Review Article

A Perspective of Anti-nutritional Factors in Cereal Grains and Legumes with Health Hazards and Potential Elimination Strategies

ABSTRACT

The nutrients contained in cereals and legumes play pivotal roles as building blocks of living organisms, yet these contain a few groups of anti-nutritional factors (ANFs) that minimize the quality of nutrition by nature or other indirect mechanisms. A good number of research have been conducted to unscrew the harmful effects of anti-nutritional factors and the present review discussed the downsides of cereals and legumes used in animal feed and human consumption along with the means of subsidence to increase the quality of nutritional values.

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Keywords: Nutrition, Cereals, Legumes, ANF, Food, Feed

1. INTRODUCTION

For the survival of living organisms and to maintain the processes of growth and healing of damaged tissues, nutrition is the precondition of health (Mattila *et. al*., 2018). Cereals and legumes play an important role in human nutrition and animal feeding. Cereal grains such as rice, wheat, and maize provide ample amounts of carbohydrates, proteins, and vitamins with dietary fiber which are very important for bodily function (Nadeem *et. al.*, 2010). For vegetable protein sources legumes such as soybean, rapeseed, mustard seed, lentil, chickpea, cranberry beans, etc. are widely cultivated throughout the world. Though cereals are deficient in lysine but main source of calories in the South Asian diet contains complex vitamin B with sulfur-containing amino acids like methionine and cysteine which are limited in legumes (Concon 1975 and Gulzar 2011). With vitamins and calories, cereals are also rich in minerals such as zinc and iron (Temba et. al., 2016). Tharanathan and Mahadevamma (2003) legumes are one of the highest crops containing protein, carbohydrates, dietary fiber, and minerals. Legumes are an excellent source of protein and essential amino acids like lysine. Legume consumption has a pivotal role in the reduction of blood pressure (Polak *et. al*., 2015). Soybean is one of the high-ranking legumes for feed and food production and a major source of vegetable protein and edible oil (Gu C. *et. al*., 2010). For containing relatively high protein and suitable amino acids, it has a universal acceptability in animal feed. Mustard seed or rapeseed is another crop from the Leguminosae family which is cultivated for edible oil and protein meals. The amino acid profile of protein in rapeseed is well balanced and the essential amino acids are far better than cereals (Thanaceelaan V., 2013). In tropical and sub-tropical climates peanut or ground nut is a seed crop that comes under the leguminous family. It is consumed as a component of formulated or processed foods, roasted nut, and edible oil extraction and the ground nut seeds are good sources of essential minerals e.g., calcium, phosphorus, magnesium, and zinc with vitamin B1 (Stalker 1997 and FAO 2002). Faba bean, lupin, rapeseed, flaxseed, oil hemp, buckwheat, and quinoa are among the most promising protein-rich plants of legumes, oil crops, and pseudo cereals may offer good alternatives to soybean and contribute to the environmental and economic sustainability of local agricultural production (Mattila *et. al*., 2018). Cereals and legumes are staple food crops all over the world and have an important role in animal feed but contain some anti-nutritional factors. According to Samtiya *et. al.,* (2020) grains and legumes not only contain high amounts of macro and micronutrients but also some antinutritional factors that combine with nutrients to reduce nutrient bioavailability. In the case of animal feeding antinutritional components are found in traditional or non-traditional roughages, cereals, legumes, shrubs, etc. in green as well as dry-matter basis (Ramachandra *et. al*., 2019). According to (Makkar H., 1993) these harmful substances also called anti-quality factors can be divided into four categories: (I) affecting protein utilization and depressing digestion (protease inhibitors, tannins, saponins, lectins, etc.), (II) metal ion scavengers (oxalates, phytates, gossypol pigments, glucosinolates), (III) antivitamins, (IV) mycotoxins, mimosine, cyanogens, nitrates, alkaloids, photosensitizing agents, isoflavones, etc.). Cereals and legumes are very rich in minerals but for the presence of antinutritional factors, the bioavailability of these minerals interferes. Cereals mostly contain phytates, and enzyme inhibitors but some cereals like sorghum and millet contain a large number of polyphenols and tannins (Salunkhe et al., 1990). Among cereals maize is one of the most important crops and contains some antinutritional factors. It has been reported by Okafor UI et. al., (2018) that most of the maize varieties contain tannins and phytic acids which make different nutrients unavailable to the human or animal body. Like other cereals, legumes are also rich in sources of different antinutritional factors that affect the nutritional value, utilization, and digestibility of protein. Soybean meal is a major source of plant protein, and it contains many kinds of anti-nutritional factors such as trypsin inhibitor, lectin, α-amylase inhibiting factor, goitrin, soybean antigen, etc. (Liener IE, 1994). The antinutritional factors present in soybean meals not only affect the digestibility and nutritional value but also cause digestive and metabolic diseases with reduced performance traits (Sun, Z.W. and Qin, G.X, 2005). After soybean meal mustard seed or rapeseed meals are one of the main protein sources for animals. Despite the significant amounts of highly valued nutrients the utilization and marketing of rapeseed meal is very limited due to the presence of glucosinolates and others (G. Mejicanos et. al., 2016). Though glucosinolates are not harmful themselves directly, their hydrolytic products such as goitrogenic and potential hepatoxic compounds e.g., isothiocyanates thiocyanates are very harmful to both animals and humans (T. Chun and B. Brian, 2004). The antinutritional factors present in food or feed ingredients are highly deleterious for health but there are several ways to reduce their activities. Some of the antinutritional factors heat stable or heal labile, so, different traditional and up-to-date ingredients or food processing techniques such as soaking, fermentation, heating, cooking, puffing, extrusion, etc. can reduce antinutritional factors in food or feed ingredients. According to Handa et. al., (2017) traditional processing techniques not only reduce the antinutritional factors but also increase protein digestibility and improve the biological value of cereal crops. In recent years several reviews have been done about antinutritional factors in food and feed and the aim of this review is to assess updated scientific information for potential health benefits and adverse effects of antinutritional factors with reduction strategies.

2. ANTINUTRITIONAL FACTORS AND ANIMAL NUTRITION

Cereals and legumes are used as sources of different types of nutrients for animal feeding. Along with nutritional sources, there are several types of anti-nutritional factors present in these ingredients. These factors include phytates or phytic acid, protease inhibitors, lectins, saponins, tannins, gossypol, amylase inhibitors, glucosinolates, antivitamin factors, metal binding agents, goitrogens, etc. They tend to antagonize nutrition, either by causing toxicity or secondary nutritional deficiency by chelation of important nutrients that are necessary for animal nutrition.

2.1. PHYTIC ACID OR PHYTATE

A six-fold dihydrogen phosphate ester of inositol naturally found in the plant kingdom and phytates mixed cation salt of phytic acids are generally known as myo-inositol-1,2, 3,4,5,6-hexakis dihydrogen phosphate, which is present in foods at various levels ranging from 0.1 to 6.0% (Gupta et. al., 2015). In the structure of phytic acid, there are 6 phosphate groups with 12 hydrogens and at physiological pH, phosphates are partially ionized. The negatively charged sites bind potassium and magnesium and in these cases, phytates contain 50-80% of the total phosphorus of the seed (Lott et. al., 2000). Phytic acids affect the bioavailability of minerals and hinder the activity of enzymes that are essential for protein degradation in the small intestine and stomach (Chan et.al., 2007; Kies et. al., 2006). At low pH, phytic acids bind with protein complex and reduce the stability of trypsin which affects the protein digestibility (Caldwell, 1992). According to Francis et. al., (2001), common feedstuffs such as soybean and rapeseed meal contain 10-15 and 50-75gm phytate per kg whereas Hossain and Jauncey (1993) reported that 5-10gm phytic acids per kg diet caused slow growth in fish. Phytate or phytic acid content can be decreased by several techniques. Soaking and cooking can greatly reduce phytic content and during germination, phytic acid is degraded by some native enzyme of seeds (Larsson and Sandberg 1992; Vadivel and Biesalski 2012). Milling is one procedure that separates the bran or aleurone layer from the seed where phytates are present, but this may remove some minerals (Gupta *et. al.* 2015).

2.2. ENZYME INHIBITORS

Enzyme inhibitors are a set of substances in size of small and large molecules of proteins that bind with enzymes and reduce their activity (Srinivasan B, 2022). Proteinase enzymes play various roles in enhancing the nutritional and functional properties of protein molecules (Salas *et. al*., 2018) Protease inhibitors, α-amylase inhibitors, lipase inhibitors, and lectins are found in legumes which could lead to low bioavailability of minerals with poor absorption and digestibility (Bajpai *et. al*., 2005). Most of the legumes contain protease inhibitors which reduce the proteolytic activity in the gastrointestinal system. According to Nørgaard et al. (2019), the presence of protease inhibitors in diets can interfere with the activity of protease enzymes within GIT. Commonly, most proteinase inhibitors observed in soybeans belong to either the Kunitz inhibitor family or Bowman-Birk inhibitors (Liu 1997). These inhibitors may bind one trypsin and one chymotrypsin at one time or at the same time. The Kunitz inhibitors only bind with trypsin, but the Bowman-Birk inhibitors inhibit both trypsin and chymotrypsin (R. Ramachandra *et. al*., 2019). According to the study of Liener. I. (1980) In the intestine, firstly inhibitors form a stable complex and stimulate secretion of pancreozymin-cholecystokinin (PZ-CCK) from the gut cell wall which stimulates pancreatic tissue to secret trypsin as well as stimulates the gall bladder to empty its content into the intestine. In young chickens, developed hypertrophy of the pancreas has been seen due to protease enzyme. Trypsin inhibitors interfere with the availability of Methionine and reduce the apparent digestibility of protein and lipids (R. Ramachandra, 2019; Berg-lea *et. al*., 1989). Trypsin inhibitors can be affected by temperature, duration of heating, moisture level, and particle size. It has been reported by Patterson *et. al.*, (2017) that boiling or cooking highly improved the nutritional value of foods by reducing their antinutritional (e.g., tannins and trypsin inhibitors) contents.
Amylase inhibitors affect the activity of α-amylase enzymes in the gastrointestinal tract of humans and animals. The function of the α-amylase enzyme is breaking down carbohydrates such as polysaccharides into oligosaccharides. The inhibitors present in cereals and legumes affect the activity of enzymes and delay carbohydrate digestion by increasing the absorption time. Bhutkar and Bhise (2012) have reported that the increasing time of carbohydrate digestion slows the glucose absorption rate and that affects the normal postprandial plasma glucose level.
Lipase inhibitory function is the result of the prevention of the normal function of lipase by binding with the surface of the micelle substates and affects the auto digestion of lipids (Wang and Huang, 1984; Gargouri *et. al.,* 1984).

2.3. LECTINS

Lectins were previously known as agglutinins or hemagglutinins, first discovered in plants but later also found in microorganisms and animals (Stillmark, 1888). These are a group of soluble heterogeneous glycoproteins that can easily attach to red blood cells and cause agglutination. Consumption of foods containing lectins may impair the transport and hydrolytic functions of enterocytes (Krupa, 2008). Though lectins are found in the highest concentration in seeds, other vegetative organs such as leaves, stems, barks, roots, and flowers may contain some amount. Lectins are resistant to digestion by pancreatic juice and like to bind with intestinal epithelial cells which causes damage to the intestinal tract and leads to impaired nutrient absorption (Muramoto, 2017). In a study, an independent mechanism is responsible for intestinal growth in rats by releasing CCK hormone and increasing the growth of the pancreas (Herzig *et. al.,* 1997). A strong relationship has been found between gut inflammation and joint inflammation and approximately 20% of patients with inflammatory intestinal disease (Crohn's disease) are complicated by joint inflammation (Hazenberg *et. al*., 1992). Lectins are heat resistant but can be destroyed by moist heating such as cooking because lectins are water soluble and typically found in the outer surface of a food, so water can expose them (Petrosski W. and Minich DM., 2020).

2.4. GOSSYPOL

It is a natural phenol which is a highly toxic substance for simple stomachs that can be found in the cotton seed derivatives. Gossypol can occur either in free form or gossypol protein complex. Rabbits and pigs are more susceptible than poultry and ruminants. Ruminants are resistant to gossypol because of the formation of stable complexes with soluble protein in the rumen. The adverse effect of gossypol includes reduced hemoglobin content, cardiac irregulatory, and accumulation of fluid in body cavities with a negative impact on certain liver enzymes (R. Ramchandra *et. al*., 2019).

2.5. TANNINS

Tannins are a class of polyphenolic biomolecules weighing more than 500 Da. These are secondary compounds that are found in plant leaves, fruits, and bark which bind with precipitate protein and various organic compounds including amino acids and alkaloids. Joye (2019) has reported that tannin ingestion causes complex formation and reduces the activity of digestive enzymes which leads to protein indigestibility. Tannin not only forms complexes with proteins but also releases different types of toxic compounds into the stomach (Kumar, 1992). A high concentration of tannin lowers cellulose activity and affects the digestion of crude fibre which reduces the digestibility of dry matter and nutrients (R. Ramchandra *et. al*., 2019). Tannin content can be reduced by both physiological and chemical processes. Tannin mostly accumulates in the seat coat, so by removing the bran can reduce its content. Tannin complexing agents, alkaline, formaldehyde, and organic acid solvents depress the bond of the tannin complex and lower the content.

2.6. SAPONINS

Saponins are non-volatile glycosides containing sugar in their structure. They are naturally produced as a foam-producing moiety of steroid or triterpenoid by many plant species including groundnut, lupin, lucerne, soybean, etc. (Kiranmayi, 2014). Saponins Have the property of interacting with monosaccharides and the cholesterol group of erythrocyte membranes which leads to hemolysis (Fleck *et. al*., 2019). Previous studies have demonstrated that saponins depress the digestion and metabolism of nutrients. According to Ali *et. al*. (2006), saponins showed inhibitory activity of amylase enzyme. From the study of Cheeke (1971), it has been found that saponins can interfere with sterol activity and absorption by forming complexes with sterols and fat-soluble vitamins. A diet containing triterpenoid saponins reduces the absorption of vitamins A and E when fed to chicks (Jenkins and Atwal, 1994). Saponins can be degraded by the heat process, but rumen microbes sometimes degrade saponin in ruminants (R. Ramchandra *et. al*., 2019).

2.7. GLUCOSINOLATES

Glucosinolates are sulfur-containing secondary metabolites of almost all plants of Brassica vegetables. They constitute a natural class of organic compounds that contain sulfur and nitrogen which are not toxic themselves, but their hydrolytic products are. Brassica plants contain the enzyme myrosinase which cleaves off the glucose group from glucosinolates and produces harmful products such as isothiocyanates and thiocyanates (T. Chun and B. Brian, 2004). Glucosinolates referred to as goitrogens and the products of hydrolysis of it with endogenous thioglucosidase are more harmful than the intact one (E. Underhill & D. Kirkland, 1980). These products from hydrolysis produce health hazards on different animals depending on the type and level present in the feed. Non-ruminant and young animals are more sensitive than ruminant and adult animals with health and production effects include depressed growth and production, reduced palatability and feed intake, hypothyroidism, and other disturbances (A. Aachary and U. Thiyam, 2012). Pigs are more susceptible to being affected severely compared to other non-ruminants such as poultry and fish. According to (MK Tripathi and AS. Mishra, 2017) young ruminants can tolerate a total of 4.2µmole g^{-1} whereas pig 0.78, rabbits 7.0, poultry 5.4, and fish 3.6 µmole g-1 diet. Different physical methods including steam heating, roasting, milling, microwave treatment, treatment with immersion water, etc. The simplest way is treatment with water (1:6) for 15-25 minutes can reduce glucosinolates by 98% and different solvents like ethanol, carbinol, acetone, and water decrease the lower molecular weight of glucosinolates (H. Fauduct *et. al.,* 1995). Drying improves the volatilization of isothiocyanates and the biological method usually fermentation by using microorganisms and enzymes reduces the toxicity of glucosinolates (Shcone F. *et. al*., 1996).

3. EFFECTS OF ANFS ON HUMAN HEALTH

Antinutritional factors and toxic substances are present in food substances which limit the availability or function of nutrients. Vegetables and fresh food become a major concern because of the high level of antinutritional factors associated with health problems. According to (Soetan KO, 2008) antinutritional factors are generated naturally in plants but by different mechanisms, they work contrary to optimum nutrition. The presence of cyanogenic glycosides, protease inhibitors, lectins, tannins, alkaloids, and saponins in food may cause harmful effects like decreasing digestibility, increasing nitrogen content in feces, formation of kidney stones, allergic reactions, disturbance in mineral metabolisms, etc. (Habtamu Fekadu Gemede & Negussie Ratta., 2014; Abhishek Thakur *et. al*., 2018). According to Cordain L. et. al., (2000), Some antinutritional factors have some positive impacts on immune modulation such as dietary lectin has an influence on both enterocyte and lymphocyte structure and function which reduces peripheral antigenic stimulation and reduction of disease symptoms in rheumatoid arthritis. Some research showed that using a low level of phytate, lectins, tannins, amylase inhibitors, and saponins helps to reduce blood glucose and insulin responses with the reduction of cancer risks (Habtamu Fekadu Gemede & Negussie Ratta., 2014). Balancing the tolerance level of antinutritional factors with different kinds of processing and treatment is effective for animal and human health.

4. CONCLUSION

In most practical cases, the deleterious effects of anti-nutritional factors have been overlooked hindering the desired quality of nutritional factors present both in cereal grains and legumes. Present review forwarding the immense importance of eliminating the anti-nutritional factors through appropriate processes.

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