South American traditional pseudocereals

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Summary

Eight of 30 plant species, which currently are of greatest economical importance worldwide, have been domesticated by the native cultures of South America. One of them is maize - the most used cereal species today. The two pseudocereal species amaranth and quinoa, which were very important to these old cultures as well, have interestingly never reached significant interest outside South America, although they have a very high nutritional value. The reasons therefore are manifold and range from religious aspects to agricultural difficulties.

Only with the modern science of the 1970s has the potential of these two plants been recognised again. Since that time, research is being undertaken worldwide to implement them within the nutrition of the northern countries. The food technology challenges to achieve this aim are the following:

- Low knowledge about the structure of the seeds, which are morphologically different to cereal kernels.
- Low knowledge about the technical functional and bio-functional properties of the chemical components.
- No dough forming properties
- New different taste

On the other side, the advantages, which are given by an increased use of amaranth and quinoa, are impressive:

- Higher protein content and better protein quality compared to cereal protein.
- Higher content of vitamins, in particular folic acid.
- The content of minerals (ash) is approximately twice as high as in cereals (e.g. wheat 1.8 %). Particularly rich are the contents of calcium, magnesium, iron, potassium and zinc.
- Low content of anti-nutritive components.
- Unique functional properties of the very small starch granules.

Introduction

Historical background

Amaranth and quinoa are among the oldest cultivated plant species. The domestication of these plants was done by the people of South America a few thousand years ago. Besides maize and potatoes, they were staple crops in the Pre-Colombian cultures in Latin-America. After the Spanish conquest, amaranth and quinoa consumption and cultivation were suppressed, for among other reasons due to different religious beliefs. Thereafter, growing of both plants was only continued on a small scale. In the modern science of the 1970s was it recognised that both grains show good nutritional properties. Since that time, interest in these grains has risen again. Research aims first focussed on agricultural aspects, later also on food technology and processing aspects. However, up until today amaranth and quinoa cultivation is still low. Amaranth is not even listed in the FAO statistics on production data. An appreciable commercial cultivation of amaranth and quinoa for human nutrition does, however take place. Besides Latin American countries, they are produced in the USA, China and Europe.

Botanical Classification

According to several phylogenetic classifications the *Amaranthus* and *Chenopodium* genus belong together to *Caryphyllales* and are thus dicotyledonae, unlike cereals, which are monocotyledonae. But as the starchy seeds can be used similarly to cereals, amaranth and quinoa are called pseudocereals. Compared to the true cereals, the seeds of these grains show different morphology. While in cereals the embryo is located within the starchy endosperm, in pseudocereals the embryo surrounds in the form of a ring the starchy tissue, which in this case is the perisperm. Additionally, the seeds of amaranth and quinoa are much smaller compared to cereals. These morphological differences have great effects on the processing properties of pseudocereals. Also, quinoa contains bitter tasting saponins, which are mainly found in the outer layer of the seeds. Thus the seed coat has to be removed before further processing, which is usually carried out by dry abrasive milling.

Nutritional Properties

Amaranth and quinoa are characterised by an excellent nutritional composition. Some components exceed the contents of those in cereal species.

Protein

The protein content of pseudocereals is higher than in cereals species. But importantly is the fact that the quality of the protein is much better. In particular, lysine, the limiting amino acid in cereals, can be found in high amounts. The high content of arginine and histidine, both essential for infants and children, make amaranth and quinoa interesting for the nutrition of children.

Protein quality not only depends on the amino acid composition, but also on the bioavailability or digestibility. Protein digestibility, available lysine, net protein utilisation (NPU) or protein efficiency ratio (PER) are widely used as indicators for the nutritional quality of proteins. In this respect, the values for pseudocereal proteins are definitively higher when compared to cereals and are close to those of casein.

As only a very low amount of prolamins, which differ from those found in wheat, is present in pseudocereals, they are suitable for diets of persons suffering from coeliac disease.

Lipids

The fat content of pseudocereals is also higher compared to most cereal species. Additionally, the fat is characterised by a high content of unsaturated fatty acids (very high content of linolenic acid). Amaranth contains a high amount of squalene, a highly unsaturated open-chain triterpene, which is usually only found in liver of deep sea fish and other marine species. Squalenes are widely used in pharmaceutical and cosmetic applications.

Carbohydrates

Mono- and disaccharides are only found in small amounts in pseudocereals.

With a diameter of only 1-3 µm amaranth and quinoa starch granules are among the smallest known. Typical is also their low amylose content of max. 10%.

The dietary fibre content of amaranth and quinoa lies in the range of cereals but shows great variation within different species.

Minerals

The content of minerals (ash) in amaranth and quinoa is about twice as high as in cereals. Particularly high are the amounts of calcium, magnesium, iron, potassium and zinc. The calcium/phosphorus ratio (Ca:P), which should be around 1 to 1.5, shows a good value of 1 to 1.9-2.7.

Vitamins

Overall, amaranth does not constitute an important source of vitamins. According to Souci et al. (2000) [1], the content of thiamine in amaranth is higher than in wheat, in contrast with previous investigations of Bressani (1994) [2]. Both amaranth and quinoa are good sources of riboflavin, Vitamin C and in particular of folic acid and Vitamin E [3, 4]. Folic acid has been found in amounts of 78.1 µg/100 g in quinoa and

102µg/1 00 g in amaranth, 2.5 times higher than in wheat (40µg/100 g) (own data, not published).

Food processing aspects

The possible utilisation of pseudocereals is summarised in Tabl 1. From the processing point of view, for amaranth and quinoa many processes require specific adaptations due to their different morphology and functional properties.

Amaranth seeds are usually used as wholegrain, whereas quinoa seeds need to be dehulled, in order to remove most of the bitter tasting saponins.

The Pre-Colombian cultures used amaranth and quinoa mainly in the cooked form (whole kernels). Investigations of Reiselhuber (2000) [5] showed that the cooking properties of amaranth, in particular, differed greatly from cereals. After termination of the cooking process the texture of the cooked seeds still changes, the cooked seeds soften further during the cooling period. In Pre-Colombian times popping was also applied and thus presents one of the oldest processes applied for amaranth. Besides maize, only amaranth can be popped directly without increased pressure.

A typical application of starch-rich seeds is the production of bread, pasta and bakery goods. But as already mentioned, amaranth and quinoa do not possess any dough-forming proteins (gluten). Thus, it is not possible to produce bread or bakery goods from these pseudocereals alone. They can only be used in blends with cereals, mainly wheat, in amounts of 20-40%. Pasta, on the other hand, can be produced from 100% amaranth or quinoa. Investigations in this respect have been undertaken by several researchers, also by the authors of this article. The missing gluten within the protein fraction of amaranth and quinoa can also be seen as an advantage. It allows the production of gluten-free products, which can be incorporated in diets for coeliac disease. Especially, as the incidence of coeliac disease is increasing world-wide.

The use of amaranth and quinoa as ingredients in convenience products like breakfast cereals, snack products, muesli and granola bars is another possibility. Food processes like extrusion cooking or drum drying can be applied. For extrusion cooking the high fat content of amaranth and quinoa has to be considered. For most extruder types, they have to be blended with low-fat raw materials in order to obtain good expansion. The intermediate extrusion cooking products can be used to produce palatable snacks, muesli, granola products and were even incorporated into beer production by the authors of this paper.

Concluding Remarks

In order to make these plants more known and increase their use within human nutrition, it is necessary to develop palatable food products, which meet the taste of the Western diet consumer. To achieve this aim, intensive research in this respect is still necessary.

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Table 1: Possible uses of amaranth and quinoa

Method	Products		Use
	Amaranth	Quinoa	
cooking	cooked seeds		direct consumption
popping	popped seeds		direct consumption or mixing with other foods
milling milling and sifting	whole flour flour fractions protein-enriched flours		e.g. as main or secondary ingredient in baked goods, pasta etc.
cooking and flaking for drying and roasting	flakes		e.g. direct consumption or mixing with other foods
drum drying	pre-gelatinized flours or flour fractions		e.g. as a binding or thickening agent
cooking extrusion	broken-up, expanded or non-expanded products		e.g. direct consumption as a snack food or breakfast cereal or as component in convenience products
cooking extrusion and milling	pre-gelatinized flours or flour fractions		e.g. as binding or thickening agent or as raw material for the production of beverages
cooking extrusion and flaking	flakes		e.g. direct consumption or mixing with other foods
germination (malting)	germinated seeds (malt)		e.g. direct consumption
protein isolation	protein concentrates		e.g. infant foods
starch isolation	amaranth starch	quinoa starch	like other isolated starches