IMPACT OF PROCESSING ON NUTRITIONAL AND ANTINUTRITIONAL FACTORS OF LEGUMES: A REVIEW

Yasir Abbas[*1], Asif Ahmad[1]
[1] Department of Food Technology, PMAS-Arid Agriculture University Rawalpindi, Pakistan
Cell: +92 3435576172
Email: yasirmirza90@yahoo.com

Abstract
Legumes grain seeds are broadly developed and consumed all over the world. Legumes are considered as an important constituent of human diet, economical source of energy, proteins, carbohydrates, fiber, B-group vitamins and minerals. Beyond these nutritional facts legumes are rich in plant bioactive compounds like phenolic contents and flavonoid content which possess very beneficial impacts on human health. However, few types of antinutritional factors found in legumes that usually inhibit the bioavailability of many nutrients. Processing is the technique to develop the sensory value, nutritive value, physical attributes and decreases antinutritional factors commonly found in the legumes grain seeds. Different processing techniques commonly applied to legumes before consumption some of those are soaking, boiling, microwave cooking, extrusion, autoclaving, germination etc. These processing shown inhibition or reduction of antinutritional factors such as tannins, trypsin inhibitors activity, phytic acids, hemagglutinins etc. This review focuses on the effect of processing such as soaking, boiling, autoclaving, microwave cooking, germination, fermentation and extrusion on nutritional composition and anti-nutritional factors of legumes. This review also covers the legumes potential health effect and constrict of anti-nutritional factors on human health. Furthermore, the utmost reduction of anti-nutritional factors and maximizing the nutritional properties of legumes grain are investigated.

Keywords: Antinutrtional factors, Health benefits, Legumes, Nutritional compositions, Processing

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1. INTRODUCTION

Legumes are broad diversity of crops that are included in flowering plants producing seeds in pods that are often cultured for food and feeds. Legumes ranked as 3rd largest family of flowering plants having more than 19500 species and over 750 genera (Lewis *et al.*, 2016). The term legumes has been mainly derived from Latin word 'legumen' which mean the seeds that are harvested in pods. In some regions, legumes are considered as pulses, pea, or member of bean family. The edible seeds of legumes play an important role in diet providing essential nutrients with medium to high calories value (Aykroyd and Doughty, 1982). A big variety of legumes exists around the world as black gram (Vigna mungo L.), red gram (pigeon pea), broad bean (Vicia faba L.), chickpea (Cicer arietinum L.), cowpea (Vigna unguiculata L.), green gram (Phaseolus aureus Roxb), horse gram (Dolichos biflorus), field bean (Dolichos lablab), and many more (Tharanathan and Mahadevamma 2003). These are inexpensive, valuable and easily available source of good proteins, and are most commonly consumed in South Asian regions including Pakistan, India, and Bangladesh.

If we have a look on nutrition composition of available legumes, these are rich sources of carbohydrates, proteins, fats, minerals, fiber, antioxidants and vitamins; these beans are considered low in fat and are cholesterol free but some legumes are rich in oil such as soybean (Karmas and Harris 2012; Hayat *et al.*,2014aS; Hayat *et al.*, 2014b). Presence of structural carbohydrates and balanced amino acid profile make it valuable for nutritionists and health professionals (Tharanathan and Mahadevamma 2003; Ghadge *et al.,* 2008). Different nutritional constituents present in the beans have useful physiological effects in humans and animals (Jenkins *et al.*, 1983; Hayat *et al.*, 2014a). Due to its high protein contents these are considered as meat of poor man, the researchers working on identifying and evaluating legumes as an alternative protein source of crop in future (Martín-Cabrejas *et al.,* 2008). The protein contents in legume seed range from 17% - 40%, contrasting with cereals (7-13) %, and equal to the protein contents found in meats (18–25) % (Swaminathan 1988). In comparison to cereal, legumes seeds are rich in lysine and poor in sulphur containing amino acids, such as methionine and cysteine. It has been also reported that the germinated legumes are rich in vitamin C and there is increase in riboflavin and niacin contents upon germination (Swaminathan 1988).These are also important source of dietary minerals provide all fifteen essential minerals that required for human (Grusak 2002).

One of the problem associated with most of the legumes are presence of antinutritional factors such as trypsin inhibitor, protease inhibitor, phytic acid, saponin, tannins, polyphenol and lectins. These antimetabolic or antiphysiological substances and flatulence compounds are the major limitations for its extensive use at household and industrial level (Adebowale *et al.,* 2005). Some other antinutritional factors such as polyphenols, phytates, enzyme inhibitors (trypsin, chymotrypsin, a-amylase) and hemagglutinins also responsible to limit its use (Alonso *et al.,* 1998; Fernández *et al.,* 1997). These antinutritional factors limit the nutritional properties and affect the digestibility of certain nutrients (Ramakrishna *et al.,* 2006).

Although legumes contain all the major constituent i.e. proteins, starch and dietary fiber which could be involved in lowering triglyceride level and serum cholesterol level in humans (Mazur *et al.,* 1998), however the mechanisms by which such types of effects are induced are unknown. Different studies shows that consumption of beans have high health beneficial and health implications regard to diabetes mellitus, obesity and cancer (Hawrylewicz *et al.,* 1995; Simpson *et al.,* 1981; Tsai *et al.,* 1987). The loss of nutrients occur during food preparation and processing, however the processor should limit these losses in order to enhance nutritional quality of food. Different processing techniques are required to inactivate or remove of antinutritional factors, thus enhancing the nutritional quality of legumes. The chemical and physical methods of processing of legumes include soaking, boiling, microwave cooking, autoclaving, extrusion cooking irradiation, fermentation and germination. Sometime a single processing treatment is not effective against antinutrients therefore combination of two or more methods are used (Sathe *et al.*, 1984b).

2. PROCESSING

Legumes go through several processes before they are used as plated items or as another food ingredient in food preparation. Thermal and chemical processing help eliminate or reduce unwanted components. Heat process is widely used for food preparation, the heat processing has both beneficial and detrimental effects on food products. A good example is that the protein found in legumes became more digestible by inactivating trypsin inhibitor. Temperature modification can alter the texture, flavor and appearance of food. Some other processing techniques such as dehulling, cooking, radiation, germination, roasting, fermentation, extrusion cooking and supplementing with various chemicals and enzymes are also effective to reduce the antinutritional components (El-Hady and Habiba 2003; Arif *et al.*, 2012). Following are the major processing techniques that are often used to reduce the unwanted substances.

2.1 Soaking

Many authors cited that soaking the bean prior cooking reduced the cooking time (Taiwo and Akanbi, 1997). Soaking allow the water to disperse in the protein fraction and starch granules which facilitate the protein denaturation and starch gelatinization, which soften the texture of beans (Siddiq and Uebersax 2012). Soaking the beans in water for 12-14 hours shown no effect on trypsin inhibitor of beans but it cause reduction in oligosaccharides, sucrose content with instance reduction in stachyose and reffinose in chickpea (Egounlety and Aworh 2003). Soaking process decreases the monosaccharide, disaccharides, and oligosaccharides in kidney beans. Change in the carbohydrate composition was seen less when the cooking water not drained off (Vidal-Valverde *et al.*, 1994). Phytate is water soluble so the legumes that soaked in water for overnight shown considerable removal of phytates in water in addition to that it also enhance the naturally occurring phytase (Kumar *et al.*, 2010). The loss in phytase may due to the leached down of phytase ion in soaking liquid under the influence of difference in chemical potential which manage the diffusion rate (Deshpande and Cheryan 1984). Addition of salt in water provide improved outcome as the legumes soaked in sodium bicarbonate solution reduced trypsin inhibitor and eliminates tannin contents in bean (Taiwo 1998). Soaking the peas in distilled water showed an increase in trypsin inhibitor (Wang *et al.*, 2008). Soaking legumes in simple tap water not reduce the tannin contents (Taiwo *et al.*, 1997).

2.2. Cooking methods

The cooking methods may greatly affect the nutrient contents of the food. The best method of increasing the nutritional properties of beans is by soaking the beans in salt solution and then cooking the soaked bean with fresh water (De León *et al.*, 1992). This make the legume soften and tenderize, as the beans contain some complex sugars that is indigestible by enzymes that result in gastric issues this problem can be solved by soaking the legumes seeds before cooking. Many researches shown that heat processing improved the absorption and digestibility of Fe (Wang *et al.*, 2010). So it provide both nutritional and health benefits, the health professionals encourage the greater consumption of beans (Messina 2014). Cooking of pre-soaked lentils seeds shown that trypsin inhibitor removed totally, reduced phytic acid and increase in catechin and tannin contents (Vidal-Valverde *et al.*, 1994). Cooking methods are considered highly effective for inactivation of protein based antinutritional factors by causing denaturation of trypsin, chymotrypsin, and some other heat sensitive compounds. This method also removed 30%-40% polyphenol in Phaselous Vulgaris (Bressani and Elías 1980).

2.3. Heat treatment

Legumes are rich in fiber associated anti-nutritional factors (named as phytate, oxalate and polyphenols) that reduced the bioavailability of minerals (Frolich 1995). So heat processing is one of an effective method that is widely used to inactive heat liable antinutritional factors. These heat treatments improved the nutritional value and quality of legume grains so that the heat treatments are used to enhance the protein quality of legume grains by inactivating the antinutrients factors, mainly the trypsin inhibitor and hemagglutinins (Sathe *et al.*, 1984a). The processing methods modify the nutritional composition and its availability in raw materials (Van der Poel 1990). In all over the world, legumes served as important raw materials used in development of beverage and cereal based food products. Use of legumes in combination with cereals compliment the amino acid profile of the final product which is otherwise deficient in cereals (Tharanathan and Mahadevamma 2003; Arif *et al.*, 2012; Hayat *et al.*, 2014a). Legumes are also consumed after processing into numerous products such as dhal, roasting and puffing into snacks, grind into flour for preparation of different other types of food products (Kurien 1981; Hayat *et al.*, 2014b).

Legumes may not consumed in raw form because of its bitter taste and antinutrients factors therefore different treatments are used to make the legumes consumable. The various techniques of processing improve the starch and protein digestibility and protein quality of legumes by destructing and therefore they can easily consumed or utilized (Alonso *et al.*, 2000). So before used in human diet legumes are being cooked. The heat treatment also causes considerable losses in vitamins, minerals and some other soluble solids (Barampama and Simard 1995).

2.4 Extrusion and Microwave cooking

The cooking takes place within an extruder where the product produces its own friction and heat due to pressure. Extrusion cooking has the advantages of versatility, high productivity, low operating costs, energy efficiency and very short cooking times. During the last decade extrusion cooking for legume processing has been developed quickly, and now this considered as a technology of its own right. There is little nutritional concern in extrude products, it prevents or reduce the nutritional destruction with improving starch and protein digestibility. Legume extrusion cooking would allow reduction of antinutritional factors and therefore improve the nutritional quality at a cost lower than other heating systems (e.g. baking, autoclaving, etc.) due to a more efficient use of energy and better process control with greater production capacities (Alonso *et al.*, 1998; Balandran-Quintana *et al.*, 1998). Extrusion was the best method to eliminate trypsin, chymotrypsin, a-amylase inhibitors and hemagglutinin activity without modifying protein content (Alonso *et al.*, 2000). The antinutrients that present in legumes was reduced significantly during extrusion cooking (El-Hady and Habiba 2003).
Microwave cooking is a heat treatment in which food is passes through microwave radiation. This cooking method is not studied extensively yet the microwave cooking reduce antinutritional factors in soybean thus improved the protein digestibility (Khatoon and Prakash 2004). Microwave have shorter processing time so it destruct antinutritional factors without disturbing its other nutritional qualities, there may also the vitamin retention have been seen in microwave cooking (El-Adawy 2002). However (Finot and Merabet 1993) reported that due to shorter time and smaller amount of water the microwave cooking affects the nutritional content then that of conventional methods.

2.5 Boiling and Autoclaving

Legumes are usually boiled in water at 100°C for few minutes the boiling process enhance the sensory properties of legume grains, make the seed tenderize and more acceptable for consumer. These techniques also help eliminate heat liable antinutrients (Bishnoi and Khetarpaul 1993). Khalil and Mansour (1995) reported that boiling process eliminated hemagglutinins in faba beans. In several cases the boiling process reduced the ODAP (oxalyldiaminopropionic acid) level according to (Padmajaprasad *et al.*, 1997) the oxalyldiaminopropionic level reduced by 90% when the grain been boiled.
Autoclaving cause significant reduction in trypsin inhibitor of chickpea (Alajaji and El-Adawy 2006) the β-ODAP content in milled grass peas was also found reduced compared to the raw seeds (Moges *et al.*, 2004) and found complete reduction in hemagglutinin (El Beltagy 1996).

2.6 Germination

Germination or sprouting of beans seed can be carried out by soaking the seed in ethanol for one minute (for sterilization) followed by keeping it in moist cotton until germination appear . The extensive enzymatic activity during germination process cause production of essential amino acid and absorbable polypeptides. The germinated seeds found enhanced protein digestibility while reduced antinutritional factors such as trypsin inhibitors, phytic acid (Ahmed *et al.*, 1995; Khalil and Mansour 1995) stachyose and raffinose (Mubarak 2005) that's why germinated legumes found better than un-germinated ones. Germination retain the minerals found in the seeds of mung bean (Mubarak 2005). Germination process is most effective against antinutritional factors in legume seeds, this process lowers the phytate contents in legumes depend upon the germinating method and the type of beans. Vidal-Valverde *et al.*, (1992) reported that germination process for 6 days shown considerable elimination in raffinose oligosaccharides in lentils.

3. NUTRITIONAL PROPERTIES OF LEGUMES

The legumes are rich sources of proteins, carbohydrates, dietary fibre as well as other macro and micro nutrients thus a great way to provide balance nutrition. Grain legumes also called pulses, which according to FAO are the crops that harvested for the dry seeds, due to its high protein contents it play an important role in the nutrition of many people. In many developing countries, they represent a major source of protein, especially among poorest population.

3.1 Nutritional composition of different legumes

The chemical compositions of legume grains have been discussed in numerous articles. Table 1 summarizes the chemical composition of different legumes seeds that are most likely used by human being. The composition is on a dry weight basis per 100g. Variation may occur for each value given with difference between cultivar, harvesting time, maturity and storage conditions.

Table 1. Nutritional compositions of various legumes seeds

Beans	**Protein**	**Crude Fiber**	**Ash**	**Fat**	**Ca**	**Zn**	**Fe**	**Ref.**
	gm/100g	gm/100g	gm/100g	gm/100g	mg/100g	mg/100g	mg/100g	
Lentils	26.1	6.3	2.8	3.2	97	4.3	7.3	(Hefnawy 2011; Iqbal *et al.*, 2006)
Chickpea	23.6	3.82	3.72	6.48	176	4.32	7.72	(Alajaji and El-Adawy 2006)
Kidney beans	28.12	3.09	4.29	1.33				(Khattab *et al.*, 2009)
Faba bean	29.2	9.9	4.2	1.1	220	11.7	6.6	(Duc *et al.*, 1999; Khalil and Mansour 1995)
Mung bean	27.5	4.63	3.76	1.85	84.0		9.7	(Mubarak 2005)
Green pea	24.9		3.6	1.5	110	3.2	2.3	(Iqbal *et al.*, 2006)

Cooking and other processing treatments bring about a number of changes in physical and chemical composition of legumes and other food materials. Cooking process also produces some physical and structural changes in dietary fibre components of numerous vegetables (Mann *et al.*, 1992) depending upon cooking methods the dietary fibre reduced to various extents. The term dietary fibre refers to non-starchy polysaccharides, starch and lignin (Lee *et al.*, 1992). Heat processing produced physicochemical changes in starch, proteins and other nutrient components of legumes, affecting its final nutritional properties (Jeunink and Cheftel 1979; Valle et al., 1994). There was also significant decrease in monosaccharides, disaccharides, reffinose and oligo saccharides in kidney and chickpea after cooking and soaking (Vidal-Valverde et al., 1993).

4.1 Effect of processing on proteins quality

In 2001 FAO reported that protein-energy malnutrition became a widespread problem throughout the world especially in developing countries and has both health and economic concerns (FAO/WHO, 2001). Too much costs of animal proteins limited the supply of animal proteins as food to the poor people who cannot afford these highest costs thus need research efforts towards the study of food properties and potential characteristics of protein from locally available food crops, especially from under-utilized or relatively neglected high protein oilseeds and legumes (Enujiugha and Ayodele-Oni 2003). Legumes are considered the major source of dietary proteins ranging from 20 to as much as 40 g/100 g dry matter (Norton et al., 1985).

(Khattab *et al.*, 2009) reported that different processing treatments such as soaking, microwave cooking, boiling and autoclaving increased the total essential amino acids. Heat treatments shown significant reduction in protein content and modification in globulin structure, the treatment also affects the amino acids such as arginine, cysteine, lysine, methionine, tyrosine and leucine in chickpeas (Clemente *et al.*, 1998). Abdel-Rahman (1983) suggested that the amino acid loss may be minimized by pressure cooking for 1 hour.

4.2 Effect of Processing on Minerals and Vitamins

Legumes are wide source of dietary minerals such as phosphorus, potassium, calcium, sulphur, the calcium content ranges from 120 to 260 mg/100 g dry mass (Chavan *et al.*, 1987). However cooking treatments leached down mineral contents in water during at different ranges therefore processing treatments reduced the mineral contents in different legumes seed (El-Adawy 2002). De-hulling and soaking showed greatest retention of minerals with relation to any other processing techniques. The germination treatment causes loss of divalent metals calcium, iron, and zinc due to its binding to protein and formation of phytate cation protein complexes (Lee and Karunanithy 1990). However, El-Adawy (2002) reported that germination process retain minerals contents in chickpeas seeds.

B-group vitamins are mainly found in legume seeds; although vitamins are losses during heat processing these losses may due to a leaching, chemical destruction or combination of both. As compare to other treatments microwave cooking improved the retention of vitamins. Conventional cooking in vegetables caused higher loss of vitamins such as in thiamin, riboflavin and ascorbic acid (Uherova *et al.*, 1993).

4.3 Effect of Processing on Carbohydrate Fraction

Different methods or treatments have different effects on the composition. Cooking of chick peas and beans increased the dietary fiber namely cellulose and lignin, these also increased after germination process. However in lentils sprouting decreased the starch contents but improved the starch digestibility (Vidal-Valverde and Frias 1991). Soaking and cooking treatments shown considerable decreases in monosaccharide, disaccharides, and oligosaccharides however boiling and pressure cooking not affect the sugar composition of chickpea and lentils (Vidal-Valverde *et al.*, 1993). Germination, low dose radiation, extrusion, cooking and fermentation processes also reduced the oligosaccharide in legumes (Vidal-Valverde *et al.*, 1998). Dehydration process transform the polysaccharides and oligo saccharides into monosaccharides fractions through hydrolysis of glycosidic linkage, thus reducing the percentage of polysaccharides in beans (Martín-Cabrejas *et al.*, 2008). Dietary fiber level and starch in legumes was affected by processing, dehydration process increase soluble dietary fiber, other processes improved the digestibility of starch (Aguilera *et al.*, 2009) but these may also depend upon the type of legumes seed as well as the type of treatments that were applied.

Different heat treatments extremely decreased the starch content in most of the legumes. After heat processing starch reduced by 43-56 % in chick peas, black gram, horse gram and pigeon peas (Jood *et al.*, 1986; Kataria *et al.*, 1990). While it dropped to a value of 17-23% in mung beans and black gram followed by cooking and presoaking treatment. Germination process in faba bean and autoclaving lima beans for 15 minutes shown the decreases in starch contents, which were accordance to the effects that observed by other researchers (Ologhobo and Fetuga 1988; Vidal-Valverde and Frias 1991).

4.4 Effect of Processing on Phytochemicals

Polyphenols presence in legumes possess anti-carcinogenic and antioxidant properties (Gamez *et al.*, 1998) as the antioxidant scavenge the free radicals and reactive oxygen species (ROS) and can be very important in inhibiting the oxidative mechanisms that may lead to different diseases (Cardador-Martínez *et al.*, 2002). Few researches shows that the thermal processing affect the nature of phenols and its biological properties in green beans (Jiratanan and Liu 2004; Martín-Cabrejas *et al.*, 2008). The question how the "processing" impacts on the antioxidant activity of beans still need more research to explain the whole phenomenon. The phenolic contents reduced drastically by 90% that cooked under high pressure (Rocha-Guzmán *et al.*, 2007), boiling and cooking also reduced the phenols in legumes seeds by 73% according to Barroga *et al.*, (1985). However Fernandez *et al.*, (1982) found that the level of phenols increases in cooked beans.

4.5 Effect of processing on Protein Digestibility

The main factor that influenced the protein digestibility of seeds is due to the presence of antinutritional factors (Liener 1989) however different processing, cooking and physical treatments reduces the level of these antinutritive factors and that then consequently affect the protein digestibility. Heating increases the in vitro protein digestibility of legumes compared to raw seeds. The heat treatments destroy the heat liable enzymes such as protease inhibitors and denature protein thus open the structure of protein and make it less resistance against protease (Walker and Kochhar 1982). Upon high heat treatments the improvement in "In Vitro Protein Digestibility" may also be due to the reduction in antinutrients factors such as tannins and phytic acid or phytate (Mubarak 2005; Udensi *et al.*, 2007). In chickpea, the protein digestibility was not significantly improved by any of the treatments however, in horse gram and cowpea, improvement in protein digestibility was observed after the processing treatments. Frying shown decreased protein digestibility in all pulses (El Faki *et al.*, 1984). Other treatments including soaking, microwave cooking, boiling, autoclaving and fermentation also improved the in vitro digestibility of protein of legumes (Khattab *et al.*, 2009; Khokhar and Chauhan 1986). Mubarak (2005) also stated that in vitro protein digestibility of mung bean increased after certain processing treatments such as soaking, boiling, autoclaving and microwave. But use of dry heat at elevated temperatures cause utilization of protein into Maillard reaction, causing browning of the product (Fagbemi *et al.*, 2005; Hsu *et al.*, 1980).

5. ANTINUTRIENTS

Antinutritional factors are compound or substance which generated by normal metabolism of species in natural food stuffs and act to reduce nutrient intake, digestion, absorption and utilization and produces many other adverse effects (Kumar 1992). Legumes contain various types of antinutritional compounds including phytic acid, tannins, polyphenols, trypsin, chymotrypsin, a-amylase inhibitors and hemagglutinin activity (Alonso et al., 2000) and flatulence causing oligosaccharides (Udensi *et al.*, 2007). These types of compounds also shown certain biochemical and physiological effects on human and animals, such as enlargement of pancreases and growth retardation (Liener 1989). These constituents also have an influence on appetite, absorption of nutrients, metabolism and on the bioavailability of certain minerals (Frolich 1995). These antinutrients also referred to as secondary metabolites that cause depression in growth performance and animal health due to binding various nutrients and reducing protein digestibility, thus it is highly advisable to use processed food or feed products to have nutritional advantages in human and in animals (Kersten *et al.*, 1991). The raw legumes grain seeds consist of these antinutrients so proper processing is necessary:

5.1 Tannins

Tannin is an antinutritional factor possess in many vegetable consisting legumes, Tannin is an important antinutritional factor exists in most of the legumes. It is characterized due to its bitter polyphenolic compound that bind or form precipitate with proteins and various other organic compounds such as alkaloids and amino acids (Redden *et al.*, 2005). The term tannins applied to any polyphenolic compound that contains sufficient hydroxyl and other groups to form strong complex with macromolecules. These tannins are available in legumes in wide range of molecular masses ranging from 500 -3000 with a great heat stability. Presence of tannins in legumes make the protein unavailable and decreased the protein digestibility in both human and animals. These tannins usually present in food products which inhibit the enzymatic activity of amylase, lipase, trypsin and chymotrypsin. Thus, decrease the quality of protein and interfere with iron absorption (Felix and Mello 2000).

5.2 Phytate

Phytate found in cereal grains, legumes seeds, nuts and also found in root, tubers and vegetables in low concentration. Presence of antinutritional factors in legumes reduce the uptake of dietary minerals such as zinc, iron and calcium in human intestine. Absorption of Fe, Ca and Zn by phytate has been revealed in humans (Sandberg 2002). Inositol pentaphosphate has been also identified as minerals inhibitor, as it absorb Fe and Zn (Lönnerdal *et al.*, 1988). Among all the antinutritional factors, phytic acid considered as the one of main concern for human health and nutrition (Kumar *et al.*, 2010). Phytic acid (myoinositol, 1, 2, 3, 4, 5, 6 hexakis-dihydrogen phosphate) and phytates are widely found in legumes (Reddy *et al.*, 1982) and other grain seed. The phytic acid usually generate in legume seeds at harvest stage and have a a negative charge that cause its binding with minerals such as iron, zinc, calcium and magnesium and form insoluble complex (Rimbach *et al.*, 1994). It also form complexes with proteins and starch (Oatway *et al.*, 2001).

5.3 Enzyme inhibitor

Amylase inhibitors and proteases such as trypsin, chymotrypsin are found in legumes seeds. There is about 0.2-2% water-soluble non-glucose proteinase inhibitor in legume seeds of the total soluble protein (Sgarbieri and Whitaker 1982) these substances reduced the protein digestion. These substances decomposed on heat therefore when raw or without being properly cooked legumes are eaten, they upset the digestive functions and cause excessive gas or diarrhea. Human pancreatic juice contain about 10-20 % of the total active trypsin (Weder and Link 1993) that have a capacity to bind proteases, which resist digestion in small intestine, and thus ensure the removal from the body through excretion. Trypsin inhibitors possess the characteristics of an insecticide (Hilder *et al.*, 1990). Amylase inhibitor alter the blood sugar level and insulin by slow in down digestion therefore it used for treatment of diabetes (Lajolo and Menezes 1991).

5.4 Lectins (Hemagglutinin)

Lectins are proteins or glycoproteins, their activities has been determined in more than 800 varieties consisting 600 genus of legume family (Liener) 1986. Total proteins of legume seeds contain 2-10% lectins or hemagglutinin. By affecting erythrocytes they enable the coagulation of (RBC) red blood cells. Lectin or hemagglutinin possess following properties: interact in blood grouping, help in mitotic cell division, and also have some toxic effect in animals. Raw beans have higher amounts of lectins, consumption of raw beans thus may cause abdominal cramps (El-Adawy 2002; Mubarak 2005).

6. IMPACT OF PROCESSING ON ANTINUTRITIONAL FACTORS

Chemical and physical methods usually used to remove or reduced antinutritional factors include soaking, cooking, autoclaving, microwave cooking, extrusion, germination, fermentation, irradiation and enzymatic treatments.

Soaking and cooking treatments shown greater reduction in tannin contents in beans (Ramírez-Cárdenas *et al.*, 2008). Beans that are cooked after soaking show more reduction in tannin contents compared to that which are cooked without pre-soaking (Nergiz and Gökgöz 2007). If the soaked water being discard before cooking then complete reduction in tannin may obtained. (Vidal-Valverde *et al.*, 1994) reported that cooking pre-soaked lentils seeds completely reduced the trypsin inhibitor, decreased phytic acid contents but the tannins content and catechin found increased.

Cooking inactivates heat sensitive anti-nutritive factors such as tannins, phytic acid, volatile compounds, trypsin, and chymotrypsin inhibitor. Different treatments such as decortications, autoclaving, soaking, extrusion, microwave, cooking, germination and fermentation, are the major efforts made to reduce the amounts of phytate and other antinutritional factors in foods. Phytate reduce the bioavailability of divalent cations due to this property phytate considered as chelating agent (Weaver and Kannan 2002). Certain thermal and biological treatments such as appertization (Tabekhia and Luh 1980) allow reduction in phytate content. Extrusion cooking treatment partially or total destroy the antinutritional factors especially protease, tannins, trypsin inhibitors, and phytates which limit nutrient in legume seed (Alonso *et al.*, 2001). Extrusion cooking is a technique reduces the antinutritional factor and thus improve the nutritional quality this technique is a cost less than other heat treatments such as baking autoclaving etc. also better treatment due to its better process control and efficient use of energy (El-Hady and Habiba 2003). However the germination and fermentation considered to be a most effective treatments to reduce the ANF (Honke *et al.*, 1998; Marfo *et al.*, 1990) but because of its additional workload their application remain limited. Long soaking before germination and fermentation may lead to significant loss in phytate contents (Duhan *et al.*, 2002). However germination conditions and their effects can vary according to the plants species, cultivar or seed varieties (Paucar-Menacho *et al.*, 2010).

Many other researchers also show the effect of processing on anti-nutrients as (Egounlety and Aworh 2003) reported the effect of soaking, dehulling, cooking and fermentation with Rhizopus oligosporus on the oligosaccharides, trypsin inhibitor, phytic acid and tannins of soybean (Glycine max Merr.), cowpea (Vigna unguiculata L. Walp) and groundbean (Macrotyloma geocarpa Harms). The pretreatments (soaking, dehulling, washing and cooking) and fermentation with Rhizopus oligosporus shown alteration in oligosaccharides, trypsin inhibitors tannins and phytic acids. Pretreatments lost 50% of raffinose and 55-60% of sucrose and stachyose. Fermentation reduced stachyose it decreases 83.9% in soybean, 91.5% in cowpea and 85.5% in ground bean while raffinose remain constant. Soaking of beans for 12-14 hours have shown no any effect on trypsin inhibitor activity while phytic acid content increased to 1.7% in soybean, 0.8% in ground bean and 0.7% in cowpea. Fermentation result in slight increase in TIA in soybean. Phytic acid is decreased by 30.7% in soybean, 32.6% in cowpea and 29.1% in ground beans. Dehulling removed the tannin contents as the tannin located in the seed coat. Vidal-Valverde *et al.* (1994) also reported the effect of processing on some antinutritional factors of lentils. Soaking in distill water, citric acid and sodium bicarbonate solutions changed the trypsin inhibitor activity, phytic acid, catechin content and tannin contents of lentils. Soaking did not modify trypsin inhibitor, decreased phytic acid level and increased the tannins and catechin contents. Cooking of presoaked seeds removed trypsin inhibitor activity, reduced phytic acid and increased tannins and catechin contents. Alonso *et al.* (2000) shown the effects of extrusion and traditional processing methods on antinutrients and in vitro protein and starch digestibility of faba and kidney beans. Dehulling of seed has shown increased in protein content and reduced condensed tannins and polyphenol level in both faba and kidney beans. Extrusion eliminates trypsin, chymotrypsin, a-amylose, and hemagglutinin activity without modifying the protein contents. Furthermore the protein and starch digestibility improved by the thermal treatments.

Table 2. Effect of different processing treatments on antinutrients factors of various legumes

Process	Temperature	Time (min)	Legumes type	Reduction in TIA	Reduction in tannins	Reduction in Phytic acid	Reduction in hemagglutinin	References
Autoclave	121°C		Legumes seeds		33.1-45.7	28-51.6%		Zia-ur-Rehman *et al.*, 2003
Boiling	100°C	90 mins	Chickpea	82.27%	48.04%	28.93%	100%	(Alajaji and El-Adawy 2006)
Soaking	25°C	12hours	Mung bean	15.8%	39.4%	26.7%	49.1%	Mubarak. 2005
Extrusion			Vicia faba		54.4%	26.7%		Alonso 2000
Microwave	High temp	15min	Chickpea	80.5%	48.45%	38.02%	100%	(Alajaji and El-Adawy 2006)

6.1 Strategy to reduce antinutritional factors

Researchers showed different treatments effective in removing the antinutritional properties from legumes seeds. Table 3 listed some physical processing used to remove antinutritional factors.

Table 3 Strategy to reduce antinutritional factors by using different processing methods

Physical processing	Comments	Results	References
Soaking	Exposure to water with or without any additives	Reduced the oligosaccharides raffinose and stachyose	(Egounlety and Aworh 2003)
Autoclaving	Heating at high temperature 121°C under pressure	Reduction in trypsin inhibitors and tannins	(Wang *et al.*, 1997)
Cooking	Ordinary domestic cookings, dehulling, germination, fermentation etc	Dehulling increased protein content, reduced condensed tannin and polyphenol. germination and fermentation decreased phytate,	(Alonso *et al.*, 2000; Egounlety and Aworh 2003)
Extrusion	High temperature for short time with pressure and shear force	Extrusion eliminate trypsin, chymotrypsin, a-amylase inhibitors and haemagglutinin activity without modifying protein	(Alonso *et al.*, 2000)
Roasting	Dry heating about 120°C-250°C	Total removal of trypsin inhibitor	(Khattab *et al.*, 2009)

7. LEGUMES POTENTIAL HEALTH BENEFITS

Legumes are considered as a good source of protein. More than 20 species of legumes are consumed by human being. Among them the major consumed legumes include chickpeas, broad beans, beans, peas, lentils, and soybeans (Karmas and Harris 2012). All these possess many health-promoting constituents, such as fiber, proteins, starch, minerals, and numerous phytochemicals having useful biological activities (Cho *et al.*, 2007; Dillard and

German 2000). Thus legume grains act as an effective balanced diet and it have the ability to prevent the diseases like type II diabetes and cardiovascular diseases (Leterme and Muñoz 2002). There are certain phytochemicals which are natural bioactive compounds that are found in fruits and vegetables (Tiwari and Cummins 2013) and it categorized in hydrophilic and lipophilic phytochemicals. As the hydrophilic types of phytochemicals, such as polyphenols, phenolic and ascorbic acids have been associated with reducing cancer and enhancing immune system, whereas the lipophilic types such as tocopherol and carotenoids prevent the eye diseases and risk of cardiovascular heart diseases (Cho et al., 2007; Dillard and German 2000). Nutritional composition of legumes provide high proportion of proteins, carbohydrates, dietary fibers, fats, B-group vitamins and minerals (Prodanov *et al.*, 2004; Ahmad *et al.*, 2014). However the composition can vary according to cultivar, species or any other climatic factors (Bishnoi and Khetarpaul 1993). Many researches has been shown that inclusion of legumes in daily diets have beneficial effects in controlling and preventing many diseases (Tharanathan and Mahadevamma 2003). The legumes also contain dietary fiber as the fibers are indigestible by human but it possesses potential health benefits. The soluble dietary fibers are fermented in colon of human and form prebiotic for the beneficial micro-organisms. Due to absorption of water from the colon of human the high fiber diet prevents constipation problem in human it also plays an important role in protective against colon cancer, cardiovascular diseases, obesity, diabetes, and other diseases (Lee *et al.*, 1992). Apparently the legumes possess natural antioxidants, many researcher believe that the dietary antioxidants release oxidative stress. Flavonoids are predominant phenolic compound found in legumes (Beninger and Hosfield 2003; Cardador-Martínez *et al.*, 2002) and in humans the flavonoids found to improve the endothelial functions and inhibit the aggregation of platelet (Vita 2005).On the other hand legumes contain some antinutritional factors such as tannins, trypsin, chmmotrypsin, phytic acid and protease inhibitors. To prevent poisoning of these antinutrients the reduction or elimination of these factors are necessary (Habiba 2002). However, these antinutrients can be reduced or destroyed by proper cooking methods.

7.1 Impact of Antinutrients on health

Antinutritional factors have potential adverse effects on human health. As the legumes contain wide range of antinutritional factors such as tannins, phytates, oxalates, saponin and lectins. . Phytate has negative impact on the bioavailability of minerals usually divalent and trivalent ions of minerals such as Zn, Mg, Ca, Cu and Mn. Whenever higher level of phytate consumption results in minerals deficiency (Gemede and Ratta 2014). Oxalate is the salt of oxalic acid calcium oxalate mostly distributed in plants. Oxalic acid formed strong bonds with minerals such as potassium, calcium and magnesium. Some oxalic salts are soluble whereas others are insoluble the insoluble salts solidify in the urinary tract when accumulate in kidney it forms kidney stones (Nachbar *et al.*, 1980). When oxalic acid is digested in gastrointestinal tract it comes in contact with nutrients (Noonan and Savage 1999) this than bind the minerals and make them unavailable. Saponin is extremely toxic to cold blooded animals. In dietary plants saponin impart a bitter taste and astringency when consumed have bitter taste and irritate throat it also reduced the bioavailability of nutrients, reduced the enzyme activity and affect digestibility of protein (Liener 1974). Some studies shown that saponin have inverse relationship with renal stones (Loewus *et al.*, 2001). Beyond its adverse effect on health recent researches shows it possesses anticarcinogenic, immunostimulatory and hypocholesterolemia properties. To inhibit dental carries saponin diet be used it also used in the treatment of hypercaliuria and as an antidote of lead poisoning (Gemede and Ratta 2014). Washing repeatedly by water reduce the adverse effects and enhance the palatability by

reducing the bitterness property (Katiyar *et al.*, 1989).
Lectins are widely distributed in legumes which are carbohydrate binding protein. It acts as protein antigen that bind glycoprotein's surface (FAO, 1995). When excess lectin is consumed then it can cause intestinal damage that leads to nutrient deficiencies, cause food allergies and immune response by provoking IgG and IgM antibodies (Felix and Mello 2000) and it also cause anemia by binding erythrocyte. Some negative impacts of antinutritional factors related to human health listed in Table 4.

Table 4. Antinutritional factors and their negative impact on human

ANF	Sources	In Vitro Effects	References
Tannins	Chick pea, pigeon pea, lima bean kidney bean, Cowpea, garden pea	Inhibit the digestive enzymes and thereby lower digestibility of most nutrients, especially protein and carbohydrates.	(Reddy *et al.*, 1985)
Trypsin inhibitors	Legumes, lentils	hypertrophy of the pancreas	(Oke 2007)
Lectins	Lentils, Peas, Soybean, Kidney Bean, Peanut	Damage of gut wall Food allergies	(Kik *et al.*, 1989) (Felix and Mello 2000)
Phytic acid	Soybean, faba bean, Lentils, Phaseolus bean	Bind essential dietary minerals as well as proteins and starch	(Phillippy 2003)
Saponins	Alfalfa, soybean, French bean,	Have amphiphilic property thus oppose lyophilic and lyophobic Reduction of blood	(Khokhar and Apenten 2003)

8. CONCLUSION

All the scientific evidence reviewed regarding to legumes nutritional compositions and phenolic contents reveals that legumes are a rich sources of proteins, fibers, minerals and other biologically active compounds. However, some antintutritional factors found in legumes shows negative impacts on human health. But these factors can be reduced or destroy by using different process. In this review all the processing methods have been discussed thoroughly. Beyond its nutritional and antinutritional factors there are certain other compounds that possess health benefit activities. The present review help the researcher to find out the properties of legumes with all aspects and also helpful for future trends related to legumes foods.

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