

PSEUDOCEREALS AND THE POSSIBILITIES OF THEIR APPLICATION IN FOOD TECHNOLOGY

GENERAL CHARACTERISTICS OF QUINOA

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Abstract: Quinoa is, apart from amaranth, the second so-called alternative plant, classified into pseudocereals. Its fruits (seeds) have already found a considerable application in food technology and gastronomy. The dominant chemical compounds of quinoa seeds are saccharides and among them the starch. What focuses attention is the relatively high total protein content (even 22%) and in it, a considerable share of exogenous amino-acids, which are deficit in traditional crops (e.g. Lysine). The greatest potential possibilities of quinoa seeds application, or products obtained from them (e.g. flour) are in bakery and confectionary technology.

Key words: pseudocereals, quinoa, general characteristics, chemical composition, nutritional value, technological application

Introduction

Quinoa (*Chenopodium quinoa* Willd) [1], also referred to as 'Inca wheat', 'Peruvian rice' and even 'the mother of crops' [2] is the second, apart from amaranth, most significant pseudocereal, which found great recognition among food technologists [3–11]. It is one of the oldest plants cultivated in the world and its origins date back to 3 thousand years BC.

Quinoa derives from mountainous areas of South America, where it was planted on vast territories from Columbia, through Peru, to Chile [2]. Quinoa seeds constituted the basic component of everyday meals, fulfilling similar functions as today's crops. The great value of quinoa was the possibility of its cultivation in mountains, even up to 4300 m above sea level, i.e. at altitudes where the cultivation of other species was practically impossible or very restricted [1].

The domination of quinoa in South America ended together with the arrival of the Spaniards. The implemented large scale wheat, barley and even rice cultivation replaced either quinoa as well as equally popular amaranth.

Renewed interest in quinoa, similarly as in amaranth, dates back to the second part of the 20th century and increased rapidly [1] when high agricultural potential of plants

started being explored. A very favourable chemical composition of seeds was also significant and especially the protein contained in it with a very favourable, from the nutritious point of view, amino-acid content.

Quinoa has been classified for over two hundred years and is included into [1]:

- order – *Centrospermae*,
- family – *Chenopodiaceae* and
- species – quinoa Willd (*Chenopodium quinoa*).

The whole *Chenopodiaceae* family covers over 100 varied species and these are not only green plants or bushes, but even trees, which most frequently occur as desert and/or steppic flora, sometimes growing by the seashore. These are the typical halophytes, xerophytes or succulents [9, 14], which explicitly indicates the difficult conditions in which they can exist and develop.

Among the *Chenopodiaceae* family, there can be found plants which are highly valued, possess established economic, industrial or feed significance (e.g. beets: sugar, fodder or red, sometimes spinach) as well as cumbersome weeds (e.g. accompanying root crops) [1, 2].

Quinoa is a green and annual plant. About 300 of its arable forms are known [1, 2], which vary between themselves in color of the plant and seeds, not mentioning the inflorescence. The very plant can disclose various shades of

green, it can also be red and even violet, which is presented in Figure 1.



Fig. 1: Various colors of quinoa. 1 – the variety with light green coloring of stems and leaves as well as light coloring of inflorescence, 2 – the variety with dark green coloring of stems and leaves as well as violet coloring of inflorescence [12].

On the other hand, in Figure 2, there are the seeds of three varieties of quinoa with different coloring – white, black and red.

The coloring of a plant greatly depends on the species features, but it can also be the consequence of environmental conditions and foremostly humidity [1, 2]. Similarly, the plants' height can be diversified and vary between 20 cm and 2 m, which also highly depends on soil moisture.

A quinoa stem has a cylindrical shape, which in the course of a plant's maturation, becomes empty, especially in the lower parts just above the ground.

The number of shoots can be different, which is also the variety feature, but it can also depend on the conditions of growth, including the soil and climate ones.



Fig. 2: White, black and red seeds of three quinoa species [4].

Quinoa has a taproot that reaches even up to 60 cm and has numerous lateral roots [1, 2].

Quinoa leaves have various sizes and shapes, depending on their location. Usually, the lower leaves, situated on the lowest level, are bigger and coarsely toothed, however, the ones located higher are more delicate and lance-shaped

[9]. The flowers are usually small and inconspicuous, wind-pollinated, usually monoecious or female. They line up in loose, biradial apices (type of inflorescence).

The fruit (seed) of quinoa is the so-called nut (see Fig. 3). In terms of size, they are relatively equal and have the diameter from 1.8 to 2.6 mm and thickness of about 1 mm [1, 2]. It can be assumed that it is a flattened ball with the shape similar to a disc. The mass of 1000 quinoa seeds is between about 2 to about 5 g [1], whereas e.g. the mass of 1000 amaranth seeds is only 0.6 – 1.1 g [13, 14].

Greater sizes and higher mass of 1000 quinoa seeds is a favourable feature from technological point of view, especially in relation to such technological operations as milling grains into flour, porridge production (obtaining porridge similar to wheat semolina) or flakes production. Greater sizes of a seed and by this higher weight of 1000 seeds mass, means a lesser percentage share of husk (fruit-seed cover) in the mass unit and through this greater efficiency of flakes and porridge or presumably other obtained products.

The renewed interest in quinoa in Poland dates back to the 80's of the previous century [2]. It was to a large extent caused by the research on the possibility of this plant's cultivation in our climate conditions conducted by the SGGW Department of Plant Physiology in Warsaw and later continued in other centers [2].



Fig. 3: Quinoa seeds [12].

Chemical composition of quinoa seeds

In Table 1, there are presented, after Brummer and Morgenstern [15] as well as after Flaming and Galway [16], the average contents of the most significant chemical components present in quinoa seeds.

Quinoa seeds, as compared to wheat, rye, corn or rice seeds, have a more favourable chemical composition, from nutritious perspective [1, 2, 14] (see Table 2).

The chemical composition of quinoa seeds is especially interesting due to a relatively high total protein content, which can reach even up to 22% [1, 2, 5, 15]. Similarly as

Table 1: The average content of the most significant chemical components in quinoa seeds [15, 17].

Chemical component	Content, [%]
Total protein	10 – 22
Total saccharides	53 – 67
Fats	4 – 10
Raw fiber	1 – 5
Ash (mineral compounds)	2 – 6

in case of grains of all traditional crops so with the seeds of pseudocereals [e.g. amaranth], the total protein content depends on numerous factors, including the variety characteristics, soil and climate conditions and content of mineral components in soil (among others, from fertilization) [2, 5, 15].

Table 2: Comparison of the average chemical composition of quinoa seeds and the grains of particular crops [1, 2, 5, 15].

Chemical compound	Quinoa	Wheat	Rye	Corn	Rice
	Average content, [% sm]				
Total saccharides	69,0	68,0	71,0	67,7	75,3●
Total protein	16,5●	12,0	9,0	10,5	8,5
Total fats	6,5●	1,9	1,9	4,5	2,3
Raw fiber	3,8●	1,8	1,9	2,3	0,9
Ash (mineral compounds)	3,8●	1,9	1,7	1,4	1,4

* the highest contents were marked ●.

When comparing the average contents of particular chemical components in quinoa seeds and the grains of selected crops (wheat, rye, corn and rice), it is clear that quinoa seeds dominate in terms of total protein content, fat, raw fibre and mineral salts and are weaker or the same regarding the general content of saccharides and foremostly starch.

High content of protein with a relatively lower amount of saccharides is very favourable from the nutritional point of view. Nutritional value of quinoa seeds does not only result from a high total protein content, but also from their very favourable amino-acid content and especially lysine, i.e. the so-called ‘limiting amino acid’ in grains and especially in wheat [16].

In quinoa seeds, saccharides exist in the most abundant quantities [53 – 67%) and the starch dominates among them. It is the feature of every grain plant and the pseudocereals as well. Either the content of starch as well as its granules (18 – 20µm) cause that it can be the potential and very valuable raw material for numerous branches of industry, such as food concentrates, pharmacy or cosmetology by fulfilling a very important role of the so-called carrier [2, 14]. The size of starch granules of quinoa seeds is by far smaller than grain starches e.g.: wheat (45 – 55 µm) or rye (50 – 75µm) [16]. However, simultaneously it should be stated that they are much bigger than the granules of e.g. amaranth starch (1 – 3 µm) [3].

In quinoa seeds, the fat content varies and it is confirmed by the latest research conducted in the Institute of Food Technology and Gastronomy of PWSiIP in Łomża [3]. It was detected that the unsaturated amino-acids content (mono- and polyunsaturated) in quinoa seeds is at the level of about 90% and the dominant acids are: linoleic and linolenic. This kind of fat composition causes that the consumption of quinoa seeds or the products obtained from it reduces cholesterol concentration, supports cardiovascular system and reduces the risk of atherosclerosis. Both of the enumerated acids also foster body fat burning.

From the saturated fatty acids, the ones that occur in greatest quantities are: palmitic (long-chain fatty acid C_{16:0}, main saturated acid of most plant oils) and stearic (also long-chain, C_{18:0}, existing in ruminants fat reserves and cocoa fat) [18].

The composition of mineral substances (micro- and macroelements) in quinoa seeds is different from the composition in traditional crops mainly due to the presence of potassium, calcium, magnesium and phosphorus [17]. The content of mineral compounds such as potassium, calcium, magnesium and phosphorus in quinoa seeds is two- or three times higher than in traditional crops [17] (see Table 2). Lower sodium content (even 25 – 60 times!) than in the corn, wheat or rye grains is also valuable [1, 2].

As it was mentioned earlier, a positive feature of quinoa seeds is a relatively high content of total protein and especially its amino-acid composition. Table 3 presents, after Alkamper [5], the contents of the selected amino-acids included in quinoa seeds protein and their comparison with the contents in grains/seeds of particular crops and other functional plants.

Table 3: Comparison of selected amino-acids contents (calculated into % of protein) in quinoa, amaranth and soya seeds as well as grains of wheat and rice [3, 14].

Amino-acid:	Quinoa	Amaranth	Wheat	Rice	Soya
Arginin	7,8	9,1●	4,3	7,2	6,9
Leucine	7,1	5,6	7,9	22,0●	7,7
Lysine	6,8●	4,6	2,7	2,0	6,4
Valine	4,4	6,5●	5,4	5,0	4,8
Threonine	4,7	4,2	5,5●	3,7	4,0
Isoleucine	6,3●	3,1	4,5	4,0	4,7
Phenylalanine	3,8	3,1	3,6	5,0●	4,8
Tyrosine	4,1	2,7	3,6	5,5●	3,3
Histidine	2,3	2,5	2,6●	1,5	2,6●
Cystine	2,0	2,1	2,9●	1,4	1,5
Methionine	2,3	0,8	1,0	3,1●	1,5
Tryptophan	1,3	1,4●	0,6	0,8	1,3

*dominant quantities in bold and marked ●.

Ceglińska and Cacak-Pietrzak [2] rightly claim that quinoa seeds protein has a better balanced amino-acid content in relation to e.g. wheat grains. As compared to the chicken egg white, treated as a model, quinoa seeds protein contains:

- 67% phenylalanine,

- 123% isoleucine,
- 94% leucine,
- 109% lysine,
- 66% methionine,
- 93% threonine as well as
- 90% tryptophan and valine each.

From the nutritional point of view, it is significant and beneficial that quinoa seeds do not contain gluten proteins, i.e. gliadin and glutenin and thus they can be applied in the diet of people suffering from coeliac disease [2].

Conclusions

1. Quinoa is included into the so-called alternative plants, i.e. those that due to their technological values, chemical composition and both of the features jointly, can substitute plants (raw materials) traditionally applied in food processing. It is also classified into the group of pseudocereals, i.e. plants that are not crops (grasses), but also due to its chemical composition and mainly the dominating starch quantity, it can substitute traditional crops.
2. Quinoa seeds, apart from the dominating amount of saccharides (especially starch), constitute a rich source of protein (even up to 22%) and 2-3 times higher, as compared to bread crops, amino-acid composition. It pertains mostly to lysine, which in grains of wheat, rye and triticale is the so-called limiting amino-acid.

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