with cultivar, but mostly ranges from 10 to 18% for protein, 4 to 9% for crude fat, 54 to 64% for carbohydrates, 2 to 4% for ash, and 2 to 5% for crude fiber[17]. Quinoa seeds are considered an interesting foodstuff, owing to their high protein content and lack of gluten. The grain has high-protein content with abundance of essential amino acids, and a wide range of vitamins and minerals[57]. The protein content in the grain ranges from 7.47 to 22.08% with an average equal to 13.81%[58]. Albumin and globulins (chenopodin) are the major protein fraction (44-77% of total protein) while the percentage of prolamines is low (0.5-0.7%)[59], which are the toxic proteins for celiac patients. The seeds have a balanced amino acid profile with high lysine (5.1-6.4%), histidine and methionine contents[59-61], being higher than in cereals.

Schoenlechner et al.[62], stressed that the amino acid profile of the proteins of quinoa is comparable to that of caseins. Besides, this pseudocereal has been attracting attention due to its high mineral content[63]. Although, digestible carbohydrates of pseudocereals flours that ranged between 56 and 59%, were inferior to the amount found for rye (64%) and wheat flours (70%)[64].

Peptides obtained by enzymatic hydrolysis from quinoa seed flour protein concentrate exhibited functional and bioactive properties, especially radical scavenging activity, which is dependent on the molecular size of the peptides[65].

Pseudocereals flours exhibit higher qualitative and quantitative lipid profiles than wheat flour. Quinoa lipids are characterized by a high degree of unsaturation, which is desirable from a nutritional point of view[66]. The predominant fatty acid is linoleic acid (50.7-54.3% of the total) followed by oleic acid (20.8-24.9%) and palmitic acid (8.3-8.9%). Likewise, a high ω-3 polyunsaturated fatty acids (PUFAs) level was reported in quinoa seeds, being this a beneficial and healthy feature[7]. Besides, lipids have a significant effect on the quality and texture of baked goods because of their ability to associate with proteins and starch, especially in breadmaking applications[67]. Thus, pseudocereals flour addition to bakery celiac formulations allows improving the textural characteristics of products enhancing their nutritional value.

Amaranth (*Amaranthus sp.*), quinoa (*Chenopodium quinoa Willd.*) and buckwheat (*Fagopyrum esculentum*) are referred to as pseudocereals, as their seeds resemble in function and composition those of the true cereals, although they are dicotyledonous plants.

Amaranth is an ancient crop consumed as vegetable and grain during the Maya and Aztec periods; the Spanish conquerors called amaranth “the Inca wheat”. Seeds more than 2,000 years old have been found in ancient tombs[68]. It was named as *kwicha* and *huautli* in the area between Mexico and Chile by pre-Columbian major civilizations and cultures like Inca, Aztec and Maya, which considered amaranth as their staple food together with maize and beans. Amaranth grains were also found in 2,000 BC graves, and it was mentioned in Bernardino de Sahagun Ribeira "Florentine Codex", listing its wide array of valuable exploitations[69]. Additionally, in a document on history, economy and ethnography of the Aztecs, commissioned by the Spanish viceroy Antonio de Mendoza in around 1541-42, it is written that each year around 8,000,000 kg of *huautli* were brought to Tenochtitlan, as an annual tribute paid to the emperor Montezuma, being this quantity comparable to the tribute in maize and bean[70].

Aztecs used amaranth in beverages, sauces, porridges; they milled it into flour and prepared *tortillas* (also with maize flour), popped grains like maize, and for various medical uses. Likewise, amaranth had an important position also in Indians' religion. The grain was ground, mixed with water, honey, or even human blood and dough was then formed into the shapes of idols (*zoale*). Idols were paraded and consumed in a ritual manner as a symbol of communion with the gods, because of that the Spaniards prohibited the cultivation and use of amaranth by legislative fiat. Besides this, the cause of reduction in amaranth production was the introduction of new crops from Europe.

In the 16th century, amaranth was first introduced as an ornamental plant in Europe. Different species of amaranth spread throughout the world during 17th, 18th and 19th centuries. In India, China and under the harsh conditions of Himalayas this plant became an important grain and/or vegetable crop. It can be used as a high-protein grain or as a leafy vegetable, and it has potential as a forage crop.

Nowadays, there are three species of amaranth grown for grain production: *A. hypochondriacus, A. cruentus* and *A. caudatus*. Although the three species are native to America, they are also currently distributed in Asia and Africa. In the Americas, *A. hypocondriacus* is sited primarily in northern and central Mexico, *A. cruentus* in southern Mexico and Central America and *A. caudatus* in the Andes, though there are cultivated areas in countries such as Argentina[68]. It is a valuable nutritious foodstuff with high production ability; a good yield of amaranth is considered to be above 12,080 kg/ha. It is a very adaptable crop, resistant to drought, to a wide range of temperature, to insects and diseases. It grows well at different altitudes and on soils with variable levels of nutrients[69]. Likewise, both edible and non-edible amaranth species has been used as biomass source because of its high yield under marginal conditions[71].

The chemical composition of the little seeds is 14-19% of protein, 5-8% of lipids, 62-69% of starch, 2-3 % of total carbohydrates and 4-5% of fiber[69]. Its composition is comparable with that of oat. Starch is the major part of carbohydrates. Starch granules are small (1-3 µm), easily degradable by α-amylases, and resistant to mechanical stress and freezing conditions. Repo-Carrasco-Valencia et al.[72] reported that *A. caudatus* starch showed 31.3-33.4% of digestibility *in vitro*.

The main lipids, composed of linoleic, oleic and palmitic acid, in amaranth seed are placed in the embryo. According to the seed composition, amaranth oil is similar to the ones obtained from cotton or maize but it has lower digestibility. Amaranth oil contains about 8% of squalen, a sterol precursor, used in medicine and cosmetic industry. About 90% of amaranth total lipids correspond to triglycerides and complex lipids (phospholipids and glycolipids). In the three cultivated species of amaranth the ratio of saturated to unsaturated fatty acids is in the range 0.26-0.31[68].

Content of minerals depends on species and growing conditions. Amounts of calcium and magnesium are higher than the amounts in other cereals. Seeds are a good source of vitamins mainly ascorbic acid and those from the B-complex, and the antioxidants α-tocopherol and β- and γ- tocotrienols.

With regard to amaranth proteins, albumin, globulin and glutelin fractions were referred to as the most abundant, with a minor fraction of prolamin (1.5-11%)[68]. Albumins and globulins contain less glutamic acid and proline and more lysine than prolamins[66]. In contrast to cereals, amaranth has higher content of amino acids mainly lysine, methionine, treonin and cysteine. Amaranth seeds are also a source of tryptophan and amino acids containing sulphur. The balanced amino acid composition of amaranth is close to the optimum protein reference pattern in the human diet according to FAO/WHO requirements[70]. This well balanced amino acid composition is the result of the fact that in amaranth 65% of proteins are found in the embryo and only 35% in the perisperm, whereas in other grains amino acids in the endosperm prevail (85% in average) and they are poorer in essential amino acids. Besides, it has been pointed out that the amino acid profile of the proteins of amaranth is comparable to that of egg[62].

The role of proteins as bioactive components has been recognized, either directly or after hydrolysis *in vivo* or *in vitro*, showing some encrypted peptides antihypertensive, antioxidant and positive effects on cholesterolemia[73,74].

Food uses of amaranth include its incorporation as ingredient in bread, pasta, baby's food, instant drinks, etc. The most common product is the flour although whole amaranth seeds can be added in breads, müsli bars, breakfast food and biscuits. Likewise, leaves and stems are and interesting vegetable suitable for soups, salads or other meals.

On the other hand, *Amaranthus australis* L. or *Amaranthus cruentus* L. crops were proposed as a source of raw material for solid biomass-based production processes that could be used to obtain high quality biofuel[71].

2.7. American Legume Grains

Beans (*Phaseolus sp.*) are one of the oldest foods known by man and has been an important part of the human diet since ancient times. Their cultivation began about 7,000 years BC in southern Mexico and Guatemala. Since the Mesoamerican cultures of Mexico were expanded, these beans and farming practices gradually spread throughout South America as they explored and traded with other cultures. Beans were called *etl*, *buul* and *purutu* by the Aztecs, Mayas and Incas respectively[75]. The oldest-known domesticated beans in the Americas were found in Guitarrero Cave, an archaeological site in Peru, and dated to around the second millennium BCE.

Five kinds of *Phaseolus* beans were domesticated by pre-Columbian cultures: common beans (*Phaseolus vulgaris*) grown from Chile to the northern part of the actual territory of the United States, and lima and sieva beans (*Phaseolus lunatus*), as well as the less widely distributed teparies (*Phaseolus acutifolius*), scarlet runner beans (*Phaseolus coccineus*) and polyanthus beans (*Phaseolus polyanthus*). One especially famous use of beans by pre-Columbian people as far north as the Atlantic seaboard is the "Three Sisters" method of companion plant cultivation: where beans are grown together with maize and squash[75]. By the time the Europeans arrived, beans were cultivated throughout the New World, in North America as well as Central and South America. Since the early 17th century, American bean varieties were already popular in Europe, Africa and Asia.

The worldwide production in 2012 was 23.23 million metric tons, harvested from 29.92 million hectares[11]. These values are overestimated because FAO does not report data for *Phaseolus* and non-*Phaseolus* species separately. India was the leading producer, responsible for 21% of the total production, followed by Brazil, Myanmar, China, the U.S., and Mexico. In Latin America, wild beans are grown in a wide arc stretching from northern Mexico (approximately 30°N) to northwestern Argentina (about 35°S) at altitudes from 500 to 2,000 m and rainfall regimes from 500 to 1,800 mm.

Before domestication, wild *P. vulgaris* had already diverged into two major gene pools, each with its characteristic geographic distribution, in Mesoamerica and the Andes[76]. The Mesoamerican area comprises the southern part of Central America, Colombia and Venezuela; likewise, in the Andean region southern Peru, Bolivia and Argentina are included. These two wild gene pools can be distinguished at the morphological and molecular levels[76].

New cultivars of *P. vulgaris* are continually being developed and released from the research centers. The economic value of a new cultivar depends on its yield, rate of maturity, its resistance to disease, and seed size, color, nutritional quality, cooking time, and the flavor and texture of the cooked food. The criteria for selection are resistance to disease, yields and maturation rate. Nowadays, nutritive quality is also taking into account.

Legumes, considered as poor men's meat, are generally good sources of nutrients. They are an important and relatively inexpensive source of protein, dietary fiber and starch for a large part of the world population, mainly in developing countries. Beans are also one of the best non-meat sources of iron, providing 23-30% of the daily recommended levels from a single serving[77].

With regard to chemical composition, beans and their derivative flours are an important source of proteins, and their contents varied significantly among the botanical origin of the flours. Legume flours are good supplements for cereal-based products. Cereals are deficient in the essential amino acid lysine, while legumes have a high content. On the other hand, cereal proteins complement legume proteins in the essential amino acid methionine[68]. Beans, as well as lentils, have a specific amino acid composition: high in lysine and low in sulphur amino acids. Pirman et al.[78], demonstrated that the amino acid composition of three cultivars of beans is similar in the uncooked state. In comparison to the lentils, beans contain more methionine, tyrosine and serine, and less arginine[78].

Common beans have been considered as a low glycemic food, mainly because of its dietary fiber and resistant starch content. Ramírez-Jiménez et al.[79], stressed that *P. vulgaris* beans showed low starch digestibility and increased amounts of resistant starch after drying treatments. Starch from legume flour is more slowly digested than those of cereal ones and its ingestion produce less abrupt changes in plasma glucose and insulin. Legume seeds are also valuable sources of dietary fiber, vitamins and minerals including folate, thiamine and riboflavin[7]. Consumption of legumes has been associated with many health benefits, including the reduction of the risk of type 2 diabetes and cardiovascular disease, as well as the prevention of the onset of various types of cancer. Beans have been studied due to bioactive components, such as antioxidants, phenolic compounds, dietary fiber fractions, resistant starch and oligosaccharides present in the seed[79].

Bean flours have been added to foods in order to increase the nutritional value or to provide specific desired functional attributes[80,81]. Despite the nutraceutical or nutritional contribution, incorporation of these flours into functional products is determined by some technological properties such as solubility, water binding capacity and fat absorption.

3. Final Considerations

The American Continent (and particularly South and Central America), as one of the most mega-diverse zones of our planet, has supplied a great quantity of plant foods for the nutrition of the humankind.

Latin-America is already the World largest net food exporting region although it has not achieved its complete potential to expand agricultural production for regional consumption and global export. This part of the planet has been endowed with abundant natural resources, even with a third of the world's fresh water stocks. Likewise, the region has a large number of experienced farmers who have conserved and transmitted their knowledge of agriculture and nourishment.

It has been mentioned that the next decades will offer a critical opportunity to reinforce novel forms of productive and environmentally sustainable agriculture in the region. Experts point out that the challenge is much bigger than just producing more food. It is essential to feed a rapidly growing global population without expanding farming into environmentally susceptible areas, reducing the productive ability of the land already cultivated, and affecting quality.

Despite of the existence of numerous species total or partially domesticated, which goes back to the first American people, the commercial utilization of the autochthonous genetic resources is still incipient in the region.

The domestication of native plants, including those already known and commercialized by local people, with little entrance in the national or international market, is a great opportunity to be developed. In many regions of the continent, this richness is yet under-utilized, particularly due to economic and market pressure, which favor exotic crops and products.

In this context of a clear need for diet diversification, those populations with special nutritional requirements, such as celiac patients, should be benefited with the offer of more balanced, rich and safe diet components. There is an urgent need to explore the possibility of learning to a great extent from traditional foods and spread on local and territorial knowledge for the development and production of innovative gluten-free foods, looking after the local livelihood from which the whole mankind could benefit.

References

1. Charrondière UR, Stadlmayr B, Rittenschober D, Mouille B, Nilsson E, Medhammar E et al. *FAO/INFOODS food composition database for biodiversity.* Food Chem. 2013; 140: 408-12.
   http://dx.doi.org/10.1016/j.foodchem.2012.08.049
   PMid:23601383
2. UNEP. United Nations Environment Programme. *Global Biodiversity Assessment.* Cambridge: Cambridge University Press. 1995; 1140.
3. Savard J-PL, Clergeaub P, Mennechez G. *Biodiversity concepts and urban ecosystems.* Landsc Urban Plan. 2000; 48: 131-42.
   http://dx.doi.org/10.1016/S0169-2046(00)00037-2
4. SOFI. *The State of Food Insecurity in the World 2012.* Rome: FAO. 2012.
   http://www.fao.org/publications/sofi/en/
5. He C. *Opening address. International Scientific Symposium. Biodiversity and Sustainable Diets United against Hunger.* Rome: Food and Agriculture Organization of the United Nations. 2010.
6. CIP. Centro Internacional de la Papa (International Potato Center). 2014.
   http://cipotato.org/es/
7. Dini C, García MA, Viña SZ. *Non-traditional flours: frontiers between ancestral heritage and innovation.* Food Funct. 2012; 3: 606-20.
   http://dx.doi.org/10.1039/c2fo30036b
   PMid:22499487
8. ICC. International Association for Cereal Science and Technology. *Growing interest in gluten-free foods and beverages and important conclusions for the future of gluten-free discussed at the GF13.* The 3rd International Symposium on Gluten-Free Foods and Beverages (Vienna, Austria, 12-14 June 2013) 2014.
   https://www.icc.or.at/news/gf13_report. Accessed on March 2014.
9. Gibson L, Benson G. *Origin, History, and Uses of Corn* (Zea mays). Iowa State University, Department of Agronomy. 2002.
   www.agron.iastate.edu/Courses/agron212/readings/corn_history.htm. Accessed: January 2014.
10. Hannon S. *The Journey of New World Foods.* 2010.
    http://www.pbs.org/when-worlds-collide/. Accessed: March 2014.
11. FAOSTAT. *FAO Statistics Division.* 2014. http://faostat.fao.org/

12. Singh N, Singh S, Shevkani K. *Maize: Composition, Bioactive Constituents, and Unleavened Bread.* In: Preedy VR, Watson RR, Patel VB (Eds.). Flours and Breads and their Fortification in Health and Disease Prevention. USA: Academic Press, Elsevier Inc. 2011; 89-99.

    http://dx.doi.org/10.1016/B978-0-12-380886-8.10009-1

13. FAO Maize in human nutrition. *FAO Corporate Document Repository. Produced by Agriculture and Consumer Protection. Food and Agriculture Organization of The United Nations.* Rome, Italy. 1992.

    http://www.fao.org/docrep/t0395e/t0395e00.HTM. Accessed: January 2014.

14. Veloso Naves MM, Vieira Leão de Castro M, Luiz de Mendonça A, Gebrim Santos G, Silva MS. *Corn germ with pericarp in relation to whole corn: nutrient contents, food and protein efficiency, and protein digestibility-corrected amino acid score.* Ciênc Tecnol Aliment Campinas. 2011; 31(1): 264-9.

    http://dx.doi.org/10.1590/S0101-20612011000100040

15. Vander Zaag P. *One potato, two potato.* Far Eastern Economic Review. 1984; 23: 64-6.

16. Kiple KF, Ornelas KC (Eds.). *The Cambridge World History of Foods* (parts 1 and 2). Cambridge University Press. 2008.

    http://www.cambridge.org/us/books/kiple/default.htm. Accessed: February 2014.

17. Rodríguez-Sandoval E, Sandoval G, Cortes-Rodríguez M. *Effect of quinoa and potato flours on the thermomechanical and breadmaking properties of wheat flour.* Brazilian J Chem Eng. 2012; 29(3): 503-10.

    http://dx.doi.org/10.1590/S0104-66322012000300007

18. Misra A, Kulshrestha K. *Potato flour incorporation in biscuit manufacture.* Plant Food Hum Nutr. 2003; 58(3): 1-9.

    http://dx.doi.org/10.1023/B:QUAL.0000040337.69812.cb

19. Ezekiel R, Singh N. *Use of potato flour in bread and flat bread.* In: Preedy VR, Watson RR, Patel VB (Eds.). Flours and Breads and their Fortification in Health and Disease Prevention. USA: Academic Press, Elsevier Inc. 2011; 247-59.

    http://dx.doi.org/10.1016/B978-0-12-380886-8.10023-6

20. USDA (U.S. Department of Agriculture, Agricultural Research Service). *USDA National Nutrient Database for Standard Reference.* 2013. Release 26. Nutrient Data Laboratory Home Page,

    http://www.ars.usda.gov/ba/bhnrc/ndl

21. Gahlawat P, Sehgal S. *Protein and starch digestibilities and mineral availability of products developed from potato, soy and corn flour.* Plant Foods Hum. Nutr. 1998; 52: 151-60.

    http://dx.doi.org/10.1023/A:1008045023304
    PMid:9839814

22. Rodríguez-Galdón B, Ríos-Mesa D, Rodríguez-Rodríguez EM, Díaz-Romero C. *Amino acid content in traditional potato cultivars from the Canary Islands.* J Food Comp Anal. 2010; 23: 148-53.

    http://dx.doi.org/10.1016/j.jfca.2009.08.009

23. Ochoa CM. *The potatoes of South America: Bolivia.* Cambridge: Cambridge University Press. 1990; 551.

24. Ispizúa VN, Guma IR, Feingold S, Clausen AM. *Genetic diversity of potato landraces from northwestern Argentina assessed with simple sequence repeats (SSRs).* Genet Resour Crop Evol. 2007; 54: 1833-48.

    http://dx.doi.org/10.1007/s10722-007-9207-8

25. Andrade-Mahecha MM, Tapia-Blácido DR, Menegalli FC. *Physical-chemical, thermal, and functional properties of achira (*Canna indica *L.) flour and starch from different geographical origin.* Starch/Stärke. 2012; 64: 348-58.

    http://dx.doi.org/10.1002/star.201100149

26. Noman ASM, Hoque MA, Haque MM, Pervin F, Karim MR. *Nutritional and anti-nutritional components in* Pachyrhizus erosus *L. tuber.* Food Chem. 2007; 102: 1112-8.

    http://dx.doi.org/10.1016/j.foodchem.2006.06.055

27. Ribeiro RA, Finger FL, Puiatti M, Casali VWD. *Chilling injury sensitivity in arracacha* (Arracacia xanthorrhiza) *roots.* Trop. Sci. 2005; 45: 55-7.

    http://dx.doi.org/10.1002/ts.48

28. Wang Y, Wang Y, McNeil B, Harvey LM. *Maca: An Andean crop with multi-pharmacological functions.* Food Research Int. 2007; 40: 783-92.

    http://dx.doi.org/10.1016/j.foodres.2007.02.005

29. Puoci F, Malanchin R, Piangiolino C, Restuccia D, Curcio M, Parisi OI et al. *Maca flour: a powerful ingredient for functionally enhanced bread.* Int Food Res J. 2013; 20(3): 1293-300.

30. Zheng BL, He K, Kim CH, Rogers L, Shao Y, Hunag ZY et al. *Effect of lipidic extract from Lepidium meyenii on sexual behavior in mice and rats.* Urology. 2000; 55: 598-602.

    http://dx.doi.org/10.1016/S0090-4295(99)00549-X

31. Sandoval M, Okuhama NN, Angeles FM, Melchor VV, Condezo LA, Lao J et al. *Antioxidant activity of the cruciferous vegetable maca* (Lepidium meyenii). Food Chem. 2002; 79: 207-13.

    http://dx.doi.org/10.1016/S0308-8146(02)00133-4

32. Lee K-J, Dabrowski K, Sandoval M, Miller MJS. *Activity-guided fractionation of phytochemicals of maca meal, their antioxidant activities and effects on growth, feed utilization, and survival in rainbow trout* (Oncorhynchus mykiss) *juveniles.* Aquaculture. 2005; 244(1-4): 293-301.

    http://dx.doi.org/10.1016/j.aquaculture.2004.12.006

33. Zhang YZ, Yu LJ, Ao MZ, Jin WW. *Effect of ethanol extract of Lepidium meyenii Walp on osteoporosis in ovariectomized rat.* J Ethnopharmacol. 2006; 105: 274-9.

    http://dx.doi.org/10.1016/j.jep.2005.12.013
    PMid:16466876

34. Campos D, Noratto G, Chirinos R, Arbizu C, Roca W, Cisneros-Zevallos L. *Antioxidant capacity and secondary metabolites in four species of Andean tuber crops: native potato* (Solanum sp.)*, mashua* (Tropaeolum tuberosum *Ruiz & Pavón), Oca* (Oxalis tuberosa *Molina) and ulluco* (Ullucus tuberosus *Caldas).* J Sci Food Agric. 2006; 86(10): 1481-8.

    http://dx.doi.org/10.1002/jsfa.2529

35. Azeredo HMC. *Betalains: properties, sources, applications, and stability - a review.* Int J Food Sci Technol. 2009; 44(12): 2365-76.

    http://dx.doi.org/10.1111/j.1365-2621.2007.01668.x

36. Coll-Aráoz MV, Kortsarz-González AM, Mercado MI, Ponessa GI, Grau A, Catalán CAN. *Ontogeny and total sugar content of yacon tuberous roots and other three* Smallanthus *species* (Heliantheae, Asteraceae)*, insights on the development of a semi-domesticated crop.* Genet Resour Crop Evol. 2014; 61: 163-72.

    http://dx.doi.org/10.1007/s10722-013-0022-0

37. Dempewolf H, Rieseberg LH, Cronk QC. *Crop domestication in the Compositae: a family-wide trait assessment.* Genet Resour Crop Evol. 2008; 55: 1141-57.

    http://dx.doi.org/10.1007/s10722-008-9315-0

38. Abera T, Admasu S, Desse G. *Effect of processing on physicochemical composition of cassava. Cyanide and other antinutrients in cassava.* Saarbrücken: VDM Verlag Dr Müller GmbH & Co. 2010.

    PMCid:PMC2791881

39. Hillocks RJ. *Cassava in Africa.* In: Hillocks RJ, Thresh JM, Bellotti AC (Eds.). Cassava: Biology, production and utilization. Oxford: CABI Publishing. 2002; 41-54.

    http://dx.doi.org/10.1079/9780851995243.0041

40. Allem AC. *The origins and taxonomy of cassava.* In: Hillocks RJ, Thresh JM, Bellotti AC (Eds.). Cassava: Biology, production and utilization. Oxford: CABI Publishing. 2002; 1-16.

    http://dx.doi.org/10.1079/9780851995243.0001

41. Malandula Chipeta M, Bokosi JM. *Status of Cassava* (Manihot esculenta) *Production and Utilization in Malawi.* Int J Agron Plant Prod. 2013; 4(S): 3637-44.

42. UNCTAD United Nations Conference on Trade and Development. Sweet Potato Commodity Profile. 2012.

    http://www.unctad.info/en/Infocomm/AACP-Products/COMMODITY-PROFILE---Sweet-potato/. Accessed: March 2014.

43. Greene JL, Bovell-Benjamin, AC. *Macroscopic and Sensory Evaluation of Bread Supplemented with Sweet-potato Flour.* J Food Sci. 2004; 69(4): 167-73.

    http://dx.doi.org/10.1111/j.1365-2621.2004.tb06359.x

44. Walter Jr WM, Collins WW, Purcell AE. *Sweet Potato Protein: A Review.* J Agric Food Chem. 1984; 32: 695-9.

    http://dx.doi.org/10.1021/jf00124a001

45. Sun M, Mu T, Zhang M, Arogundade LA. *Nutritional assessment and effects of heat processing on digestibility of Chinese sweet potato protein.* J Food Comp Anal. 2012; 26: 104-10.

    http://dx.doi.org/10.1016/j.jfca.2012.03.008

46. Maeshima M, Sasaki T, Asahi T. *Characterization of major proteins in sweet potato tuberous roots.* Phytochem. 1985; 24: 1899-902.

    http://dx.doi.org/10.1016/S0031-9422(00)83088-5

47. Guerrero-Beltrán JA, Estrada-Girón Y, Swanson BG, Barbosa-Cánovas GV. *Pressure and temperature combination for inactivation of soymilk trypsin inhibitors.* Food Chem. 2009; 116(3): 676-9.

    http://dx.doi.org/10.1016/j.foodchem.2009.03.001

48. Aquino MU. *BAR (Bureau of Agricultural Research) Chronicle (Philippines).* 2009; 10(8): 13.

49. Kumar CG, Parrack P. *Arrowroot* (Marantha arundinacea) *starch as a new low-cost substrate for alkaline protease production.* World J Microbiol Biotechnol. 2003; 19: 757-62.

    http://dx.doi.org/10.1023/A:1025156105148

50. Hernández-Medina M, Torruco-Uco JG, Chel-Guerrero, L., Betancur-Ancona, D. *Caracterización fisicoquímica de almidones de tubérculos cultivados en Yucatán, México.* Ciênc. Tecnol. Aliment. 2008; 28 (3): 718-26. ISSN 1678-457X.
    http://dx.doi.org/10.1590/S0101-20612008000300031

51. Tapia M. *The Environment, Crops and Agricultural Systems in the Andes and Southern Peru.* IICA. 1982.

52. Cusack D. *Quinoa: grain of the Incas.* Ecologist. 1984; 14: 21-31.

53. Abugoch L, Castro E, Tapia C, Añon MC, Gajardo P, Villaroel A. *Stability of quinoa flour proteins (*Chenopodium quinoa *Willd.) during storage.* Int. J. Food Sci Technol. 2009; 44: 2013-20.

    http://dx.doi.org/10.1111/j.1365-2621.2009.02023.x

54. Galwey NW. *The potential of quinoa as a multipurpose crop for agricultural diversification: a review.* Ind. Crops Prod. 1992; 1(2-4): 101-6.

    http://dx.doi.org/10.1016/0926-6690(92)90006-H

55. Jacobsen SE. *The worldwide potential of quinoa (*Chenopodium quinoa *Willd.).* Food Rev Int. 2003; 19(1-2): 167-77.

    http://dx.doi.org/10.1081/FRI-120018883

56. Bhargava A, Shukla S, Ohri D. Chenopodium quinoa*—An Indian perspective.* Ind Crops and Prod. 2006; 23: 73-87.

    http://dx.doi.org/10.1016/j.indcrop.2005.04.002

57. Repo-Carrasco R, Espinoza C, Jacobsen SE. *Nutritional value and use of the Andean crops quinoa* (Chenopodium quinoa) *and kañiwa* (Chenopodium pallidicaule). Food Rev Int. 2003; 19(1-2): 179-89.

    http://dx.doi.org/10.1081/FRI-120018884

58. Cardozo A, Tapia ME. *Valor nutritivo. Quinua y Kaniwa. Cultivos Andinos.* In: Tapia ME (Ed). Serie libros y Materiales educativos.. Bogotá: Instituto Interamericano de Ciencias Agrícolas. 1979. 49: 149-92.

59. Koziol MJ. *Chemical composition and nutritional value of quinoa (*Chenopodium quinoa *Willd.).* J Food Comp Anal. 1992; 5: 35-68.

    http://dx.doi.org/10.1016/0889-1575(92)90006-6

60. Van Etten CH, Miller RW, Wolff IA, Jones Q. *Amino acid composition of seeds from 200 angiosperm plants.* J Agric Food Chem. 1963; 11: 399-410.

    http://dx.doi.org/10.1021/jf60129a016

61. Peiretti PG, Gaia F, Tassone S. *Fatty acid profile and nutritive value of quinoa* Chenopodium quinoa *Willd. seeds and plants at different growth stages.* Animal Feed Sci Technol. 2013; 183: 56-61.

    http://dx.doi.org/10.1016/j.anifeedsci.2013.04.012

62. Schoenlechner R, Siebenhandl S, Berghofer E. *Pseudocereals.* In: Arendt EK, Dal Bello F (Eds.). Gluten-free Cereal Products and Beverages. Ireland: Cork. 2008; 149-76.

    http://dx.doi.org/10.1016/B978-012373739-7.50009-5

63. Park SH, Morita N. *Dough and breadmaking properties of wheat flour substituted by 10% with germinated quinoa flour.* Food Sci and Technol Int. 2005; 11(6): 471-6.

    http://dx.doi.org/10.1177/1082013205060766

64. Collar C, Angioloni A. *Pseudocereals and teff in complex breadmaking matrices: Impact on lipid dynamics.* J. Cereal Sci. 2014; 59: 145-54.

    http://dx.doi.org/10.1016/j.jcs.2013.12.008

65. Aluko RE, Monu E. *Functional and Bioactive Properties of Quinoa Seed Protein Hydrolysates.* J. Food Sci. 2003; 68: 1254-8.

    http://dx.doi.org/10.1111/j.1365-2621.2003.tb09635.x

66. Alvarez-Jubete L, Arendt EK, Gallagher E. *Nutritive value of pseudocereals and their increasing use as functional gluten-free ingredients.* Trends Food Sci Technol. 2010; 21: 106-13.

    http://dx.doi.org/10.1016/j.tifs.2009.10.014

67. Collar C, Martínez JC, Rosell CM. *Lipid binding of fresh and stored formulated wheat breads. Relationships with dough and bread technological performance.* Food Sci Technol Int. 2001; 7(6): 501-10.

68. Añón MC, Puppo MC, Pedroza-Islas R, Oliete B, Villagómez-Zavala D. *Valor nutricional y saludable de materias primas para la elaboración de productos de panificación.* In: Lutz M, León, AE (Eds.). Aspectos nutricionales y saludables de los productos de panificación. Valparaíso: Ed. Universidad de Valparaiso. 2009; 71-119.

69. Amicarelli V, Camaggio G. Amaranthus*: a crop to rediscover.* Forum Ware International. 2012; 2: 4-11.

70. Grobelnik Mlakar S, Turinek M, Jakop M, Bavec M, Bavec F. *Grain amaranth as an alternative and perspective crop in temperate climate.* Revija za geografijo - Journal for Geography. 2010; 5(1): 135-45.

71. Viglasky J, Andrejcak I, Huska J, Suchomel J. *Amaranth* (Amarantus L.) *is a potential source of raw material for biofuels production.* Agron Researc. 2009; 7(2): 865-73.

72. Repo-Carrasco-Valencia R, Peña J, Kallio H, Salminen S. *Dietary fiber and other functional components in two varieties of crude and extruded kiwicha* (Amaranthus caudatus)*.* J. Cereal Sci. 2009; 49(2): 219-24.

    http://dx.doi.org/10.1016/j.jcs.2008.10.003

73. Fritz M, Vecchi B, Rinaldi G, Añón MC. *Amaranth seed protein hydrolysates have in-vivo and in-vitro antihypertensive activity.* Food Chem. 2011; 126: 878-84.

    http://dx.doi.org/10.1016/j.foodchem.2010.11.065

74. Orsini Delgado MC, Tironi VA, Añón MC. *Antioxidant activity of amaranth protein or their hydrolysates under simulate gastrointestinal digestion.* LWT Food Sci and Technol. 2011; 44: 1752-60.

    http://dx.doi.org/10.1016/j.lwt.2011.04.002

75. Chazan M. *World Prehistory and Archaeology: Pathways through Time.* Pearson Education, Inc. 2008.

76. Gepts P. *Origin and evolution of common bean: past events and recent trends.* Hort Sci. 1998; 33(7): 1124-30.

77. Shimelis EA, Rakshit SK. *Proximate composition and physico-chemical properties of improved dry bean* (Phaseolus vulgaris L.) *varieties grown in Ethiopia.* LWT Food Sci and Technol. 2005; 38: 331-8.

    http://dx.doi.org/10.1016/j.lwt.2004.07.002

78. Pirman T, Stibilj V, Stekar JMA, Combe E. *Amino acid composition of beans and lentil.* Zb Bioteh Fak Univ Ljubl, Kmet Zooteh. 2001; 78: 57-68.

79. Ramírez-Jiménez AK, Reynoso-Camacho R, Mendoza-Díaz S, Loarca Piña G. *Functional and technological potential of dehydrated* Phaseolus vulgaris L. *flours.* Food Chem. 2014.

    http://dx.doi.org/10.1016/j.foodchem.2014.04.008

80. Anton AA, Gary Fulcher R, Arntfield SD. *Physical and nutritional impact of fortification of corn starch-based extruded snacks with common bean* (Phaseolus vulgaris L.) *flour: Effects of bean addition and extrusion cooking.* Food Chem. 2009; 113(4): 989-96.

    http://dx.doi.org/10.1016/j.foodchem.2008.08.050

81. Boye J, Zare F, Pletch A. *Pulse proteins: Processing, characterization, functional properties and applications in food and feed.* Food Res Int. 2010; 43: 414-31.

    http://dx.doi.org/10.1016/j.foodres.2009.09.003