Pseudocereals: Super “Foods”, or Pantry “Hokum”?

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Move over wheat, rice, barley, oat, and maize: Your botanical imposters are poised for global conquest! Yes, the pseudocereals are on the up-and-up, particularly among North American and European culinary savants and other health-conscious types. And in a nod aimed at focusing attention on underexploited genetic resources for developing countries, the Food and Agriculture Organization of the United Nations (FAO) anointed 2013 as the “international year of quinoa,” a pseudocereal. But what exactly are pseudocereals, and why all the ballyhoo over them?

The term “pseudocereal” refers to a class of cosmopolitan grain-like plants, including the familiar buckwheat (*Fagopyrum esculentum*), and not-so-familiar plants like quinoa (*Chenopodium quinoa*), kañiwa (*Chenopodium pallidacuale*), amaranth (*Amaranthus* spp.), huazontle (*Chenopodium nuttaliae*), and chia (*Salvia hispanica*). True cereals are monocotyledon (one seed leaf) plants, all members of grass family “Poaceae” in botany lingo. Maize, wheat, oat, sorghum, are familiar monocot grass crops. Pseudocereals, on the other hand, are dicotlyledon (two seed leaves) broadleaf plants like soybean and cotton. Grasses and broadleaf plants also differ based on fruit type and storage tissues. For example, the fruit (i.e. the edible seed) of all true cereals is called a caryopsis (**Figure 1**). For all cereals, the main starch reserves for the embryo are stored in the endosperm tissue. The fruit of quinoa and related chenopods is an indehiscent achene, which is a fancy way of saying it’s a seed that doesn’t spontaneously split away from the mother plant when ripe (**Figure 2**). Chia seed is also an achene (**Figure 3**), but the plant is unrelated to quinoa (chia belongs to same family as mint and sage). The fruit of amaranth is a dry, one-seeded, usually dehiscent, utricle that splits away from the mother plant when ripe (**Figure 4**). The endosperm tissue in quinoa and amaranth is reduced to one or two layers surrounding the hypocotyl-radicle axis, which, in plain speak, is the primary shoot-root axis (this location is pointed in **Figures 2** and **4**).

Pseudocereals like quinoa, chia, and amaranth have surged in popularity because their seeds are nutritious, offering a favorable balance of amino

Figure 1. Caryopsis (cereal) fruit showing major food storage tissues.

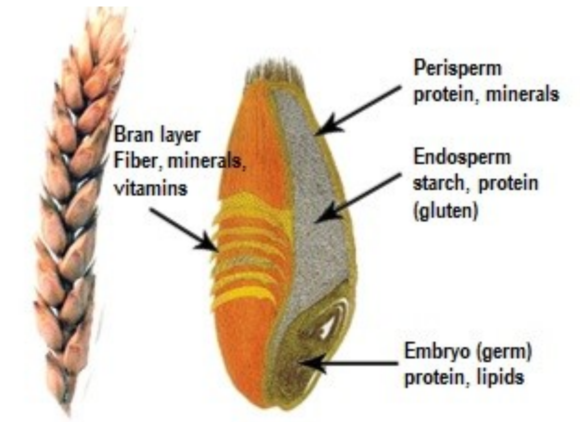

Figure 2. Quinoa fruit (achene) under magnification showing major food storage tissues. Quinoa seed is loosely held within a yellowish-magenta-tinted papery tissue called a ‘perianth’.

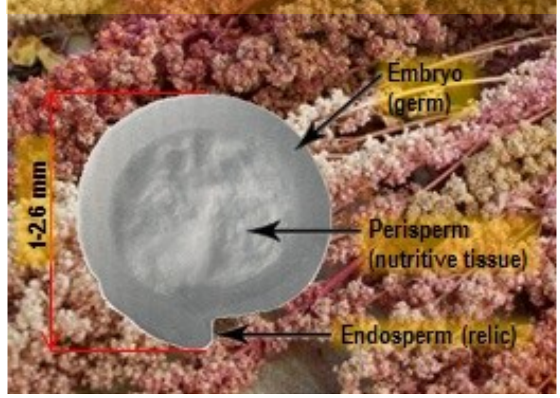

Image source: adapted from Belton and Taylor.

Figure 3. Chia fruit (achene).

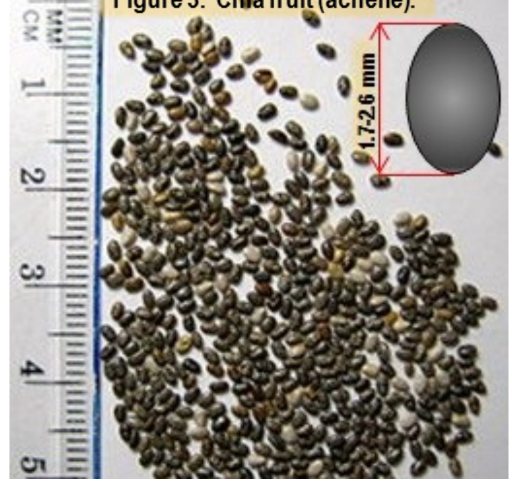

Image source: adapted from Wikipedia.

acids, health-promoting fatty acids like omega-3, dietary fiber, minerals, or a combination of these. Pseudocereal grains also earn bonus points for being gluten-free, a food preference that appears to be on the increase. As such, pseudocereals have acquired *haute cuisine* status in kitchens as superfoods possessing all kinds of life-extending, health-promising virtues. Comparisons to meat have been made.

In turn, curious (and skeptical) minds want to know: Do these grains live up to the commercial hype? Are they really super "foods", or is it pantry "hokum"? To answer this question, objectively, absent commercial marketing and its train of bogus and/or questionable nutritional information, we have painstakingly examined the global scientific literature to produce a survey of the pseudocereals: history, botany, and nutritional value in the human diet.

First, a pre-show caveat to chew over: Comparing the nutrient content of foods is very risky business. This is because nutrients in food can vary tremendously for reasons of climate, variety, pest pressure, or management practices like irrigation and soil mineral fertility. It's easy to cherry-pick data that is biased or aberrant relative to the "average" for that food. This happens, inadvertently, because information on new crops like quinoa, amaranth, and chia is sparse compared to that of commercial cereal and oilseed grains. On the other hand, it would not be valid to compare the amino acid content of high-lysine corn to that of unimproved non-commercial varieties of quinoa. Also, the nutrient content of cereal and oilseed grains has increased over time from improved genetics and cropping practices. Comparing average wheat protein today to that of wheat in 1950 would be biased in favor of today's higher protein content. To be completely unbiased, it would be necessary to compare protein (and amino acid content) of wheat among 1950s-era varieties. Saying that, the nutrient contents listed in **Tables 1-6** in this report are considered representative of the market products at the time they were analyzed, for comparative study only.

Quinoa and Allies: History, Botany, Cultivation

Quinoa (*Chenopodium quinoa* Willd) is an annual, domesticated herbaceous plant native to the Andean region of South America. Pronounced KEE-no-ah, quinoa is called in the Quechan language *kinwa*, or

Figure 4. Amaranth fruit (utricle) under magnification showing major food storage tissues.

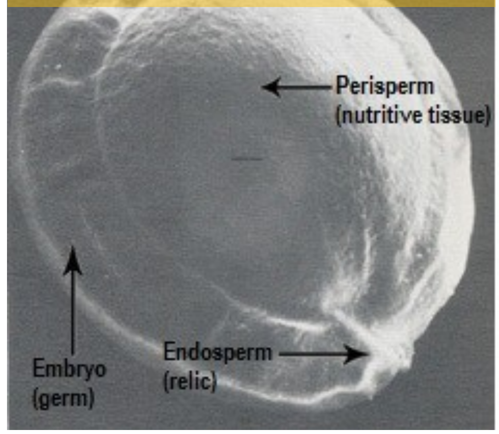

Image source: R.Saunders.

"mother grain". The word quinoa is from the Spanish language (hence the three-syllable pronunciation; "keen-wah" is an acceptable variant closer to its Quechan roots). Two closely related species, kañiwa (*Chenopodium pallidacuale*), and huazontle (*Chenopodium nuttaliae*) also occur within South and Central America. Quinoa, kañiwa, and huazontle belong to the botanical family Amaranthaceae, which also includes the tribe of edible amaranths. Botanists once placed *Chenopodium* species in the family Chenopodiaceae, or "goosefoot" family, from which the vernacular epithet "chenopod" is coined. The chenopods consist of about 200 species that have managed to colonize virtually all of the Earth's continents, i.e. any terrain that isn't frozen solid or completely sterile (Wilson 1990). Indeed, anyone who is remotely familiar with farming or gardening knows all about the chenopods, and not in a kindly way! Lamb's quarters (*Chenopodium album*) is a wild North American quinoa look-alike weed that infests practically all disturbed ground (**Figure 5**). The same is true of many species of amaranth, nicknamed deferentially, "pigweeds", some of which have gained infamy in the era of transgenic, herbicide-tolerant crops (Trucco and Tramel 2011).

The leaves of *Chenopodium album* are commonly eaten in Northern India, the Punjab, and other localities, where it too occurs as weed (Joshi et. al. 2002; Partap et al. 1998). For those old enough to remember, lamb's quarters was featured in back-to-the-land classics like Stalking the Wild Asparagus (Gibbons 1962) and still occasionally finds its way into the cuisine through local food and gourmet enthusiasts. Another chenopod, *C. ambroisoides*, also known as Epizote or Mexicantea, is a widely dispersed invasive aromatic species (**Figure 6**). And *Atriplex* species (orach, saltbush) is an indicator plant of salt-affected and saline environments (**Figure 7**). The chenopods also include several well-known domesticated crops like spinach (*Spinacea oleracea*), garden and sugar beet (*Beta vugaris*, many cultivars), and Swiss chard (*Beta vulgaris* subsp. *cicla*).

Quinoa was a food grain in the diet of the Inca civilization dating back millennia. Archeological evidence suggests it was being cultivated ~7000 and ~5000 years ago in Peru and in Chile, respectively (Tapia 1979). Popular narrative asserts, as if borrowing a page from the El Dorado mythology, that chenopods suffered a decline in production after the Spanish conquest of the region in 1532 A.D., surviving as relic crops until "rediscovered" in the1970s. I have found little hard evidence for this. If these crops were abandoned or "lost", as claimed, the reasons are obscure but in recent times may have been accelerated by import subsidies favoring cheaper grains like corn, as well as crop failure and cultural factors (Tapia 1979). The mid-1970s witnessed a resurgence in interest in indigenous crops through National Academy of Science publications like Underexploited Tropical Plants with Promising Economic Value (NAS 1975), followed by Amaranth: Modern Prospects for an Ancient Crop (NAS 1984) and Lost Crops of the Incas: Little Known Plants of the Andes with Promise for Worldwide Cultivation (NAS 1989). Charles Heiser (1920-2010), well-known author and ethnobotanist, included a chapter on chenopods in Of Plants and People (1985), drawing mainly on his experience in the highlands of Ecuador. Quinoa even garnered attention from NASA in 1996, where it came under scrutiny as a potential crop for the Controlled Ecological Life Support System (CELSS) project aimed at equipping manned long-duration space vehicles with food products of superior nutritional quality. The FAO has also taken interest in quinoa's potential for contributing to world food security, declaring 2013 as the "international year of quinoa" and publishing a 55-page monograph on it.

Quinoa, kañiwa, and huazontle are cultivated worldwide, but production statistics are elusive. Almost certainly, huazontle is little known outside Central America and limited there to local production. To this author's knowledge, quinoa and kañiwa are the only chenopods that are exploited commercially. According to FAO data (FAO 2011), the main producing countries are Bolivia, Peru, and Ecuador (**Figure 8**). Bolivia is the largest exporter of quinoa, with grain exports in 2009 valued at over US $43 million. Major importing countries are the United States (45%), France (16%), and the Netherlands (13%), the rest going to Germany, Canada, Israel, Brazil, and the UK. Outside South America, quinoa is produced in Colorado, USA, and has undergone experimental testing in Canada, Finland, and the UK (Risi and Galway 1989).

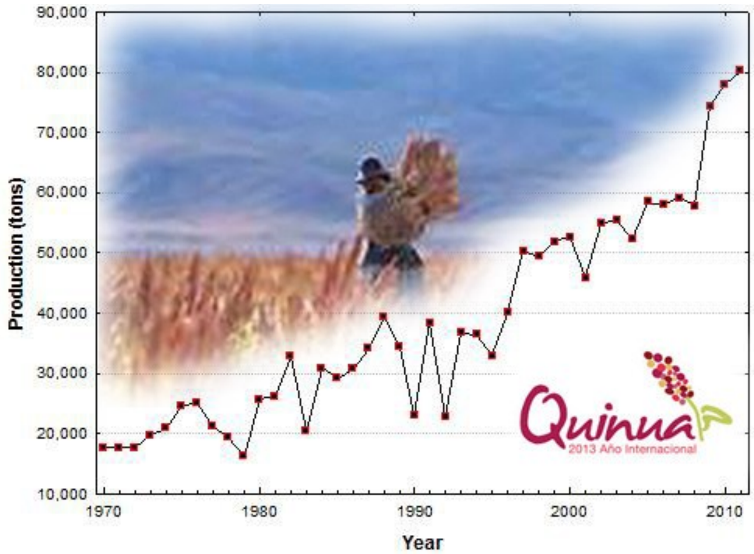

Figure 8. Quinoa production 1970-2011 from Bolivia, Ecuador, and Peru. *Data source: FAOSTAT(2011).*

Roland Specialty Foods is a distributor of quinoa and kañiwa products in North America, offered through retail sellers like Amazon.com. A 4.5 kg (10 lb) bag of Roland quinoa grain recently (06-01-13) sold for US $54.94, a wallet-unfriendly US $12.21 per kg. If you're thinking quinoa is the "grain of the god$", you're with me. Let's examine what you're getting for that rapturous sum…

Quinoa & Allies: Nutritional Pedigree

I. Protein and Amino Acids

Table 1 shows the proximate composition of quinoa and kañiwa compared to that of the major cereal and legume food grains. No compositional data was found for huazontle. Perisperm, embryo, and endosperm are the three main areas of the quinoa seed where nutrients are stored (see **Figure 2**). Protein content of quinoa and kañiwa grain is 14.8% and 18.8%, respectively. This is higher than the major cereal grains in **Table 1** but low compared to legumes like soybean. Quinoa protein content ranges from 11% to 15% (Guzmán-Moldonado and Paredes -López 1998). Storage proteins in quinoa and kañiwa

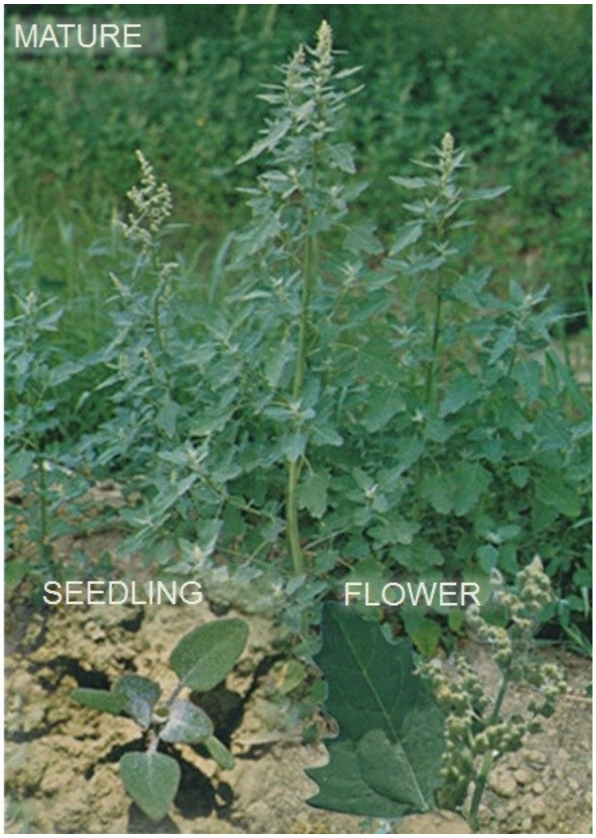

Figure 5. Lamb's quarters (*Chenopodium album*), a cosmopolitan weed closely related to quinoa. *Image source: adapted from UCLA growers handbook 4030.*

Figure 6. Mexican tea (*Chenopodium abrosioides*), a close relative of quinoa native to tropical America. In North America, Mexican tea has become widely established as a weed in agricultural row crops, pastures, and waste places. *Image source: adapted from UCLA growers handbook 4030.*

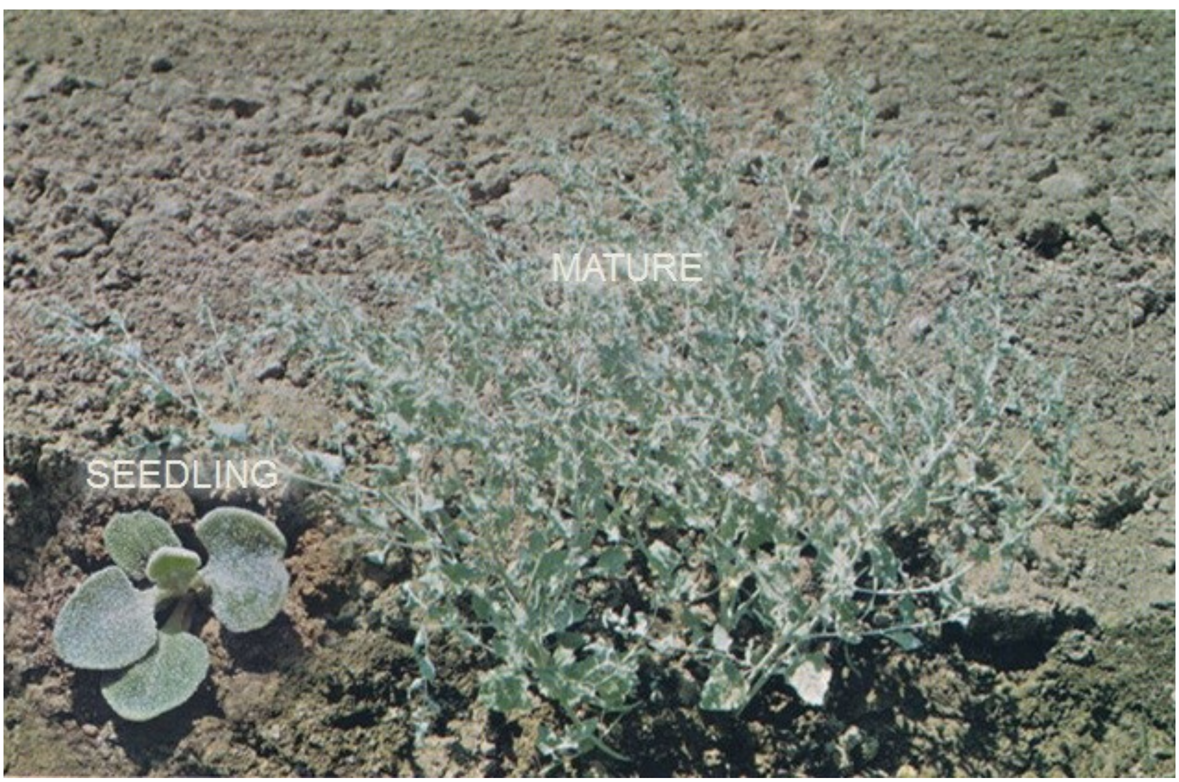

Figure 7. Saltbush (*Atriplex patula* var. *hastata*), a chenopod indicator plant of salt-affected and saline environments. *Image source: adapted from UCLA growers handbook 4030.*

are predominantly globulins and albumins (41-45%) with smaller amounts of prolamins and glutelins (Scarpati de Briceño 1979). Globulins and albumins have a better balance of amino acids relative to prolamins (found in wheat and other grain seeds), and compare favorably to casein (milk protein). Quinoa seed proteins are concentrated in the embryo but may be found throughout all tissues of the grain.

Quinoa's mystique as a "super" food largely rests on protein quality, especially regarding its amino acid profile. **Table 2** shows the essential amino acid (EAA) composition of quinoa and kañiwa, compared with the major cereal and legume food grains. Essential amino acids are the amino acids that cannot be produced by humans and must be supplied to the body through dietary sources. Quinoa and kañiwa proteins are often touted as containing "all essential amino acids" needed for human health. This is true.

Table 1. Proximate composition of pseudocereal grain seeds compared to major cereal and legume food grains (g/100g dry matter basis).

	Protein	Fat	Fiber¥	Carbohydrate	Ash
Amaranth[1]	14.8	6.9	9.7	75	3.4
Quinoa[2]	14.4	6.0	4.0	73	2.9
Kañiwa[2]	18.8	7.6	5.0	63	4.1
Chia[1]	21.8	29.5	27.5	43	5.9
Wheat[1,3]	12.7	2.2	2.6	64	1.8
Oats[3]	12.9	7.5	3.9	75	2.1
Barley, pearl[3]	9.5	1.1	0.9	86	1.3
Corn [3]	11.2	4.8	1.9	80	1.7
Rice, brown[3]	8.5	2.2	1.0	87	1.4
Soybean[4]	36.5	19.9	9.3	30.2	4.9

Sources: [1]Weber et al.(1991); [2]Repo-Carrasco et al.(2003); [3]Kent(1994); [4]USDA-NAL database.
¥Crude fiber (insoluble) including cellulose and lignin; crude fiber may be anywhere from one-half to one-seventh dietary (soluble+insoluble) fiber content.

Table 2. Essential amino acid composition of pseudocereal grain seeds compared to major cereal and legume food grains.

Seed Grain	Amino Acid (g/100 g protein¥)								
	Trp	Met+Cys	Thr	Ile	Val	Lys	Phe+Tyr	Leu	His
Quinoa[1]	1.5	3.4	3.8	3.2	3.9	5.1	6.3	7.9	2.4
Kañiwa[2]	0.9	4.6	3.3	3.4	4.2	5.3	6.0	6.1	2.7
Kiwicha[2]	1.1	6.1	3.3	3.2	3.8	6.0	6.4	5.4	2.4
Amaranth[3,4]	1.0	4.4	3.6	3.6	3.5	5.6	7.1	5.7	1.9
Chia[3]	----	2.6	2.2	3.7	4.1	4.2	7.5	5.7	NA
Wheat [5]	1.1	4.0	2.9	3.3	4.4	2.9	7.5	6.7	2.3
Oats[5]	1.3	4.4	3.3	3.8	5.1	3.7	8.3	7.3	2.1
Barley[5]	1.5	4.0	3.3	3.6	5.0	3.5	8.2	6.7	2.1
Corn[5]	0.6	3.5	3.6	3.7	4.8	2.7	8.7	12.5	2.7
Rice[5]	1.2	3.4	3.9	3.8	5.5	3.8	8.7	8.2	2.5
Soybean[5]	1.3	2.6	3.9	4.5	4.8	6.4	8.1	7.8	2.5
FAO/WHO/UNU[6.1]	0.7	2.5	2.7	3.1	4.1	5.2	4.6	6.3	1.8
FAO/WHO/UNU[6.2]	0.7	2.3	2.5	3.0	4.0	4.8	4.1	6.1	1.6
FAO/WHO/UNU[6.3]	0.6	2.2	2.3	3.0	3.9	4.5	3.8	5.9	1.5

Sources: [1]Ruales and Nair(1992); [2]Repo-Carrasco et al.(2003); [3]Weber et al.(1991); [4]Písaříková et al.(2005); [5]Lásztity and Hidvégi (1985); [6.1]reference amino acid pattern, pre-school child 1-2 yr; [6.2]adolescent 3-10 yr; and [6.3]adult human(2007).
¥Equivalent to g/16 g N based on average 6.25% N content in protein; the conversion factor is actually closer to 5.80 for cereal grains but 6.25 (Kjeldahl) is standard for reporting. Three letter codes (e.g. Trp, Ile) for amino acids follow IUPAC-IUB nomenclature.

However, the major food and oilseed grains also contain all essential amino acids and, in that regard, do not differ from quinoa. Quinoa's higher methionine and cysteine (sulfur-containing EAAs) complement the generally lower levels of these EAAs found in other food grains, particularly soybean. Many quinoa enthusiasts (including the FAO) have extolled the high lysine content of quinoa protein. This is because most cereal grains are low in this EEA, which can foster malnourishment when dietary protein intake is limited to, or heavily dependent upon, low-lysine grains. This is most acute in developing countries where local grain varieties with unique genetic or culinary properties often are preferred in the diet. However, the lysine data for quinoa that I found does not paint as rosy a picture as the FAO and other quinoa fans would have appear. **Table 2** shows that lysine content of quinoa protein is high relative to cereal grains, but is considerably lower than soybean. It is also less than the FAO/WHO/UNU pre-school reference amino acid pattern. Briefly, reference AA patterns have been developed by nutrition experts over decades of research, indicating the *minimum* number of EEAs needed to maintain a positive nitrogen (i.e. protein) balance, adjusted for age. Current (2007) reference patterns for pre-school children, adolescents, and adult categories are highlighted in orange, blue, and green, respectively, in **Table 2**. Thus, if the number for any of the EAAs in **Table 2** is *less* than the corresponding reference pattern for that EEA, they are *limiting amino acids* for that protein. The term "limiting amino acid" is preferred because once the body runs out of any of them, protein synthesis ceases. The concept of limiting EAAs is central to understanding the biological value of proteins, especially plant-based proteins with incomplete EAA profiles.

So, how does the lysine in quinoa stack up? Based on published information since the late 1950s, all one can say is that the lysine in quinoa varies from 4.1 g/100 g protein reported by Chiriboga and Velasquez in 1957 (Mahoney *et al*. 1975) and Ruales and Nair in 2002 (pre-cooked quinoa flour), to 6.6 g/100 g reported by White et. al. (1955), Van Ettan *et al*. (1963), and everything in-between. The EEA figures for quinoa grain in **Table 2** are taken from Ruales and Nair (1992). In that study, and in the 2002 follow-up, lysine was the limiting amino acid[1]. Quinoa's lysine is indeed limited with regard to pre-school nutrition, but valine is the *first* limiting amino acid in our quinoa protein because it scores lower relative to its pre-school and adolescent reference pattern, compared to lysine. Levels of essential isoleucine (Ile) are also borderline sufficient. Kañiwa protein is limiting in pre-school leucine and borderline for lysine and valine.

[1] An error in units reported for the FAO/WHO reference amino acid patterns by Rules and Nair (1992) led the authors to conclude, erroneously, that phenylalanine+tyrosine were the first limiting amino acids. I queried the corresponding author about this, but as of this time have not gotten a reply.

But hold on, protein lovers! The protein quality picture gets murkier when digestibility is factored into the mix. For this reason, the FAO/WHO EEA reference patterns in **Table 2** have largely been replaced by the "Protein Digestibility Corrected Amino Acid Score" (PDCAAS). The PDCAAS is the current standard for evaluating protein *quality* based on both the amino acid requirements of humans and, their ability to digest it (Millward, 2008). The PDCAAS method was adopted by the US Food and Drug Administration and FAO/WHO in 1993. The formula for calculating PDCAAS is:

Amino acid score x true fecal protein digestibility

where amino acid (AA) score is defined as:

$$\frac{mg\ of\ limiting\ AA\ in\ 1.0g\ of\ test\ protein}{mg\ of\ same\ AA\ in\ 1.0g\ of\ reference\ protein}$$

Thus, the PDCAAS evaluates food protein quality based on the amino acid requirement of humans, adjusted for its digestibility. How does quinoa measure up?

To answer this, we must calculate quinoa's PDCAAS and compare it with other foods. To this end, I present **Table 3**, which shows PDCAAS scores for wheat, rice, soybean flour, and soybean protein isolate, and casein. Some of this information is taken from Protein Quality of Cooked Pulses published jointly by PulseCanada and Agriculture and Agri-Foods Canada (AAFC, sort of the Canadian equivalent to USDA). From Table 1 in that document, the column labeled 'amino acid score', shows the limiting amino acid with the lowest ratio relative to the reference pattern for pre-school children, aged 2 to 5 years old. The adjacent column shows the True Protein Digestibility (TPD) relative to the standard of casein (milk protein). True protein digestibility is an experimental rating based on live animal feeding trials. For a protein to be 100% digestible, the amount of protein (as nitrogen) excreted after a meal must not exceed the nitrogen intake (Darragh, 2000). TPDs can vary depending on grain milling, protein isolation, and other factors. Thus, TPDs for rice and wheat in **Table 3** are for the flour products, because that is how they are typically consumed in the human diet. Two values are shown for soybeans, one for soy flour (uncommon in the diet) and the other for the protein isolate (more common in processed foods and in vegetarian fare). Casein, of course, is pure milk protein, and is considered the gold standard for protein quality.

First, let's calculate quinoa's amino acid score. From our quinoa AA profile in **Table 2**, valine was the first limiting AA with amino acid score of 3.9/4.1=0.95 according to formula [2] for the amino acid score on page 6. Values for TPD are typically published in nutrition research. In our case, the TPD for raw, unwashed quinoa grain is 91.7, determined in the Ruales and Nair (1992) study (the TPD for washed quinoa in the same study was 91.6, not significantly different). Quinoa's pre-school PDCAAS score is 0.95 x 91.7 or 87%. This is less than the PDCAAS score for soy protein isolate and casein, but quite a bit higher than that of wheat and rice. Wheat and rice are both lysine-limited, wheat more so than rice. Wheat protein is of generally low digestibility, so the low PDCAAS score for wheat flour reflects these aspects of protein quality. Combining quinoa or kañiwa with lysine-limited wheat, rice, or corn improves the quality of the combined proteins. The black magic art, however, is determining in what proportion each must be combined to provide a complete protein equal to casein, and the daily intake needed to achieve a sustainable level of human protein balance (Woolf *et al*. 2011). In other words, you cannot combine 50% grain 'x' with 50% quinoa in a recipe and reach a PCDAAS score of 100+%. The relative amount of limiting EAAs of each protein must be considered. Moreover, if you are a bodybuilder or training for a triathlon or some highly energy-intensive actively, this will affect the *quantity* of protein needed. There is very little information about how to achieve this balance scientifically (and practically) in terms of daily quinoa-based meal preparation. Did NASA ever figure this out? I wonder.

Table 3. PDCAAS values for quinoa compared to cereal and oil seed grains.

	Amino Acid Score*	True Protein Digestibility§ (%)	PDCAAS¥
Quinoa[1]	0.95	91.7	87
Wheat Flour[2]	0.47	92.3	43
Rice Flour[2]	0.54	92.0	50
Soy Flour[2]	0.92	83.5	77
Soy Protein Isolate[3]	0.99	97.3	96
Casein[2]	1.04	96.6	100

Sources:[1]Ruales and Nair(1992); [2]http://www.pulsecanada.com protein fact sheet; [3]Hughes et. al. (2011), mean of three determinations from lab B.
*Limiting amino acid per FAO/WHO/UNU pre-school ratio
§AOAC and/or FAO-compliant methods
¥PDCAAS=Amino Acid Score x % True Protein Digestibility

Another factor to bear in mind is that the reference amino acid patterns used to calculate the PDCAAS amino acid score have changed over time, and will no doubt change in the future. This is because research on human nutrition is a work in progress, improving and providing better and more precise estimates of the nutrients required for human health. Most of these changes are incremental, arising from fine-tuning the established basics. However, some EEA reference scores have changed significantly, lysine for example. The FAO/WHO pre-school reference pattern for lysine was 5.8 in 1985, compared to 5.2 in 2007. Thus, the PCDAAS for our quinoa protein under the 1985 reference pattern would be 81%. This is still better than wheat or rice flour, but poor relative to soy protein isolate or casein.

In fact, one of the most frustrating aspects of researching grain and vegetable nutrition is that some scientists still publish essential amino acid content referenced to pre-2007 FAO/WHO standards. A particular favorite seems to be the 1985 standard. This author encountered papers from as recent as 2010 published in "peer review" journals citing obsolete 1985 reference patterns! This is wrong and will lead to false conclusions. Moreover, the PDCAAS methodology has come under criticism for not taking account of anti-nutritional factors that are present in some raw unprocessed grains (legumes are especially guilty) and amino acids that may pass the terminal ileum (last point in the small intestine where nutrients are absorbed) but not excreted (possibly absorbed by bacteria) or otherwise used for protein synthesis. Nonetheless, PDCAAS is the currently accepted standard for evaluating protein quality by virtually all international entities involved with nutrition research.

The PDCAAS for kañiwa can't be calculated exactly because it's TPD has not been published (holler if you know a source). Because kañiwa is closely related to quinoa, we can estimate its PDCAAS based in the TPD for quinoa. In this regard, kañiwa would have a pre-school PDCAAS of 89 based on lysine as the first limiting amino acid.

II. Fat and Fiber Content

Fat content of quinoa and kañiwa grain is considerably higher than that of cereal grain, but low compared to soybean (**Table 1**). Much of the fat appears to be in the seed embryo (Prego *et al*. 1998). **Table 4** compares the fatty acid composition of quinoa and corn and soybean oil. There are two known essential fatty acids in the human diet: linolenic (omega-3, C18:3) and linoleic (omega-6, C18:2) acids. These are called essential fatty acids for the same reason as amino acids, i.e., they are essential for human metabolism and cannot be synthesized by the body or by other dietary fatty acids. Quinoa fat has a high content of unsaturated fatty acids, with linoleic acid and oleic acid (the same fatty acid in olive oil) accounting for more than 75% of fatty acids. Quinoa has a relatively small amount of linoleic (omega-3) fatty acid compared to soybeans. The lipid fraction also contains some 1.8% phospholipids (lecithin), substances which have medical value and are used as food additives and emulsifiers. The grain is reported to be rich in natural antioxidants like tocopherols (Ruales and Nair 1993), but these substances are not rare in nature.

Fiber content of quinoa grain is comparable to that of other cereals (**Table 1**). Fiber is a complex substance that varies greatly in chemical composition and properties. Unfortunately, there's no standard for reporting fiber content in the literature. Sometimes this makes for ambiguity when comparing fiber content from different studies, "apples to oranges", as they say. Here, we differentiate between crude insoluble fiber (cellulose and lignin, roughly equivalent to the scientist's acid detergent fiber or ADF) and dietary fiber, which includes soluble and insoluble components. Soluble fiber includes gums, pectins, and hemicelluloses. This distinction is not always explicit in the literature. Soluble and insoluble fibers have different functions in the human diet. Soluble fiber dissolves in and absorbs water to form a gel. This slows digestion and stomach emptying, which has beneficial effects on blood sugar levels and reduces the absorption of dietary cholesterol. Insoluble fiber does not dissolve in water. It adds bulk to the diet, acts as a laxative, and prevents constipation (think "Metamucil"). That said, quinoa dietary fiber content ranges from 12.9% (Schoenlechner *et al*. 2008) to 13.4% (Ruales and Nair 1994). The proportion of soluble fiber is 13.5% of total dietary fiber (Ranhorta *et al*. 1993). Compare this to 13.9% total and 14% soluble dietary fiber for rolled oats (Matz 1991), and 17.1% total and 9.1% soluble fiber for soybean (Kikuchi *et al*. 1971). The main carbohydrate component in quinoa is starch (Ando *et al*. 2002; Tang *et al*. 2002), which is lower than that of oats, barley, corn, and rice. Quinoa starch is high in amylopectin, which imparts some interesting physical properties but otherwise it doesn't make a difference in human nutrition.

Table 4. Comparison of quinoa, maize, and soybean fatty acids (% of lipid fraction).

	Quinoa[1]	Maize[2]	Soybean[2]
Myristic (C14:0)	0.1	trace	0.1
Palmitic (C16:0)	9.7	12.2	11.0
Palmitoleic (C16:1)	0.2	0.1	0.1
Stearic (C18:0)	0.6	2.2	4.0
Oleic (C18:1)	24.8	27.5	23.4
Linoleic (C18:2)	52.3	57.0	53.2
Linolenic (C18:3)	3.9	0.9	7.8
Arachidic (C20:0)	0.4	0.1	0.3
Saturated Fat, %	10.4	14.4	15.1
Unsaturated, %	81.6	85.6	84.8
Mono-unsaturated	25.0	27.6	23.5
Poly-unsaturated	56.6	58.0	61.3

Sources: [1]Ruales and Nair(1993); [2]Chow (2007).

III. Mineral-Vitamin Content

You may be wondering what the "ash" column in **Table 1** signifies. In fact, this is a common way to express the mineral content of food that has undergone chemical analysis. When a substance is burned, all its water, nitrogen, and carbon are driven off, leaving a residue of inorganic mineral matter called "ash". This is the same ash that you clean out of the fireplace and use as a soil amendment and mineral fertilizer (unlike in a fireplace, in analytical chemistry the ignition temperature, time, etc. are precisely controlled). Thus, a substance that makes a lot of ash is richer in mineral matter than a substance that makes a small amount ash. The human body doesn't absorb mineral matter in the form of ash, exactly. The minerals in food are released when they are digested and metabolized, processes that are analogous to high temperature combustion.

The ash content of pseudocereal seeds is shown in **Table 1**. Note the mineral content of pseudocereal seeds is higher than that of cereal grains, and on par with soybeans. Mineral content in quinoa is concentrated in the outer bran layer, similar to that of cereal grains. The mineral content of quinoa grain appears to be less than other pseudocereals like amaranth, but in fact its ash content varies from 2.1% to 10.7% (Guzmán-Moldonado and Paredes-López 1998). This suggests that growing conditions influence the mineral composition of quinoa. While quinoa is relatively rich in essential calcium, magnesium, iron, phosphorus, and potassium, the content of these minerals varies tremendously, as shown by the Ruales and Nair (1993) and Repo-Carrasco *et al*. (2003) data in **Table 5**. These minerals probably account for much of the observed variation in quinoa ash content. Manganese content in quinoa is similar to that in wheat and oats. Many of the so-called "trace minerals" have not been determined for pseudocereals. Information on the major, minor, and trace mineral content of cereal grains is available in general references like Kent's Technology of Cereals (1994; see Table 3.6), for comparison. Calcium and iron are the two most important minerals for human health. Quinoa is a better source of these two essential minerals compared to cereal grains, although one would have to consume, daily, something on the order of 1 kg quinoa to meet the minimum adult RDA for calcium (**Table 5**).

Table 5. Mineral content of psuedocereal grain seeds.

Mineral (mg/100 g grain)	Quinoa[1]	Quinoa[2]	Kañiwa[3]	Amaranth[4]	Chia[5]	RDA[§]
Calcium	110	87	110	175	806	800-1,000
Copper	1	1	n.r.	1.2	2.4	0.7
Iron	9	8	15	17.4	11.7	6-8
Magnesium	500	262	n.r.	244	346	250-350
Manganese	4	3	n.r.	4.6	n.r.	2-5[¥]
Phosphorus	360	535	375	453[4.1]	1020	580
Potassium	900	120	n.r.	290	n.r.	4,500-4,700
Zinc	0.8	3.6	n.r.	3.7	10	6.8-9.4

Sources:[1]Chauhan et al.(1992; [2]Ruales and Nair(1993);[3]Repo-Carrasco et al.(2003);[4]Becker et al.(1981) and [4.1]Repo-Carrasco for *A. caudatus*;[5]Capitani et al.(2012; seed meal).

[§]NAS Institute of Medicine Food and Nutrition Board Recommended Dietary Allowance for male and non-pregnant, non-lactating females. See: http://www.iom.edu/Reports/2006/Dietary-Reference-Intakes-Essential-Guide-Nutrient-Requirements.aspx

[¥]Daily intake for manganese has not been established by NAS; this range represents the estimated 'safe and adequate' dietary intake by the Food and Nutrition Board of the National Research Council.

Table 6. Vitamin content of pseudocereal grain seeds.

VItamin (mg/100 g grain)	Quinoa[1]	Quinoa[2]	Amaranth[2]	RDA[§]
Alpha-tocopherol	2.6	2.0-5.4	0.3-1.6[3]	12
Folic acid (µg/100 g)	78.1	No data	42-44	320µg
Niacin	No data	1.5	1.0-1.5	11-12
Thiamine (B_1)	0.4	0.3	0.10-0.14	0.9-1.0
Riboflavin (B_2)	0.2	0.4	0.19-0.32	0.9-1.1
Pyridoxine (B_6)	No data	No Data	0.6[4]	1.1-1.4
Vitamin A	20	15	No data	0.5-0.625
Vitamin C	16.4	3.0-4.9	3.0-7.1	60-75

Sources: [1]Ruales and Nair(1993); [2]Guzmán-Moldonado and Paredes-López(1998); [3]Lehmann et al.(1994);[4]Lebiedzińska and Szefer(2006).

[§]NAS Institute of Medicine Food and Nutrition Board Recommended Dietary Allowance for 19+ yr adult male and non-pregnant, non-lactating females. See: http://www.iom.edu/Reports/2006/Dietary-Reference-Intakes-Essential-Guide-Nutrient-Requirements.aspx

The content of vitamins in quinoa is shown in **Table 6**. Most vitamins in quinoa grain are presumed to be located in the germ (embryo). Quinoa's vitamin content is a mixed bag: high in riboflavin, folic acid, and alpha tocopherol (vitamin E) but low in niacin and thiamine compared to cereal grains. An adequate intake of the B-complex vitamins is critical for human health. Certain diseases, for example, pellagra, are associated with high dietary intake of low-niacin cereal grains like maize. Niacin content of maize averages 1.9 mg/100 g grain (Kent, 1994; see Table 14.7) and is like quinoa. To prevent niacin deficiency one would have to consume something in the order of 800 g, daily, of quinoa to meet the adult RDA for that vitamin. As such, quinoa would not be considered a balanced source of B vitamins in the diet.

IV. Non-nutritional factors

The seeds of pseudocereals contain a wide variety of chemicals that are not classified as nutrients. These may include, but are not limited to, polyphenols, phytic acid, saponins, and enzyme inhibitors. Phytic acid is perhaps the best known of these. Phytate is the salt of phytic acid, the main storage form of phosphorus in plant tissue. Thus, seeds with a high phosphorus content are likely high in phytate. The phosphorus in dietary phytate is unavailable to non-ruminants and humans because they lack the enzyme phytase needed to digest it (luckily, ruminants have microorganisms that can digest phytate). Quinoa contains between 0.1% and 1.0% phytic acid (Chauhan *et al*. 1992; Ruales and Nair 1993b). At the upper end, this is higher than that found in grains but on par with other oilseeds like soybean. Phytate is considered an "anti-nutritional" factor when present in excessive amounts in the diet because it reduces the bioavailability of the minerals calcium, magnesium, iron, and zinc, and the vitamin niacin. It is a particular concern for vegetarians who depend on plant sources for mineral nutrition. Phytate content can be reduced to some extent by cooking, or better yet, acid soaking, lactic acid fermentation, and sprouting. Whole grain quinoa also contains between 0.03 and 2.05% saponins (Rideout *et al*. 1991; Chauhan *et al*. 1992; Gee *et al*. 2006; Ruales and Nair 1993b; Cuadrado *et al*. 1995) which is somewhat higher than that found in cereal grains but similar to that in legumes like soybeans. The role of saponins in human nutrition is not clearly established. Saponins, if present in high enough amounts, impart a bitter taste to raw quinoa. Because of their unpleasant taste, many animals avoid eating saponin-rich plant food, providing a degree of natural protection against predation. Quinoa also contains a variety of polyphenols, including flavonoids. Polyphenols are natural substances that are widely found in the plant kingdom. Some of these have pharmaceutical effects, including anti-inflammatory, anti-bacterial, anti-viral, and anti-allergenic, and favorable lipid and platelet actions. However, I found no reports of such pharmaceutical effects from eating quinoa.

Summing Up

Is quinoa a "super" food, as advertised? Let's compare. The protein content of quinoa grain is somewhat *higher* than cereal grains, but much *lower* than legumes like soybeans. Quinoa protein contains all essential amino acids needed for human health, but so do cereal and oilseed legumes. Cereal grains are typically deficient in the essential amino acid lysine. Quinoa is *better supplied* with lysine but *lags behind soybeans* in this essential amino acid. Quinoa's *higher* level of methionine and cysteine complements the *lower* levels of these amino acids found in legumes. However, levels of methionine and cysteine in cereal grains are *as good as or better* than quinoa. We also observed that quinoa's pre-school amino acid pattern *can be limited* in essential amino acids, and its amino acid composition varies quite a bit depending on variety, possibly other factors like growing habitat. With a PDCAAS score of 87, quinoa protein is *superior* to cereal grains like wheat and rice, but *inferior* to soy protein isolate and casein. When combined with cereal grains, quinoa can *improve* the quality of dietary protein. However, the same effect can be achieved by combining cereal grains and legumes at considerably less cost. Quinoa is relatively low in fat compared to soybean and chia, so the contribution of its fatty acids to human energy or dietary balance is probably small. Quinoa contains useful quantities of essential linoleic acid but has lower amounts of linolenic (omega-3) fatty acid than soybean. Quinoa is low in saturated fatty acids (myristic, palmitic, and stearic).

The nutritional profile outlined above suggests that quinoa is more like an "average" food than a "super" food. In most respects quinoa is inferior to soybeans, and most certainly is not a substitute for meat. Quinoa and kañiwa are gluten-free products and can be substituted for wheat. Otherwise, these grains offer little in the way of unique protein, fatty acid, fiber, mineral, and vitamin nutrition that would be beneficial in the diet of North American or European consumers (soybeans are also gluten-free). On the other hand, quinoa is an important crop for some resource-limited smallholders in developing countries, where it may contribute significantly to the family diet and income. It also tolerates weather extremes better than corn and wheat. Adding quinoa to the diet can be viewed as a consumer choice supporting the livelihood of small farmers in developing countries, or encouraging export at the expense of local consumption, however you look at it. In the event, I see little reason to reach for quinoa. But if you do, *bon appetit*!

General References

Abugoch James, L.E. 2009. Chapter 1 Quinoa (Chenopodium quinoa Willd.): Composition, Chemistry, Nutritional, and Functional Properties. p. 1–31. *In* Steve L. Taylor (ed.), Advances in Food and Nutrition Research. Academic Press.

Arendt, E., and F. Dal Bello. 2008. Gluten-free cereal products and beverages. 1st ed. Academic Press, Amsterdam.

Belton, P.S., and J.R.N. (John R.N.) Taylor. 2002. Pseudocereals and less common cereals : grain properties and utilization potential. Springer, Berlin.

Dhillon, B.S. 2006. Plant genetic resources : foodgrain crops. Narosa, New Delhi.

Jellen, E.N., B.A. Kolano. 2011. Chenopodium. p. 35–61. *In* Kole, C. (ed.), Wild Crop Relatives: Genomic and Breeding Resources. Legume Crops and Forages. Springer Berlin Heidelberg.

Johnson, D.L. and S.M. Ward. 1993. Quinoa. p. 219-222. *In* J. Janick, and J.E. Simon (eds.), New crops. Wiley, New York.

Paredes-Lopez, O. 1994. Amaranth : biology, chemistry, and technology. CRC Press, Boca Raton.

Popenoe, H., King, S.R., Leon, J., and L.S. Kalinowski. 1989. 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.

Schaafsma, G. 2000. The Protein Digestibility–Corrected Amino Acid Score. J. Nutr. 130(7): 1865S –1867S.

Cited References

Ando, H., Y.C. Chen, H. Tang, M. Shimizu, K. Watanabe, and T. Mitsunaga. 2002. Food Components in Fractions of Quinoa Seed. Food Science and Technology Research 8(1): 80–84.

Becker, R., E.L. Wheeler, K. Lorenz, A.E. Stafford, O.K. Grosjean, A.A. Betschart, and R.M. Saunders. 1981. A Compositional Study of Amaranth Grain. Journal of Food Science 46(4): 1175–1180.

Taylor , John R.N. and M.L. Parker. (2002) Quinoa. p. 93-122. *In* P.S. Belton and John R.N. Taylor (eds), Pseudocereals and less common cereals : grain properties and utilization potential. Springer, Berlin.

Capitani, M.I., V. Spotorno, S.M. Nolasco, and M.C. Tomás. 2012. Physicochemical and functional characterization of by-products from chia (*Salvia hispanica* L.) seeds of Argentina. Food Science and Technology 45(1): 94–102.

Chauhan, G.S., N. a. M. Eskin, and R. Tkachuk. 1992. Nutrients and antinutrients in quinoa seed. Cereal Chemistry 69(1): 85–88.

Chow, C.K. 2007. Fatty Acids in Foods and their Health Implications,Third Edition. CRC Press, Boca Raton.

Cuadrado, C., G. Ayet, C. Burbano, M. Muzquiz, L. Camacho, E. Cavieres, M. Lovon, A. Osagie, and K.R. Price. 1995. Occurrence of saponins and sapogenols in Andean crops. Journal of the Science of Food and Agriculture 67(2): 169–172.

Darragh, A.J., and S.M. Hodgkinson. 2000. Quantifying the Digestibility of Dietary Protein. J. Nutr. 130(7): 1850S–1856S.

Food and Agriculture Organization.. Quinoa: An ancient crop to contribute to world food security. Available at http://www.rlc.fao.org/en/publications/ quinoa-ancient-crop-food-security/ (verified 14 March 2013).

Gee, J.M., K.R. Price, C.L. Ridout, G.M. Wortley, R.F. Hurrell, and I.T. Johnson. 1993. Saponins of quinoa (*Chenopodium quinoa*): Effects of processing on their abundance in quinoa products and their biological effects on intestinal mucosal tissue. Journal of the Science of Food and Agriculture 63 (2): 201–209.

Gibbons, E. 1962. Stalking the wild asparagus. D. McKay Co., New York.

Guzmán-Maldonado, S.H. and O. Paredes-López. 1998. Functional Products of Plants Indigenous to Latin America: Amaranth, Quinoa, Common Beans and Botanicals. p.293-328. *In* G. Mazza (ed), Functional foods : biochemical & processing aspects. Technomic Pub., Lancaster, PA.

Hughes, G.J., D.J. Ryan, R. Mukherjea, and C.S. Schasteen. 2011. Protein Digestibility-Corrected Amino Acid Scores (PDCAAS) for Soy Protein Isolates and Concentrate: Criteria for Evaluation. J. Agric. Food Chem. 59(23): 12707–12712.

Joshi V, Gautam P.L., Mal B., Sharma G.D., and S. Kochhar (2002) Conservation and use of underutilized crops: an Indian perspective. p 359–369. *In* Engels JMM, Rao VR, Brown AHD, Jackson MT (eds), Managing plant genetic diversity. IPGRI, Rome.

Kent, N.L., and A.D. Evers. 1994. Technology of cereals : an introduction for students of food science and agriculture. 4th ed. Pergamon,, Oxford, England.

Kikuchi T., Ishii, S., Fukushima, D. and Yokotsuka, T. Food-chemical studies on soybean polysaccharides. Part I. Chemical and physical properties of soybean cell wall polysaccharides and their changes during cooking. Nippon Nogeikagaku Kaishi (Agri. Biol. Chem.) 45(5): 228–234.

Lásztity, R., M. Hidvégi, and I.A. for C. Chemistry. 1985. Amino Acid Composition and Biological Value of Cereal Proteins: Proceedings of the International Association for Cereal Chemistry

Symposium on Amino Acid Composition and Biological Value of Cereal Proteins, Budapest, Hungary, May 31-June 1, 1983, with Supplemental Invited Contributions. Springer.

Lebiedzińska, A., and P. Szefer. 2006. Vitamins B in grain and cereal–grain food, soy-products and seeds. Food Chemistry 95(1): 116–122.

Lehmann, J.W., D.H. Putnam, and A.A. Qureshi. 1994. Vitamin E isomers in grain amaranths (*Amaranthus* spp.). Lipids 29(3): 177–181.

Mahoney, A.W., J.G. Lopez, and D.G. Hendricks. 1975. Evaluation of the protein quality of quinoa. J. Agric. Food Chem. 23(2): 190–193.

Matz, S.A. 1991. The chemistry and technology of cereals as food and feed. 2nd ed. Pan-Tech International; Van Nostrand Reinhold/AVI , McAllen, Tex.

Millward, D.J., D.K. Layman, D. Tomé, and G. Schaafsma. 2008. Protein quality assessment: impact of expanding understanding of protein and amino acid needs for optimal health. Am. J. Clin. Nutr. 87 (5): 1576S–1581S.

National Agricultural Library. United States Department of Agriculture. Available at: http://www.nal.usda.gov/.

Partap T, Joshi B.D., and N.W. Galwey.1998. Chenopods, *Chenopodium* spp. *In* Promoting the conservation and use of underutilized and neglected crops, vol 22. IPGCPR/IPGRI,Gatersleben/Rome.

Písaríková, B., S. Krácmar, and I. Herzig. 2005. Amino acid contents and biological value of protein in various amaranth species. Czech J. Anim. Sci. 50: 169–174.

Prego, I., S. Maldonado, and M. Otegui. 1998. Seed structure and localization of reserves in *Chenopodium quinoa*. Ann Bot 82(4): 481–488.

Ranhotra, G. J., Gelroth, B. Glaser, K. Lorenz, and D. Johnson. 1993. Composition and protein nutritional quality of quinoa. Cereal chemistry. 70 (3): 303–305.

Repo-Carrasco, R., C. Espinoza, and S.E. Jacobsen. 2003. Nutritional value and use of the Andean crops quinoa (*Chenopodium quinoa*) and kañiwa (*Chenopodium pallidicaule*). Food Reviews International 19(1-2): 179–189.

Ridout, C.L., K.R. Price, M.S. Dupont, M.L. Parker, and G.R. Fenwick. 1991. Quinoa saponins—analysis and preliminary investigations into the effects of reduction by processing. Journal of the Science of Food and Agriculture 54(2): 165–176.

Risi J.C. and N.W. Galway. 1989. Chenopodium grains of the Andes: a crop for temperate latitudes. p.222-234. *In* Day, P.R., N. Haq, and G.E. Wickens (eds), New crops for food and industry. Chapman and Hall, London.

Ruales, J., and B.M. Nair. 1992. Nutritional quality of the protein in quinoa (*Chenopodium quinoa*, Willd) seeds. Plant Food Hum. Nutr. 42(1): 1–11.

Ruales, J., and B.M. Nair. 1993a. Content of fat, vitamins and minerals in quinoa (*Chenopodium quinoa*, Willd) seeds. Food Chemistry 48(2): 131–136.

Ruales, J., and B.M. Nair. 1993b. Saponins, phytic acid, tannins and protease inhibitors in quinoa (*Chenopodium quinoa*, Willd) seeds. Food Chemistry 48(2): 137–143.

Ruales, J., and B.M. Nair. 1994. Properties of starch and dietary fibre in raw and processed quinoa (*Chenopodium quinoa*, Willd) seeds. Plant Food Hum. Nutr. 45(3): 223–246.

Ruales, J., Y. de Grijalva, P. Lopez-Jaramillo, and B.M. Nair. 2002. 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 & Nutrition 53(2): 143–154.

Scarpati de Briceño, Z. 1979. Aislamiento y caracterizacion de almidón de quinua (*Chenopodium quinoa*) y canihua (*Chenopodium pallidicaule*). Universidad Nacional Agraria, Lima, Perú. Congreso Nacional en Ciencia y Tecnologia de Alimentos, 30.

Tang, H., K. Watanabe, and T. Mitsunaga. 2002. Characterization of storage starches from quinoa, barley and adzuki seeds. Carbohydrate Polymers 49 (1): 13–22.

Tapia, M. 1979. La quinua y la kañiwa: cultivos andinos. Serie Libros y Materiales Educativos 49. Bogota: llCA, CUD.

Van Etten, C.H., Miller, R.W., Wolff, I.A., Jones, Q., 1963. Amino acid composition of seeds from 200 angiosperm plants. J. Agric. Food Chem. 11, 399–410.

Weber, C.W., H.S. Gentry, E.A. Kohlhepp, and P.R. McCrohan. 1991. The nutritional and chemical evaluation of Chia seeds. Ecology of Food and Nutrition 26(2): 119–125.

White, P.L., Alvistur, E., Dias, C., Vinas, E., White, H.S., Collazos, C., 1955. Nutrient content and protein quality of quinoa and canihua, edible seed products of the Andes mountains. J. Agr. Food Chem. 3, 531–534.

Wilson, H.D. 1990. Quinua and Relatives (*Chenopodium* sect.*Chenopodium* subsect.*Celluloid*). Econ Bot 44(3): 92–110.

Woolf, P.J., L.L. Fu, and A. Basu. 2011. vProtein: Identifying Optimal Amino Acid Complements from Plant-Based Foods. PLoS One 6(4)Available at http://www.ncbi.nlm.nih.gov/pmc/articles/ PMC3081312/ (verified 26 February 2013).

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