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Effect of puffing and cooking on phytochemical profile of psoudo-cereals: A review

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Abstract
Pseudo-cereals are seeds of non-grass and wild plants which are used in the same manner as cereals. They are enriched with essential amino acids and their protein content is either similar or greater than that of cereals. They contain adequate amounts of dietary fibres that help improve lipid metabolism. Interest in the research of pseudo-cereals is growing among the research community due to its extraordinary nutritional and phytochemical profile and its potential in the development of gluten-free products. Pseudo-cereals have a higher concentration of anti-nutritional factors, which is one of their drawbacks. Processing food grains meets the requirement of removing anti-nutrients. However, food preparation and production technologies that involve malting, fermentation, puffing, extrusion cooking, etc. can affect the nutritional, bioactive chemicals, and functional properties of Pseudo-cereals. The changes in nutritional, bioactive chemicals and functional properties of Pseudo-cereals during various post-harvest processes and techniques are discussed in this study.

Keywords: Anti-nutrients, buckwheat, celiac disease, gluten-free, hypoglycemic activity, Maillard reaction

Introduction
In the near future, as the human population is expected to increase, we will need to adopt an interdisciplinary strategy to battle the food problem by not only enhancing the quality of the food available through enrichment or bio fortification but also by finding additional possible plants that are already enriched with essential micronutrients, which is an important part of food security. More than 50% of the world's population is supported by this small number of crops. Despite being high in starch and used as a source of energy, they lack several crucial micronutrients, which have caused some to experience covert hunger. Nearly 2 billion individuals worldwide suffer from this micronutrient shortage, which has led to grave health issues (FAO, 2013) [8] The nutritional content of gluten-free items made from cereal needs to be improved, according to the findings of several recent studies. When gluten-containing grains (barley, wheat, rye, and possibly oats) are consumed by those who are genetically predisposed to developing celiac disease, it causes an autoimmune enteropathy. It has been proposed that elements like the standard of gluten-free items on the market and food preferences may serve as significant drivers of the under nutrition of celiac patients. Additionally, a nutritional imbalance in the proportion of energy consumed from carbs in celiac patients following a gluten-free diet may have an impact on dietary intakes of vitamin-B, iron, and fibre because grain foods make up a significant portion of these nutrients' daily intakes (Catassi & Fasano, 2008) [5].

1. What are Psoudo-cereals?
As compared to cereals, pseudo-cereal grains are higher in lipids and proteins and lower in starch. The reason for this is that pseudo-cereal grains have more embryo and less endosperm (the organ that stores starch), whereas cereal grains have more endosperm and less embryo. Essential amino acids, including methionine, lysine, and cysteine are abundant in pseudo-cereals. Proteins are preserved as prolamins in cereals, whereas they are present as globulins and albumins in pseudo-cereals. Cereals' high prolamin content is to blame for illnesses like celiac disease. Pseudo-cereals are therefore being sought after as a cereal substitute for gluten-free diets. The nutritional content of gluten-free items made from cereal needs to be improved, according to the findings of several recent studies. There are several gluten-free pseudo-cereals available, including amaranth, quinoa, and buckwheat, all of which have excellent nutritional profiles. Therefore, a growing body of research is emphasising their usage in the creation of

high-quality, nutritious gluten-free foods like bread and pasta. However, there is still very little commercialization of these goods. An important step forward in ensuring that people with celiac disease receive a proper intake of nutrients would be the development of tasty gluten-free pseudo-cereal products (Pirzadah and Malik, 2020) [19].

2. Physical, Biochemical and Phytochemical Profile of Psoudo-cereals

Amaranth seeds have a lenticular form, are small (1–1.5 mm in diameter), and weigh between 0.6 and 1.3 mg each (Bressani, 2003) [4]. With a diameter of 1 to 2.5 mm, quinoa seeds are typically larger than amaranth seeds. Amaranth and quinoa have very different grain structures than other grains like maize and wheat. The circular embryo or germ of quinoa and amaranth seeds surrounds the pericarperm, which is rich in starch, and combined with the seed coat, represents the bran portion, which is comparatively high in fat and protein. The triangular buckwheat kernel is 4–9 mm long and made up of the hull, spermoderm, endosperm, and embryo. In buckwheat seeds, the embryo and its two cotyledons extend through the starchy endosperm, just like in ordinary cereals (Mazza & Oomah, 2003) [17].

Amaranth, buckwheat, and quinoa all have higher protein contents than popular cereals like wheat, with amaranth often having the greatest protein level, followed by buckwheat and quinoa. Amaranth, quinoa, and buckwheat proteins are mostly globulins and albumins, with very little to no stored prolamin proteins, which are the primary storage proteins in cereals and also the harmful proteins in celiac disease. Compared to prolamins, globulins and albumins have a drastically different amino acid content, which affects how nutritious they are. Compared to prolamins, globulins and albumins have higher concentrations of lysine and lower concentrations of glutamic acid and proline. As a result, compared to conventional cereals, the amino acid profile of pseudocereal protein is superior due to its well-balanced composition and high quantity of important amino acids (Gorinstein *et al*., 2002) [10].

Amaranth, quinoa, and buckwheat, which are pseudo-cereals, are excellent sources of dietary fiber. In particular, buckwheat seeds have much more dietary fibre than quinoa and amaranth, which are comparable to the levels of fibre in typical cereals (Alvarez-Jubete *et al*., 2009) [1].

The fat content of the pseudocereals is a significant aspect of their makeup. Amaranth and quinoa have a lipid content that is two to three times higher than that of buckwheat and other popular cereals like wheat. High levels of unsaturation in the lipids of amaranth, quinoa, and buckwheat are advantageous from a nutritional standpoint. The most prevalent fatty acids are linoleic acid (which makes up 50% of the overall fatty acids in amaranth, quinoa, and about 35% of buckwheat), oleic acid (25% in amaranth, quinoa, and about 35% of buckwheat), and palmitic acid (Bonafaccia *et al*., 2003) [3]

According to experts, the majority of carbohydrate-containing foods should have a low glycemic index (GI), or slowly absorbed carbs (FAO/WHO, 1997) [9]. Given that CD patients appear to have a higher incidence of type-I diabetes, maintaining good glycemic control is very crucial. There is a need to improve the formulation of these food products, according to the limited available data on the GI of gluten-free foods. Quinoa has been suggested as a substitute for conventional components in the creation of cereal-based gluten-free goods with a low GI since it has demonstrated some hypoglycemic activity in vivo. A potential ingredient for foods with a low GI has also been mentioned: buckwheat. Additionally, amaranth grain has been demonstrated to successfully lower serum glucose levels and raise serum levels of insulin in diabetic rats, indicating that amaranth grain may be helpful in the treatment of hyperglycemia and the prevention of diabetic complications (Kim, Kim, Cho, Kim & Shin, 2006) [14].

In general, the pseudocereals buckwheat, quinoa, and amaranth are good sources of vitamins and minerals. Thiamine, riboflavin, and pyridoxine are three B vitamins that are abundant in amaranth. Riboflavin, thiamine, and folic acid are all present in quinoa. Additionally, buckwheat, quinoa, and amaranth seeds are great providers of vitamin E. According to reports, the total vitamin E content of amaranth, quinoa, and buckwheat seeds is 5.7, 8.7, and 5.5 mg/100 g on a dry weight basis, respectively. The gluten-free diet and goods are lacking in the minerals calcium, magnesium, and iron (Hopman *et al*., 2006) [12].

3. Thermal processing and their effect on nutraceutical properties of psoudo-cereals

They have a great nutraceutical potential given the abundance of innumerable bioactive components, such as phenolic compounds, proteins and a variety of anti-oxidants, which contribute to their outstanding nutritional profile. However, in addition to useful components, they generally contain anti-nutrients, including tannins, phytate and saponins that lower the absorption of advantageous supplements. Pseudo-cereals are processed thermally in order to address this, including popping, frying, steaming, and other processes. By reducing the number of anti-nutrients, such treatments increase the bioavailability of nutrients and hence raise the nutritive value of pseudo-cereals. The digestibility and flavour of the corresponding food product are improved by thermal processing. It increases self-life and decreases chemicals that are anti-nutritional. Pseudocereals must be thermally processed using low-cost technology to create conventional or cutting-edge end products for populations in underdeveloped or economically prosperous nations. Pseudo-cereals undergo a variety of processing procedures to reduce their anti-nutritional components and enhance their nutritional value. The following subheading explains the various processing techniques that are described in the literature.

3.1 Popping / Puffing

In order to create high internal pressure from water vaporisation, which causes the pericarp to break and the grain endosperm to expand, heat must be applied at atmospheric pressure. This low-cost technology is known as heat-induced puffing (popping). Puffed grains are frequently used as ready-to-eat foods or as ingredients in snack recipes, and their popularity is growing as people's lifestyles change. During the puffing process, physical, structural, and chemical modifications take place. Dehydration, gelatinization of the starch, volume gain, and texture modifications all occur with puffing grains (Hoke *et al*., 2007) [11]. Additionally, puffing generates volatiles with palatable flavours while increasing the digestibility and technical functioning of carbohydrates and proteins. The use of puffing to generate amaranth flours for use as ingredients in bakery goods (cookies and bread) with innovative textures and flavours has been suggested as a result of these positive modifications. Previous research on the nutritional effects of puffing amaranth grains has revealed that phenolic acids, B-group vitamins, and amino acids are all thermally degraded during the puffing process (Murakami Yutani *et al*., 2014) [18].

Amaranths puffing results in a decrease in amino acid content, this can be attributed to thermally-induced chemical changes of protein residues such as glycation, glycoxidation, and oxidation. At the start of the thermally induced Maillard process, the carbonyl moiety from a reducing sugar condenses with protein amino groups at the Lys side chain or N-terminus. Heated proteins may also undergo other sugar-independent changes, such as oxidative deamidation at Cys -elimination, the N-terminal amino acid and the production of cross-linked lysinoalanine and histidinoalanine derivatives (Arena *et al*., 2017) [2].

Puffed buckwheat has white colour with brown spots and opened tetrahedron form. Buckwheat puffing product ability to bind water (193%) and higher capacity for binding oil (243%). Researcher discovered via their study that the ideal moisture content and resting period before hydrothermal treatments can expand the volume of puffed seeds by 30–70%. Protein, lysine and mineral content slightly less in puffed buckwheat and have significant level of dieatary fiber (9.8g/100g dry matter). Contents of K and Mg in puffed products were significantly lost (28.3 and 42.2%, respectively). It was brought on by dissolving during conditioning and moistening as well as by the rapid loss of water from the seed during puffing. phenolic compound was reduced by 36.5% in case of puffing. roasting at 200 °C for 10 minutes reduced antioxidant activity by 13.4% (Iren *et al*. 2010) [22].

Depending on the puffing process used, the bulk density of popped quinoa with and without coating layer ranged from 107 to 600 kg/m3 and from 9 to 475 kg/m3, respectively. Because there is no covering, quinoa expands more when microwaved. Some damage of the quinoa pericarp during desaponification may promote partial starch gelatinisation in the presence of fibres being helpful in microwave puffing. After puffing, quinoa samples' water absorption and water solubility index ranged from 1.91 to 5.27 kg kg^{-1} and 7.1 and 40.4% (Kowalski *et al*., 2016) [15]. During puffing, temperatures over 76.7 °C and moisture levels below 16.9% w/w encourage the caramelization and Maillard reactions of reducing sugars as well as the quinoa pigments' degradation. As compared to the raw material, puffing techniques for quinoa significantly reduce the maximum force for rupture and apparent modulus of elasticity. The result of quinoa's high amylose concentration is softer, less rigid food with lower mechanical strength. Amylose promotes the degree of expansion following heating and starch gelatinization (Joshi *et al*., 2014) [13]. Quinoa that had been coated displayed comparable mechanical behaviour, with the exception of fractal toughness when heated in a microwave. Quinoa that had been coated and heated in a microwave produced the least amount of internal grain porosity and the lowest expansion index (1.41 m m 1). Due to heating, puffing activities cause moisture loss in the majority of quinoa snacks. In addition, a drop in mineral content, particularly in gun-puffed quinoa, was noted as a result of the process-related pericarp loss. The samples of quinoa ranged in protein content from 11.06 to 13.28 g 100 g 1 DW (Coutinho *et al*., 2013) [6].

3.2 Cooking

Pseudo-cereal grains are typically consumed after boiling. However, overboiling the grains reduces their phenolic content. Pressure cooking resulted in the highest phenolic content retention. From an anti-nutritional perspective, boiling did not significantly reduce anti-nutritional substances, particularly phytic acid. Analysis of the minerals in amaranthus indicated that steaming and boiling had a negative impact on the amount of folate and other important amino acids (Henrion *et al*., 2021) [23].

Repo-Carrasco- (2010) [20], investigated the results of roasting and boiling quinoa and amaranth seeds. Following these processing methods, the bioavailability of iron, calcium, and zinc increased significantly. Compared to other cereals, this one has a higher concentration of bioactive ingredients such as phenols, dietary fibre, and minerals (calcium, zinc, and iron). Dialyzability experiments were used to determine nutrients' possible bioavailability. Although grains may become more dialyzable of zinc, iron, and calcium after boiling, minerals after roasting were not significantly affected.

In Tartarian buckwheat, researchers examined the effects of hydrothermal processing, germination, and Fe speciation on Fe absorption by human intestinal Caco-2 cells. They discovered that groats had the lowest Fe content (23.8 1.65 mg/kg) and the lowest levels of Fe2+ (8%). Similar Fe contents (78.2 2.65 and 68.9 2.73 mg/kg) and Fe2+ fractions (15% and 18%) were found in grains and sprouts. Phytate and citrate were the predominant cation-exchange agents for Fe in the Tartary buckwheat material. Sprouts had a lower concentration of phytate, which increased their bioavailability.

Dehulled buckwheat groats with 4–8 mm granules were utilised as the raw material for extrusion after being set according to certain parameters, such as moisture content and resting duration (wetted to 18% and rested for 3 h as ideal). The final extruder temperature for the product under investigation in this study was 200 °C for 1-3 sec. The buckwheat extrudate had a pale brownish colour. Bulk densities varied greatly, which was caused by the high degree of expansion. Extruded buckwheat had ability to bind water (234%) was significantly improved and a lesser capacity for bindng oil (104%) by extruding. The extruded buckwheat sample was also tested for protein, lysine, and mineral content. The protein content and the amount of lysine, an important amino acid, did not significantly change in the extrudate. Riboflavin, niacin, and tocopherol, three vitamins, were measured in raw buckwheat groat and extrudate buckwheat product, but only tocopherol content was examined in buckwheat extrudate. The amount of tocopherol in the buckwheat that remained in it after extrusion was 44.5%. K (415-578 mg/100 g DM), Mg (152-263 mg/100 g DM), and Fe (3.6-4.2 mg/100 g DM) are particularly abundant in buckwheat snack products. The total quantity of phenolic compounds was reduced by 36.5% due to extrusion. According to Sensoy *et al*. (2006), Extrusion at 170°C had no effect on antioxidant activity. The trypsin inhibitor activity was also investigated in buckwheat samples, one of the antinutritive components of the seed samples. Although the trypsin inhibitory activity of buckwheat seeds is not very great, hydrothermal treatments at various temperatures and lengths of time can reduce the antinutritive component levels. Only 37.5% trypsin inhibitor activity was present after extrusion (De la Barca *et al*., 2010) [7].

Quinoa recovery by chitosan-starch layer encouraged grain expansion during extrusion, encouraging a more uniform distribution of fibres inside the chitosan-starch matrix that may prevent early cell collapse and promote porosity of extrudates. Uncoated quinoa grains may have a relatively high proportion of proteins and fibers, which may have a negative impact on starch gelatinization and cause less expansion and greater bulk density. Kowalski *et al*. (2016) [15], reported WAI and WSI values of 2.82 kg kg_1 and 14%, respectively, for extruded quinoa. Extrusion causes lipid breakdown due to the high temperature (110–120 °C) and fast screw speed (500 r.p.m.). The starch structure may also undergo micro- and macromolecular modifications during extrusion, altering the behaviour of the amylose and amylopectin chains, which impacts the gelatinization and crystallisation of the starch.

Conclusions

The application of all these processing treatments, there was considerable reduction in anti-nutrientsand improvement in availability or digestibility of nutrients.Pseudocereal grains are gluten-free. So, their flour or products can be used by the people who are suffering from celiac diseases. Pseudo cereals have great potential to be utilized as gluten free ingredients in for development of value added gluten free products. Beside their gluten free characteristics, these have been reported to possess high quality protein, ample quantities of fiber and minerals such as iron and calcium. Many bioactive compounds such as polyphenols, phytosterols, squalene and saponins with health-promoting effects are present in abundance in preudocereals. Processing treatments such as popping, cooking, steaming malting and fermentation have been found to increase the nutritive value of these grains as well as the products developed by their incorporation. These can be widely utilized for development of gluten free processed products such as pasta, bread and confectionary products. Process conditions, starch gelatinization, and carbohydrate content all had an impact on the physical, nutritional, and textural characteristics of the food. Higher temperatures and lower humidity will result in dextrinization rather than gelatinization, which will result in lesser water absorption. More temperatures and lower humidity will result in more homogenous heating and ultimately higher starch gelatinization.

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