Effect of different cooking methods on anti-nutritional factors- An Overview

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Abstract

India is the country where most of the population is dependent on the plant based food. Plant based foods include cereals, legumes, fruits and vegetables which contains various nutrients plays vital role in the growth, development and different internal function in body. Other than these nutrients all of these food sources contain anti- nutritional factors such as goiterogenic factors, lathyrogens, saponins, trypsin inhibitors, phytohemagglutinins tanins, cynogens, phytates, oxalates etc. Some of the studies have reported that the presence of some anti-nutrients in food within limited amount works as preventive measure in chronic diseases like cancers and coronary disease etc so that, known as bioactive compounds which are non-nutritive in nature. These further reveal that the anti- nutritional factors are not always harmful in nature due to lack of nutritive value. Although the beneficial and harmful effect of these compounds depends on their chemical structure, concentration, time of exposure as well as their interaction with other nutrients. These non-nutritive substances are known as pro-nutrients which having positive effect on health whereas anti-nutritional factors have negative effect on health. Number of studies revealed the various methods to improve the nutritional availability of vital nutrients by the selection of different cooking methods. These cooking methods include different traditional methods such as washing, peeling, soaking, blanching, cooking, sprouting, fermentation etc. which can further effectively reduce the content of these anti-nutritional factors.

Keywords: Anti-nutritional factors, bioactive compounds, tannins, saponins, enzymetic inhibitors, cooking methods.

Introduction

Most of the part of diet comes from plant origin in human nutrition. India is a country where the consumption of plant based food is in abundance which further improves the nutritional status of individuals. Plant based foods include cereals, legumes, fruits and vegetables which contains various nutrients plays vital role in the growth, development and different internal function in body. Classification on the basis of various functions of the nutrients cereals are considered as energy giving food due to presence of good amount of carbohydrates whereas legumes and pulses contains high amount of protein by which these are categorised as body building food. Vegetables and fruits are rich in vitamins and minerals which further responsible to improve immune system Other than these nutrients all of

these food sources contain anti- nutritional factors such as goiterogenic factors, lathyrogens, saponins, trypsin inhibitors, phytohemagglutinins tanins, cynogens, phytates, oxalates etc. (Said, 2014).

Plants contain number of vital nutrients in abundance which plays important role in growth, development and for fulfilment of different body functions. Plants are rich source of energy suppling nutrients such as carbohydrates, protein and lipids and functions in potential defence mechanism of plants. On the other hand, Plants contain certain chemical compounds in substantial amount which adversely affects the digestion, absorption and utilization of other nutritional substances such as proteins, vitamins and minerals (Soetan and Oyewol, 2009). These compounds get synthesized naturally in food or by the metabolism of species and can also formed by different mechanisms like utilization of food, inactivation of some of the nutrients etc. These chemical substances are not having exclusive association with plant originated foodstuffs. Plants have nature to make defence mechanism for protection purpose and produce these chemical compounds. These chemical compounds are known as Anti-nutritional factors. These anti-nutrients are present in almost all plant based foodstuffs (Shanthakumari *et. al*, 2008).

Although studies reported that the presence of some anti-nutrients in food within limited amount works as preventive measure in chronic diseases like cancers and coronary disease etc so that, known as bioactive compounds which are non-nutritive in nature. These further reveal that the anti- nutritional factors are not always harmful in nature due to lack of nutritive value (Muzquiz, 2000). Although the beneficial and harmful effect of these compounds depends on their chemical structure, concentration, time of exposure as well as their interaction with other nutrients. These non-nutritive substances are known as pro-nutrients which having positive effect on health whereas anti-nutritional factors have negative effect on health (Gemede and Ratta, 2014).

There are various functions associated with anti-nutritional factors such as:

- They may act as enzyme inhibitors. For e.g. trypsin inhibitors are present in pulses and legumes
- They may act as metal chelators and does not allow the nutrients to be available to the body. For e.g. phytate in cereals chelates calcium, iron, magnesium & zinc and makes them unavailable to body.
- They have anti-physiological effect like reduction of immune-competence, impairment in reproduction functions etc.

The anti-nutritional factors have adverse effect on nutritional availability. Number of studies revealed the various methods to improve the nutritional availability of vital nutrients by the selection of different cooking methods. These cooking methods include different traditional methods such as washing, peeling, soaking, blanching, cooking, sprouting, fermentation etc. which can further effectively reduce the content of these anti-nutritional factors. Although sometime these techniques are not enough to reduce the content of anti-nutritional factors so that used in the combination of two or more techniques. For e.g.

soaking is generally used in combination with cooking in case of pulses and legumes (Tiwari and Cummins, 2013).

Anti-nutritional factors in foods from plant origin

As per various researches anti-nutritional factors are the naturally occurring chemical compounds which can classified under a broad group of secondary metabolites. On the basis of functions these compounds can be categorised as the compounds with anti-nutritional effect and anti-physiological effects whereas on the other hand, the compounds which are responsible to reduce the feed intake in animals and also reduce the availability of the nutrients to the body (Panhwar, 2005). On the basis of heat resistance anti-nutritional factors are divided in two major groups as

Heat-stable anti-nutritional factors: The anti-nutrients which have stability at high temperature such as phytates, tanins, alkaloids, saponins etc.

Heat-labile anti-nutritional factors: The anti-nutrients which are sensitive to standard heat and can be lost at high temperature such as lectins, cynogenic glycosides, proteinase inhibitors etc.

Phytates

Phytic acid is generally found in form of salt named as Phytate which is commonly present in plants, animals as well soil. These are chiefly exists in mono and divalent cation form salt of potassium, magnesium and calcium which can further accumulates in the seed part of food during the ripening period. It is 1, 2, 3, 4, 5, 6-hexaphosphate of myo-inositol which occurs in distinct parts of cereal grains. Phytate is pervasive among plants and seed grains which further bound approximately 85% of the phosphorus content and reduce the bioavailability. The body of ruminants is able to avail this bound form of phosphorus due to the presence of certain enzyme as rumen, in stomach chamber which is not available in humans and non-ruminants (Loewus, 2002).

Phytate is able to work in high range of pH which further leads to unavailability or reduced availability of vital nutrients specially minerals such as zinc, copper, calcium, manganese, magnesium etc. Along with this, phytate bound with proteins and forms a complex which modifies the structure of protein and further adversely affects the enzymatic activity, protein-solubility; proteolytic digestibility etc. Phytate also have tendency to bound carbohydrates which further make a complex and reduce the rate of availability of starches present in food compounds. A degrading enzyme, phytase is used for the degradation of phytate during processing as well as in the GIT (Gastro-Intestinal Tract) (Greiner and konietzny, 2006).

On the other hand, phytate is associated with a number of health benefits such as works as anti-oxidant, anti-carcinogenic effect etc. Phytate is capable to reduce iron-induced oxidative injury and also reverse the process of tumour formation due to the tendency of mineral chelating. It can bound and make

complex with carbohydrates so helps to maintain bold glucose level in diabetic patients (Shamsuddin, 2002). Due to the chelating potential, it can reduce the condition of renal calculi due to bind calcium content (Dost and Tokul, 2006).

Tannins

Tannin is considered as a polyphenolic compound which is present in bitter plants. This group of compound are formed as oligomers of flavan-3-ols and flavan-3, 4-diols, which is further known as condensed tannins and majorly found in cereals and legumes. This group of anti-nutrient is distributed in wide range of plant species but tree bark contains it in abundance. The molecular weight of tannins ranges from 500 to more than 3000 (McGee, 2004). As per the name, tannin is an astringent which can used in tanning of animal leather as well as it also used in refining process of beer and wine, as dying agent and also in medicines. The negative effect of tannins depends on the concentration and structure of compounds. Tannins are heat stable in nature and decrease the bioavailability of proteins due to formation of complex with proteins.

Tannin adversely affects the activity of digestive enzymes such as chymotrypsin, trypsin, amylase as well as lipase which further decrease the availability of vital nutrients (Adeparusi, 2001). Tannins are divided in further categories such as hydrolyzable tannins, condensed tannins and pseudo-tannins.

Hydrolyzable tannins: This group of compound contains carbohydrate molecule which can esterified with gallic acid or ellagic acid. These can further hydrolysed by weak acids or weak bases and converts into carbohydrate and phenolic compound.

Condensed tannins: These are also known as proanthocyanidins which are the polymers of flavonoid units (2-50 or more units) and bound with carbon-carbon bonds and cannot hydrolyse. Tannins are water soluble in nature as same as phytate but very large compounds of condensed tannins are insoluble in water.

Pseudo-tannins: These are not separate than other tannins but cannot follow the Goldbeaters skin test and having low molecular weight. Some examples of pseudo-tannins are chlorogenic acid present in coffee, catechins in cocoa etc. These compounds are highly distributed in plants which further not directly participate in metabolic process. The concentration of compounds is found in bran fraction of cereal grains and mostly in coloured seeds (Sandberg, 2002).

Saponins:

Saponins are non-volatile and surface active substances, widely distributed in plants. Saponin is a term derived from Latin word "Sapo" which means 'soap' and having tendency for the formation of soap like foam with interaction to water. These are steroids heterogeneous in nature which can produce steroidal glycosides or triterpene. The complex structure and variation results in distinctive changes in chemical, physical and biological properties includes bitterness, sweetness etc. whereas emulsifying and foaming properties, pharmacological properties as well as antimicrobial properties (Sparg *et al*, 2004).

These are at most occurs in a wide range of plants like cereals, legumes, oilseeds such as lentil, kidney-bean, peas, chick-pea, lupin, groundnut etc. Saponins were found to decrease the bioavailability of important nutrients and adversely affect the enzymatic activity which further inhibits the protein digestibility (Simee, 2011). Although, saponins are also having tendency to decrease uptake of cholesterol and glucose via gut due to intra-lumenal physicochemical interaction. On the other hand, saponins have beneficial effect on human health which includes hypocholesterolemic effect and anti-carcinogenic effect has also been reported in some of the studies (Farzana, 2017). It is also used as adjuvant in different viral as well as in bacterial vaccination. Studies have also shown an inverse relationship with the incidence of renal calculi (Gemede and Ratta, 2014).

Enzyme Inhibitors

Protease inhibitors are majorly dispersed within plants which include seeds of cereals and legumes. This is the class of anti-nutrients which mostly found in plant origin. These have the ability to impair the activity of proteolytic enzymes in GI tract. Protease inhibitors are heat labile in nature and easily denatured by heat processing method. Protease inhibitors are linked with growth impairment and pancreatic hypertrophy. Certain benefits are associated with anti-health benefits which includes various types of chemical- induced cancer (Finotti *et al*, 2006).

Raw legume seeds contain vital nutrients along with anti-nutrients such as trypsin inhibitors and chymotrypsin inhibitors which are also protease inhibitors. Both of these inhibitors are responsible for the limiting the activity of trypsin and chymotrypsin in gut which further inhibits protein digestion. The activity of these anti-nutritional factors forms a complex with dietary protein even in the presence of large amount of digestive enzymes (Liener, 2005).

Amylase inhibitors are called starch blocker because they have ability to inhibit absorption of dietary starch in body. It is heat labile in nature and found to be active at pH ranged from 4.5 to 9.5, respectively (Marshall and Lauda, 2007). Amylase inhibitors are capable to limit the pancreatic amylase but are not able to restrict fungal, bacterial and endogenous amylase. These are heat labile and having hypo-glycaemic effect.

Lathyrogens:

The consumption of lathyrus (lathyrus sativm) for long period can causes lathyrism, which is a paralytic condition and become public health hazard. In India, lathyrism linked with crippling disease,

exists and majorly affects the poorer section of people. The lathyrus is considered as staple diet during drought and famine condition due to the drought resistance of lathyrus pulse as well as can grow in heavy rain and flooded condition.

Alkaloids:

Alkaloids have a largest group of chemical compounds which can naturally synthesize in plants. These are organic substances with small molecules where number of carbon rings with side chains and carbon get replaced by nitrogen atoms. These alkaloids can produce by amino acid. Alkaloids are considered as anti-nutritional factor due to their adverse action on nervous system and disrupt the electrochemical transmit. The high consumption of tryptamine alkaloids can enhance heartbeat and further leads to fatalness and proceed to death. The absorption of glycoalkaloids improves in the condition of alkaline pH which further binds with sterols and cause the disruption of sterols. According to a study, alkaloids can cause food allergy whereas the lesser amount of alkaloids helps to stimulate circulation and respiration and anti-cancerous effect in human body (Simee, 2011).

Phytohemagglutinins

Phytohemagglutinins (lectins) are the substances which having ability to agglutinate red blood cells with sugar specificity because these are capable to bind carbohydrates. Lectin is a word comes from Latin word “legere” which means “to select” (Fereidoon, 2014). It is a glycoprotein in nature and mostly found in legumes and some oil seeds such as soyabean. Lectins can directly bind with intestinal mucosa which further interferes with the digestion and absorption of carbohydrates. Dietary lectins act as antigen of proteins which can bind the surface glycoproteins present in lymphocytes or erythrocytes (Gemede and Ratta, 2014). The high consumption of lectins can cause intestinal damage, inhibition of digestion and which can further cause nutritional deficiency. Furthermore, it exhibits certain chemical and biological properties such as interaction within the specific blood groups, agglutination of tumour cells, mitogenesis etc.

Cyanogenic glycosides:

These compounds are also considered as secondary metabolites and naturally produced in plants. These compounds are formed by an a-hydroxynitrile type aglycone and a sugar molecule. The derivation of cyanogenic glucoside takes place from five amino acids like valine, isoleucine, leucine, phenylalanine and tyrosine which further forms the non-proteinogenic amino acid substance named as cyclopentenyl glycine. These substances contain cyanogenetic glycosides which produce HCN due to hydrolysis. The presence of cynide further leads to increase the blood glucose level as well as reduces the ATP/ADP ration which indicates the transfer of aerobic metabolism to anaerobic metabolism. These are predominantly present in Cassava and limabeans. According to studies, limabeans *(Phaseolus lunatus)* are responsible for serious outbreak of human poisoning and cause human intoxication. The production of cynide is very high in lima beans and has been contributing factor of fatal human poisoning. However, the production of HCN from

Bengal gram, red gram, peas and kidney bean is almost negligible ranging from 0.5 to 2.3 mg/100 g, and not leads to toxicity (Zagrobelny, 2008).

Table 1: various anti nutritional factors present in food

Sr. No.	Anti-nutritional factors	Chemical nature	Food product in which they are present
1.	Enzyme inhibitors	Nitrogenous or protein compounds	Cereals, Legumes & pulses
2.	Lectins	Nitrogenous or protein compounds	Legumes & pulses
3.	Hemagglutinins	Nitrogenous or protein compounds	Legumes & pulses
4.	Amino acids or derivatives	Nitrogenous or protein compounds	Legumes & pulses
5.	Lathyrogenic amino acids	Nitrogenous or protein compounds	Legumes & pulses
6.	Maillard reaction products	Nitrogenous or protein compounds	heated foods containing amino acids and sugar
7.	α-galactosides	Carbohydrates	Legumes & pulses
8.	β- glucans	Carbohydrates	Legumes & pulses
9.	Cyclic, oxidised fatty acids	Fats	Legumes
10.	Erucic acid	Fats	Legumes
11.	Phytic acid and its salts	Phytates	Cereals & vegetable products
12.	Chlorogenic acid	Phenolic compounds	Pulses
13.	Flavonoids	Phenolic compounds	Pulses
14.	Gossypol	Phenolic compounds	Cotton seeds
15.	Polyphenols	Phenolic compounds	Cereals, legumes & pulses
16.	Tannins	Phenolic compounds	Cereals, legumes & pulses
17.	Cyanogens	Glycosides & heterosides	Cassava, linseeds, peas, beans
18.	Favism factors	Glycosides & heterosides	Broad beans & legumes
19.	Goitrogens (red skin)	Glycosides & heterosides	Ground nut, rape seeds,

			soybean & mustard
20.	Steroidic and triterpenoid glycosides	Glycosides & heterosides	Legumes & pulses
21.	Phyto-estrogens	Glycosides & heterosides	Legumes & pulses
22.	alkaloids	Alkaloids	Legumes & pulses
23.	mycotoxins	Mycotoxins	Legumes & pulses
24.	Nitrates	N-nitroso compounds or nitrosamines	Leafy vegetables

Effects of anti-nutritional factors

The effect of various anti nutrients has been summarized in following table:

Table 2: Effect of anti-nutritional factors on body

Sr. no.	Anti-nutritional factors	Effect on body
1.	Protease inhibitor	Impaired growth and poor food utilisation
2.	Amylase inhibitor	Poor digestion of carbohydrates
3.	Lectins	Poor food digestion & agglutination of tumour cells
4.	Glucosinolates	Effect on thyroid function
5.	Phytic acid	Reduces the bioavailability of minerals
6.	Cyanogens	Causes food poisoning
7.	Mycotoxins	Causes toxicity in various cells

Methods to reduce anti-nutritional factors

The anti-nutritional factors further play important role in the reduced digestion, absorption and utilization of vital nutrients. There are some methods by which the effect of these anti-nutritional factors can be reduced or they can remove from the food stuff which further leads to enhance the availability of nutrients for proper functioning of body. Some of the important methods are discussed below:

Soaking

Soaking is a very old process used to remove anti nutrients. By soaking anti nutrients come into soaking water and when soaking water is removed anti nutrients are also removed. Therefore, soaking method is capable to remove heat sensitive and water soluble toxic substances and anti-nutritional factors like lectins, enzyme inhibitors, saponins etc. Some amount of phytic acid can also be degraded due to this conventional method. It is preferred that water should be changed twice or thrice during soaking. Time and

temperature of soaking also influences the anti-nutritional content. It has been found that grain phytase is maximally active at pH 4.5-5.5, which is mildly acidic. Therefore, soaking in acidic medium rather than in simple water is preferred to reduce phytic acid to maximum possible level.

Table 3: Effect of soaking method on anti-nutritional factors

Cereals, pulses or legumes	**% reduction in anti-nutritional factors due to soaking**			**Reference**
	Phytic acid	**tannin**	**polyphenols**	
Guar seeds	25.9 (incr.)	91.4	12	Ahmed *et.al*, 2006
Pearl millet	70	8.8	29.4	Eltayeb *et.al*, 2007
Pearl millet	36.7	-	39.6	Sharma and Kapoor, 1996

Increment in protein content may be due to quantitative reduction of anti-nutritional factors such as tannins and phytic acid and other water soluble constituents. Leaching out of phytic acid, results in reduction of phytic acid during soaking method. Phytic acid was reduced by soaking due to hydrophilic nature of phytates (Eltayeb *et.al*, 2007).

Cooking

Cooking is the method of preparing food with heat. It includes:

- Roasting
- baking
- boiling
- frying
- smoking
- microwave cooking

Heat treatment is able to destroy protein based anti-nutritional factors like lectins, protease inhibitors etc. Heat treatment leads to the destruction of certain amino acids as well as vitamins too. It is essential to use optimum temperature for optimum time duration for the maintenance of nutritional value of food as well as for removal of anti-nutritional factors. Exceed of temperature and duration of time can further leads to the nutritional losses of food (Ahmed *et.al*, 2006).

Table 4: Effect of cooking on anti-nutritional factors

Cereals, pulses or legumes	**% reduction in anti-nutritional factors by use of cooking**				**Reference**
	Tannin	**Phytic acid**	**Trypsin inhibitor**	**Vit. B1 (nutrient**	

				loss)	
Guar seeds	57.1	37.2	-	-	Ahmed *et.al*, 2006
Spinach relish	-	-	-	35.5	Duodu *et. al*, 1999
Black gram	36.4	52.3	73.5	-	Kakker, 1999
Indian beans (roasting)	14.1	7.5	44.6	-	Ramakrishna *et.al*, 2006
Pearl millet	-	5.8	43.2	-	Sharma and Kapoor, 1996

Autoclaving reduced the tannin content may be due to denaturation of tannin due while heating (Ahmed *et.al*, 2006). The stability of phytic acid may be due to inactivation of endogenous phytase due to heat treatment and hence unable to breakdown phytic acid. Vitamin B1 content was decreased due to leaching out of this water soluble vitamin during blanching before cooking (Duodu *et. al*, 1999). Roasting is a process which also decreased phytic acid due to the same reason as of cooking i.e. due to breakdown of phytic acid at high temperature (Kakker, 1999). Reduction in trypsin inhibitor ctivity was due to denaturation of trypsin inhibitors during cooking at high temperature (Ramakrishna *et.al*, 2006). The reduction of phytic acid can takes place due to the high temperature of autoclaving which further leads to breakdown of phytic acid (Sharma and Kapoor, 1996).

Table 5: Examples of different cooked foods prepared from cereals and legumes

Cooking Methods	Example of food product
Roasting	Roasted chana, gram, peanuts, baby corn
Baking	Biscuits, cakes, crackers, pastries
Boiling	Lentils, boiled chickpeas, gram, peas
Frying	Fried rice, modak, dal baati, pakoda
Microwave cooking	Pizza, cake, sheera, halwa

Irradiation

Food irradiation is the process majorly associated with the food processing and preservation technology. According to FAO/IAEA, (2007) the traditional processing can increase the capability to enhance the shelf life of food products. As per the report irradiation is the process which helps to extend shelf-life of the products and makes the product safe for consumption. Such kind of products can subsidize the availability of food in various regions especially in the area of lacking of refrigeration. In addition,

irradiation process can lead to low microbial load in ready to eat food which can be beneficial for the patients suffering from immune-depressive diseases such as HIV/AIDS. Although, with the presence of number of benefits, some disadvantages are also associated with this method. Irradiation is responsible for the cause of nutritional losses at greater extent such as thiamine and ascorbic acid which are highly sensitive to irradiation process.

Table 6: Effect of irradiation on anti-nutritional factors

Cereals, pulses or legumes	% reduction in anti-nutritional factors by irradiation		Reference
	Phytic acid	Vit. B (nutrient)	
sorghum	40.37	85.7	Duodu *et. al*, 1999

In such study the thiamine content was increased due the use of decorticated sorghum endosperm meal. Sorghum contains rich concentration of vitamin B complex in aleurone layer as well as in germ part and decortication of tissues can cause nutritional loss of these nutrients in greater extent (Duodu *et. al*, 1999).

Blanching

Blanching is a process of immersion of food substance in hot water containing salt and boiling for sometime .It inactivates many of the enzymes like polyphenol oxidase, trypsin inhibitor etc and also dissolves many of the anti-nutrients in blanching water.

Table 7: Effect of blanching on anti-nutritional factors

Cereals, pulses or legumes	% reduction in anti-nutritional factors by blanching						Reference
	Trypsin inhibitor	tannin	alkaloids	saponins	phytate	HCN	
Asparagus beans (8 min)	5.3	0.226	0.32	0.36	0.17	8.22	Nwosu, 2010

Trypsin inhibitor content may be decreased due to leaching out of these inhibitors in hot water (Nwosu, 2010).

Fermentation

Fermentation is the process which is widely used across the world. Number of fermented foods is the part of world's diet where the cereals are significant substrates of fermentation process. Fermentation process makes changes in the chemical, functional and physiological properties of food which further leads to the change in the quality measures such as flavor, texture, nutritive value as well as it also helps to

reduce the anti-nutritional factors present in certain food which further improves the nutritional quality of the product. Natural fermentation can enhance the availability of lysine and relative nutrients present in cereals. Bacterial fermentation enhances the bioavailability of essential amino acids due to the increased proteolytic activity as compared to yeast fermentation because it can further cause the degradation of carbohydrates present in food. The content of starch and fibre also get decrease due to the fermentation of cereals (Ahmed *et.al*, 2010).

Fermentation alters the mineral content of the product by:

- Hydrolysis of the chelating agents like phytic acid, during fermentation leads to improve bioavailability of minerals.
- Producing certain enzymes like lactic acid fermentation produces enzyme phytase and hence is very useful in reducing phytate content in cereals
- Variation in the cereals take place during fermentation process depends on the method of fermentation as well as the raw material used for fermentation. In general the content of vitamin B takes place during fermentation process.

Table 8: Effect of fermentation on anti-nutritional factors

Cereals, pulses or legumes	% reduction in anti-nutritional factors by fermentation			Reference
	Phytic acid	Polyphenols	tannins	
Pearl millet	67.5	21.0	-	Ahmed *et.al*, 2010
Pearl millet	66.0	45.9	34.8	Eltayeb *et.al*, 2008
Pearl millet	65.36	59.09	16.2	Eltayeb *et.al*, 2007
Finger	-	30.1 (incr.)	-	Sripriya *et. al*, 1997

The reduction in phytic acid and increase in non phytate and inorganic phosphorus was due to teh production of enzyme phytase during fermentation, which released the bound minerals from phytic acid and increased their bioavailability (Ahmed *et.al*, 2010). Fermentation for 24 hrs increases the bioavailaibility to greater extent as compared to 12 hrs. The reason may be that this is the log period for the enzyme in which its production was more and hence more phytic acid was available. The release of phytase enzyme released by micro-organism further contributes in the reduction of phytic acid content (Eltayeb *et.al*, 2008). During the fermentation process the microbial enzyme activity increase which leads to the increase in solubility of proteins and free amino acids (Eltayeb *et.al*, 2007). Increase in carbohydrates was due to hydrolyzation of polysaccharides, which were hydrolysed due to fermenting microbes possessing alpha and beta amylases. The content of organic acid increases due to the microbial activity which converts

some of the carbohydrate content into the organic acids like lactic acid, acetic acid etc. (Sripriya *et. al*, 1997).

Traditional fermented products

Some of the traditional fermented products from cereals, pulses & legumes are:

Table 9: Traditional fermented products

Sr no.	Starting material	Predominant micro organism	Fermented product
1.	Rice and black gram	L.mesenteroides, S.faecalis, P.cerevisiae	idli
1.	Soybean, Wheat, rice	Aspergillus oryzae, Hanensula and Saccharomyces	Soy sauce
2.	Rice	Mucor, Rhizopus and yeasts	Ragi
4.	Rice	Monascus purpureus	Ang-kak
5.	Soybean	Rhizopus oliporus	Temph
6.	soybean	Mucor spp.	Su-fu
7.	soybean	Bacillius subtilis	Natto
8.	Soybean, rice and other cereals	Aspergillus oryzae, Saccharomyces rouxii	Miso

Sprouting

Sprouting is the process which increases the bioavailability of minerals, vitamins and amino acids. During the sprouting process some desirable changes takes place due to the conversion of complex compounds into simpler form as well as transforms into essential and non-essential constituents. Sprouting is the process which further increase the activity of hydrolytic enzymes, leads to the enhancement of the content of proteins, fats, amino acids, total sugars, vitamin B complex and at the same it decrease the content of dry matter, starch and anti-nutritional factors. The enhanced content of protein, fat, fibre, ash takes place due to the disappearance of starch whereas the improvement of the content of amino acids

composition, sugars, vitamin B complex as well as reduced content of anti-nutritional factors such as phytate, protease inhibitors take place due to the metabolic effect of sprouting process.

Table 10: Effect of sprouting on anti-nutritional factors

Cereals, pulses or legumes	% reduction in anti-nutritional factors by sprouting				Reference
	Phytic acid	Polyphenols	Tannins	Trypsin inhibitor	
Guar seeds	41.9	28.0	33.9	-	Ahmed *et.al*, 2006
Pea seeds (solara)	42.8	69.2	25.5	-	Alonso *et. al*, 1998
Pearl millet	66.1	4.0	1.84 (increase)	-	Eltayeb *et.al*, 2007
Pearl millet	-	77.3	34.2	-	Nithya *et.al*, 2007
Indian beans (32 hrs)	-	70	52.9	83.4	Ramakrishna *et.al*, 2006
Finger millet	-	10.5	-	-	Sripriya *et. al*, 1997

Increment in tannin content takes place due to the solubilisation of insoluble tannins, which can further cause the migration of soluble tannin from seed coat to the core of the seed (Ahmed *et.al*, 2006). The specious enhancement in protein can be recognized for the utilization of carbohydrates as energy sources for the sprouts. The enhancement in digestibility occurs due to the pre-digestion of starch content by amylolytic enzymes (Eltayeb *et.al*, 2007). The reduction of the phytic acid takes place due to the leaching out of phytic acid during hydration process and due to the activation of phytase enzyme during germination. However, the reduction in polyphenols may be occurs due to the presence of phenolic oxidase in germination process (Ramakrishna *et.al*, 2006). The content of amylose enhanced due to the improved activity of amylase enzyme during germination process. Amylase can promoted the hydrolysis of starch molecules and hence starch content was decreased and total and reducing sugar content was increased. Soluble protein content may be increased due to hydrolysis of proteins by the enzymes produced during sprouting (Eltayeb *et.al*, 2007).

Malting

Malting is the process of germinating the grains and then quickly halting from the germinating part to drying part with hot air. It produces the enzymes which are further responsible for the breakdown of

starch into simple sugars and hence increases starch digestibility. It also develops other enzymes such as protease etc. to break down protein molecules.

Extrusion

Extrusion is the process of forcing the food under one or more of the conditions of shaping, mixing, cooking, puffing or dying & cutting. Extrusion causes denaturation of proteins and gelatinization of starch. It also reduces many of the anti-nutritional factors.

Table 11: Effect of extrusion on anti-nutritional factors

Cereals, pulses or legumes	% reduction in anti-nutritional factors by extrusion			Reference
	Tannins	Trypsin inhibitor	hemagglutinins	
Pea seeds (solara)	83.6	95	100	Alonso *et. al*, 1998

The drastic reduction in tannin could be attributed due to the devastation of condensed tannins at high temperature. It was suggested that the reactions which involves the deamination, splits the covalent bonds, like hydrolysis of peptide bonds at aspartic acid residues, and interchange or breakdown of disulfide bonds, could be involve in the thermal inactivation of trypsin inhibitor activity.

Dehulling and Debranning

Some antinutrients are present in the hull or bran of cereals, legumes or pulses. For e.g. Phytate is generally present in the hull of seeds and nuts, tannins are generally present in the bran. So these anti nutrients can be removed by dehulling and debranning.

Table 12: effect of dehulling & debranning on anti-nutritional factors

Cereals, pulses or legumes	% reduction in anti-nutritional factors by dehullung & debranning			Reference
	Tannins	polyphenols	Phytic acid	
Guar seeds	85.7	12.0	20.5	Ahmed *et.al*, 2006
Pea seeds (solara)	20.7	25.6	12.7 (incr.)	Alonso *et. al*, 1998
Pearl millet	2.0	12.5	72.6	Etlayeb *et.al*, 2007

Since most of the tannin is located in the testa, its physical removal reduced the tannin content (Ahmed *et.al*, 2006). Proteins are naturally present in the cotyledon fraction; therefore, the removal of the seed coats could cause the relative increase in protein content of food (Alonso *et. al*, 1998). Similarly, the

reduction in polyphenols present in pearl millet was found due to the removal of outer layer, which is further reported to be good source of polyphenols (Etlayeb *et.al*, 2007).

Grinding

Grinding is the process which prominently rises the surface area of the food substances whereas breaks up the cellular structure and further releasing the enzymes which are important for the transformation to come whether grains are finely grinded or coarsely grinded has impact on anti-nutritional factors of food especially in case of grains. The effect has been determined by various people as given below in table:

Table 13: Effect of grinding on anti-nutritional factors in food

Cereals, pulses or legumes	% reduction in anti-nutritional factors by grinding			Reference
	Phytic acid	Polyphenols	Amylase inhibitor activity	
Finely grounded	34.4	50.8	87.0	Sharma and Kapoor, 1996
Coarsely grounded	32.1	46.5	86.0	

Lower content of phytic acid in finely grounded pearl millet could be found due to the more effective action of microbes for the presence of smaller particle size.

Conclusion

Plants are the basic source of food in human diet which contains several nutrients in different amounts which are further responsible for the growth, development and normal bodily functions. Along with these essential nutrients some of the chemical compounds are also present in food which present in abundance but adversely affect the bioavailability of various nutrients. These are naturally occurring secondary metabolites due the metabolic reactions of plants itself as well as due to the metabolism of different micro-organisms. Presence of these anti-nutritional factors enhances the unavailability of essential nutrients and further leads to various nutritional problems. There are certain traditional as well as processing methods available which can further improve the quality of food as well as reduce the concentration of these anti-nutritional factors. All these methods have the individual effect on the quality of food but use in combination can be able to decrease the anti-nutritional factors in abundance which further leads to the enhanced quality of food. These methods can improve the bioavailability of nutrients

and some desirable changes related to the physiological, biological and nutritional components can be improved which enhance the shelf-life and acceptability of the product.

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