



ENHANCEMENT OF BIOAVAILABLE MICRONUTRIENTS AND REDUCTION OF ANTINUTRIENTS IN FOODS WITH SOME PROCESSES

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ABSTRACT

The most of plant foods, nuts and cereals contain antinutrient compounds. They reduce to mineral bioavailability and protein absorption of foods thanks to their chelating properties. They causes to micronutrient malnutrition and mineral deficiencies. The micronutrient malnutrition is a widespread global health problem not only in developing but also in many countries. Increasing micronutrient intake in food through food processing based approaches is a sustainable method of prevention of micronutrient malnutrition which should be achieved through food diversification. There are traditional and technological methods that provide reducing of antinutrient compounds. The pretreatment and processing techniques as soaking, fermentation, germination, debranning, and autoclaving are even traditional methods which use generally in consumption of foods. Removing antinutrients, the bioavailability of some cation (Ca, Fe and Zn) and the absorption of proteins make to increase and consequently nutrition value of food increase. It is possible to reduce antinutrient factors by using domestic or industrial basic food processing techniques alone or in combination. This review focused on various methods to reduce antinutrients in food such as phytic acid, tannin, and oxalate in food grain to improve nutritional quality of foods.

Keywords: Micronutrients, Antinutrients, Digestibility, Bioavailability

Introduction

The malnutrition influences more than half of the world population, especially in developing countries in which the plants to be a major source of food. The deficiencies of micronutrients such as minerals and vitamins have caused to be most serious health problems (Jorge *et al.*, 2008). The solely total micronutrient content is not important in foods, their bioavailability is more effective factor than their level. In unrefined foods the low bioavailability of minerals causes metabolic disorder related to these nutritional factors. Therefore improving the nutritional value of such type of foods will improve the nutritional status of the population (Steiner *et al.*, 2007; Gupta *et al.*, 2015).

Phytate has long been recognized as an antinutritional factor affecting the bioavailability of major minerals such as Ca and trace ones such as Fe, Cu, Zn and Mn. Other antinutrients of importance in foods are tannins, polyphenols, oxalates and tripsins. The known that they limit the bioavailability of food materials (Eltayeb *et al.*, 2007). Decreasing of antinutritional factors is very advantageous, due to their influences on nutrition. However, many antinutrients besides their primary effects on the bioavailability of nutrients may also be toxic beyond a certain dose, for example oxalate or cyanogenic acid. Therefore interest has grown to reduce their antinutritional effects nowadays (Novak and Haslberger, 2000).

Soaking, dehulling, cooking and fermentation are important traditional methods used to reduce antinutrients. Furthermore germination and fermentation enhance the nutritional value of cereals and legumes by causing significant changes in chemical composition and elimination of antinutritional factors (Abdelrahman *et al.*, 2005).

The aim of this review was to evaluate the effect of processing methods which can be decrease the level of antinutrients such as phytic acid, polyphenols and tannin which are mostly found in food materials.

Antinutrients in Foods

The compounds such as phytic acid, tannin and polyphenols found in leguminous, vegetables and cereal grains are known as anti-nutritional factors affecting the bioavailability of proteins, minor minerals such as Zn, Fe, Cu and major minerals such as Ca and P. Antinutrients reduce the maximum utilization of nutrients (especially proteins, vitamins or minerals), and as a consequence they obstruct an optimal bioavailability of the nutrients present in a food and decrease its nutritive value (Eltayeb *et al.*, 2007).

Phytic acid myoinositol is 1,2,3,4,5,6-hexa dihydrogen phosphate. It is the major storage form of phosphorous comprising 1–5% by weight in cereals, nuts and legumes (Vats and Banerjee, 2004). Moreover it include 50–85 % of total phosphorous in plants (Reddy *et al.*, 1982). Cereals, legumes, oil seeds, hard shelled fruits, which are necessary in human nutrition, are the considerable phytic acid sources. They represents approximately 40 % and 60 % of total calorie intake for daily human diet (Schlemmer *et al.*, 2009). Especially cereals and cereal products are rich in phytic acid content. In cereal grains such as wheat and rice, it is generally found in bran fraction such as aleurone layer and pericarp, in corn it is seen in endosperm (Gupta *et al.*, 2015). It was reported that the phytic acid concentration in wheat germ and wheat bran are 1.1–3.9 % and 2.0–5.3 % respectively (Kasim and Edwards, 1998). The phytic acid content is upto 8.7 % in rice bran (Lehrfeld, 1994; Zhang and Bai, 2014). Therefore, the rafination of the cereals significantly effect to phytic acid content (Suma and Urooj, 2014). The phytic acid content varies from approximately 1.0–5.4 % of the other group oilseeds which includes soybeans, sesame seeds, sunflower kernels, linseeds and rape seeds (Lolas *et al.*, 1976). Another group of foods contained phytic acid is nuts such as walnuts, almond, in which phytic acid content ranged from approx. 0.1–9.4 % (Chen, 2004; VenktachalamandSathe, 2006; Schlemmer *et al.*, 2009). Phytic acid acts blocking the absorption of minerals such as Fe, Zn, and Ca. For that reason it also named antinutritive agent. This binding phenomonia caused to insoluble salt form with poor bioavailability of minerals (Urbano *et al.*, 2000; Feil, 2001).

Another antinutrient groups in foods are tannins and free phenolics. In terms of human nutrition, the content of both tannins and total free phenolics are not desirable for human consumption. Whereas phytic acid reduces the bioavailability of some essential minerals, tannins inhibit the digestibility of protein (Rehman and Shah, 2001). It was reported that, phenolic compounds decreased the digestibility of proteins, carbohydrates and the bioavailability of vitamins such as vitamin B12 and minerals (Liener, 1994). They also decreases the activity of digestive enzymes such as trypsin, chymotrypsin lipase and α – amylase.

Oxalic acid is a dicarboxylic acid generally found in plants and animals. Besides dietary intake it in the human body may also be derived from metabolism of ascorbic acid and glyoxylate. The previously conducted studies reported that star fruit, spinach, amaranth, bamboo shoot, ginger, almond, cashew, pine nut, hazel and peanut contained high levels of

oxalates. Moreover, water spinach, Chinese wolfberry, black glutinous rice, dragon fruit, rice bean, abalone fruit and Chinese torreyia fruit were also presented as high oxalate-foods (Ruan *et al.*, 2013). The consumption of high amount of oxalate could be fatal, because of oxalosis or the formation of calcium oxalate deposits in vital tissues or organs of the body (Sanz and Reig, 1992). The oxalate intake should be to less than 40–50 mg per day recommended by the American Dietetic Association, (2005) for the patients with kidney stone problems.

Technological Processes and Changes in Antinutrients Content

Most of the anti nutritive substances become ineffective or their level can be reduced with simple treatments such as heating, soaking, germination or autoclaving.

Milling and Debranning

Milling is the most commonly used method to remove the bran layer from grains. Furthermore this technique removes the antinutrients such as phytic acid but also has major disadvantages as it also removes major parts of minerals and dietary fibers (Gupta *et al.*, 2015).

Soaking

The soaking is an easy method used generally in daily life and an important method helped in germination and fermentation of cereals. During soaking, phytase enzyme activates and effects to antinutrient compounds. Soaking process has both physical and chemical positive effects in structure of foods. For this reason, cereals such as chickpea, wheat and barley used to product in daily life should be consumed after soaked for a while (Gupta *et al.*, 2015).

This method is the complete submergence of grains in water for a certain soaking period which results in the activation of endogenous phytases. The endogenous phytases are present in grains naturally. So by activation of these enzymes with several treatment such as soaking it has been reported that significant amount of phytic acid content in grains have been removed. Soaking is widely applied and most important method in germination and fermentation process of cereals. Furthermore it is a pretreatment before cooking for all grains. Soaking of cereals with endogenous or exogenous phytase increases in vitro solubility of minerals such as Fe and Zn by 2–23% (Lestienne *et al.*, 2005).

In this method, the soaking water's heat and soaking time act significant. In a study conducted by Greiner and Konietzny (2006), soaking at temperature between 45°C

and 65°C and pH value between 5 and 6 a considerable percentage of phytate was hydrolysed. The grains and beans soaking is quite effective for increasing in mineral and protein bioavailability as well as reduction of phytic acid (Coulibly *et al.*, 2011). The soaking duration and the combination with other treatments such as cooking are more effective than the only usage of soaking. As soaking time increased from 2h to 12 h phytic acid content in chick pea decrease by 47.4 % to 55.71 % has been reported (Ertas and Turker, 2014).

On the other hand disadvantages of treatment, it can be disappearing of water soluble protein and minerals.

Fermentation

Fermentation is the one of the important processes that decrease the levels of antinutrients in food grains and increase minerals extractability, *in-vitro* protein digestibility and nutritive value of grains. The reduction in phytic acid during fermentation could be attributed to the action of the enzyme phytase released by microorganisms' fermentation. Therefore cereals based foods certainly should be consumed after fermentation treatment. It reduces amounts of phytic acid, tannin, polyphenols with fermentation treatment and it increase food's mineral bioavailability and digestibility (Gupta *et al.*, 2015).

Fermentation is the one of the processes that decrease the levels of antinutrients in food grains and increase minerals extractability (Badau *et al.*, 2005). Fermentation of food grains improves bioavailability of minerals and proteins. The phytic acid is present in grains in the form of complexes with metal cations such as Zn, Fe, Ca and proteins. The enzymatic degradation of phytic acid requires an optimum pH (generally below pH 4.5) which can be provided by natural fermentation such as be in sourdough fermentation (Hayta and Hendek Ertop, 2017). The degradation of phytic acid can increase the amount of soluble of minerals. It have been reported that fermentation of millet grain for 12 h and 24 h could reduce the food inhibitors, phytic acid and tannins (Coulibly *et al.*, 2011). The natural fermentation also named as spontan fermentation can achieve a large reduction in phytic acid in cereals and legumes by the action of microbial as well as grain phytases. Because, the phytases which is based on grain and microbiota act on phytic acid during fermentation. The combination of fermentation with other treatments such as germination are more effective than the only usage of fermentation. There was recorded that 88.3% reduction in phytate content when germinated pearl millet were fermented with mixed pure cultures of *Saccharomyces diasticus*, *S. cerevisiae*, *Lactobacillus brevis* and *L.*

fermentum at 30 °C for 72 h (Kaur *et al.*, 2014). Abdelrahaman *et al.* (2005) reported that, germination and fermentation enhance the nutritional value of pearl millet by causing significant changes in chemical composition and elimination of antinutritional factors.

Germination

Germination is highly effective method to reduction of phytic acid content by up to 40% (Masud *et al.*, 2007). During the germination process, the endogenous enzyme activity which has phytate degrading ability increases. This condition provide to degradation and decline antinutrients as phytic acid. In non-germinated cereal and legume grains have a little endogenous activity (Greiner and Konietzny, 2006). In a study conducted by Marshall *et al.* (2011), cereal grains were screened for phytic acid content and found that germination for 10 days resulted in a significant reduction ($p < 0.05$) in the phytate contents of all cereal grains screened.

Autoclaving and Cooking

Autoclaving is heat treatment application. Together with application heat treatment to cereals or other vegetable goods, acidity increase and phytase enzyme activate. The most of foods become usefull and healty with heat treatment application in daily diet. All legumes and some cereals are usually cooked either by simple boiling or in a pressure cooker for their consuming. The literature is reported that simple boiling improves the nutritional quality of food grains due to reduction in antinutrients (Rehman and Shah, 2005).

The phytic acid content is greatly reduced during cooking and soaking (Vellingiri and Hans, 2010). Together soaking and cooking are much more effective to reduce phytic acid level than only soaking for a short duration (Vidal-Valverde *et al.*, 1994). In a study, autoclave and microwave treatments decreased phytic acid content as they also increased total mineral content and HCl-extractability of minerals in whole wheat bread (Mustafa and Adem, 2014).

It has been observed, by previous studies, that different cooking methods improve the nutritional quality of food legumes to various extents (Nielson, 1991; Chi-Fai *et al.*, 1997). Singh (1993) reported that improvement in protein quality of pigeon was obtained after the partial removal of polyphenols as a result of a simple boiling method. In another study, it was founded that pressure cooking was more effective than ordinary cooking in reducing the antinutrients of black grams and mung beans (Kataria *et al.*, 1989). Moreover it was revealed that the boiling and autoclaving in water

improved the protein quality of winged beans due to reduction in the levels of antinutrients (Kadam *et al.*, 1987). Rehman and Shah (2001), observed an improvement in protein digestibility of black grams due to removal of tannins after pressure cooking.

Furthermore, it was reported by earlier studies that cooking treatment improves the digestibility of starch through gelatinization and destruction of antinutrients (Mbofung *et al.*, 1999; Rehman *et al.*, 2001). The improvement in starch digestibility can based on due to hydrolysis of starch as a result of heat treatments. According to another phenomonia, partial removal of tannins and phytic acid probably is creates a large space within the matrix, which increased the susceptibility to enzymatic attack and consequently improves the digestibility of protein and starch after the cooking process (Rehman and Shah, 2005).

It has been shown that a significant difference in oxalate content was obtained according to cooking methods. For example, when the taro samples were boiled in water for 40 min, oxalate content decreased by at least 47%. However, when the samples were baked at 180 °C for 40 min, this treatment did not bring about a significant change in the oxalate level (Savage and Martensson, 2010).

It was reported that the toasting process resulted in a significant reduction in trypsin-inhibitor activity of the toasted meal of soybean relative to the seed (Novak and Haslberger, 2000).

According to different studies, among the various common processing methods, the autoclaving treatment was found to be more effective in reducing various antinutritional compounds (Shimelis and Raksihit, 2007; Vadivel *et al.*, 2007; Doss *et al.*, 2011). Doss *et al.* (2011), reported that the autoclaving, cooking and soaking processing methods were found to reduced significant levels of various antinutritioanal compounds such as total free phenolic respectively.

Conclusion

The processing methods of foods can significantly decrease antinutrients. Genetic improvement as well as several pretreatment methods such as fermentation, soaking, germination also improves nutritional quality. Further decrease in antinutritional factors can be obtained by the usage of various fermentation methods such as spontaneous fermentation named as sourdough method of the processed grains. Cost effective processes for commercial and industrial productions should be developed. Future researchs are needed to determine the optimal processing conditions and to appropriate delivery of phytase enzyme to foods.

There are close negative correlation between the level of antinutrients and the bioavailability of micronutrients. For that reason the studies for determination of *in vitro* bioavailability of micronutrients in foods should be also done.

Nowadays there has been consumer's tendency towards food types that are produced with unrefined grains, cereals and legumes such as whole wheat flour or wheat bran. In this respect, the bioavailability of foods containing different types of cereals and grain fractions has been expected to improve by the use of this processes.

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