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Pulses: Nutritional or Anti-nutritional? A review on Bioactive Components and Digestibility

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ABSTRACT

Pulses form stable dietary components for majority of population across the world. Different people consume pulses in different ways like Uncooked, Soaked, and cooked or only cooked without soaking. All these processing techniques lead to changes in the nutritional value of the pulses. Studies have also reported that in addition to nutritional components like Proteins, Carbohydrates, and fats, pulses also contain anti-nutritional components like Lectins, Tannins, and Polyphenols that greatly interfere with digestion of pulses in the human intestine. Hence in the current study a comprehensive review is being compiled to evaluate the nutritional and antinutritional aspects of pulses and effect of processing methods on *invitro* protein and starch digestibility of the pulses.

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1- Introduction

Due to its promising nutritional and functional qualities as well as the rising consumer desire for plant-based foods, the value-added processing of pulses (peas, chickpeas, lentils, beans, and lupins etc) is significant interest for the creation of new food ingredients. Producing pulses is a leading industry in Canada. In 2009, 5.2 million tonnes (Mt) of various pulse crops were produced in Canada. 75% of the production, or $2.1 billion in 2009, is exported, which is a significant portion. More than 19 registered lentil varieties are currently available in Canada, with the Laird variety accounting for more than 60% of all production [1]

Pulses belong to Leguminosae family Fabaceae, include a dry range of dry edible seeds including lentils, peas, chickpeas and faba beans etc. [2] They are rich in complex carbohydrates, dietary fibre, proteins, minerals, and vitamins [3]. Their balanced nutritional composition makes them a great addition to a healthy diet [4]. Recently, there has been an increase in interest in turning pulses into a variety of useful ingredients that may be used to create wholesome and premium food products. Moreover, consuming pulses regularly can help prevent chronic diseases such as cardiovascular disease, type 2 diabetes, and certain types of cancer. Pulses were also low in fat and have a low glycaemic index, making them a suitable food for people who want to manage their weight and blood sugar levels. The increasing interest in using pulses as ingredients in food products is a great way to make them more accessible to a wider range of people. By turning them into flours, pastes, and other forms, they can be incorporated into a variety of recipes, including baked goods, pasta, and snacks, providing the benefits of pulses in a convenient and tasty way.

Pulses are indeed a globally important food crop due to their dietary and economic significance. Pulses refer to the edible seeds of plants belonging to the Leguminosae family, such as lentils, chickpeas, beans, and peas. They are an important source of protein, carbohydrates, fibre, and essential nutrients, such as iron and folate. In India, pulses are the second most crucial component of the diet after cereals, and they have traditionally been regarded as the poor man's meat due to their high protein content. They are also an affordable source of protein in the diets of animals and humans. However, the protein nutritional value of legumes can be reduced due to the presence of anti-nutritional substances, such as tannins, phenols, phytic acid, trypsin, chymotrypsin inhibitors, and others. These substances can interfere with the absorption of nutrients in the body, leading to deficiencies and other health problems. To reduce the impact of these anti-nutritional substances, traditional food processing methods such as soaking, sprouting, and fermentation are used. These methods can help to increase the availability of nutrients in pulses and improve their digestibility. Overall, pulses are an essential food crop with numerous benefits for human health and nutrition. With the proper processing techniques, their nutritional value can be further enhanced, making them an even more valuable source of protein and other nutrients.

Pulses, which are plant-based protein sources, have gained popularity as an alternative to animal-based protein sources due to their high nutritional value and low environmental impact. Pulses are also a good source of dietary fibre, which helps maintain gut health and lower cholesterol levels. Phytochemicals, such as flavonoids and carotenoids, are present in pulses and provide antioxidant properties that protect against chronic diseases [5]. Vitamins and minerals found in pulses play a vital role in maintaining overall health. For example,

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iron is essential for the formation of red blood cells, and folate is essential for DNA synthesis and cell division. Potassium is necessary for regulating blood pressure and maintaining proper fluid balance in the body, while magnesium is essential for maintaining healthy bones and teeth [6,7]. The high lysine and folate levels found in pulses make them an ideal complement to cereal grains, which are typically low in these nutrients. Combining pulses with cereals can create a balanced and nutritious diet, especially in regions where pulses and cereals are staples. The consumption of pulses as a dietary protein source can offer several benefits, including increased nutrient intake, improved gut health, and reduced environmental impact. Incorporating pulses into the diet can be an effective way to maintain overall health and support sustainable food systems [8].

According to estimates from the WHO, up to 80% of the population in many developing countries with limited access to modern treatment rely on traditional medicines, typically plant-based pharmaceuticals, for primary healthcare. These medications are the major form of health care for the poor, and they are widely used. Therefore, ethnobotany researchers how locals use medicinal plants. Plants have been used by humans as healing agent since ancient times, and they continue to a major source of medicine used to cure minor illness all over the world today. To preserve this knowledge for future generations and to spread it among the scientific community, which is helpful for drug discovery and development, ethnobotanical practices which means to understand the interrelations between the plants and humans, must be documented [9].

The current review is an attempt to understand the in vitro starch and protein digestibility of various pulse varieties commonly consumed as whole legumes grown in different regions. In terms of the effects of anti-nutritional and nutritional factors on human health, the study revealed that anti-nutritional factors such as tannins, TIA, and phytic acid can inhibit the absorption of essential nutrients such as iron, calcium, and zincStudies have been reported to evaluate the starch and protein digestibility and total phenolic content of different pulse varieties, including uncooked, pressure-cooked, dehulled, and soaked cooking methods. The results showed that the different pulse varieties had varying levels of starch and protein digestibility, with some varieties exhibiting higher levels than others. [10]

The study also explored the effects of anti-nutritional and nutritional factors of pulses on human health. The findings of the study provide valuable insights into the nutritional value of pulses and the best ways to prepare them for optimal nutrient bioavailability.

2. NUTRITIONAL VALUE OF PULSES

2.1 *Starch*

Pulses conserve starch as the most prevalent carbohydrate polymer in the seeds, just like many other plants. Two different kinds of polymers; amylose and amylopectin, make up starch. It is made up of separate semi-crystalline granules of highly branched amylopectin chains (70–80%) and linearly organised amylose (20–30%). Amylose is an essentially linear -D-glucopyranose polymer connected by a few -1,6 branch linkages and -1,4 glycosidic bonds. Amylopectin, on the other hand, is a highly branched molecule with about 5% -1,6 branch connections. Starch is produced as a significant by-product during the fractionation of pulses to create new food ingredients for the market. Common pulse starches, such as those found in pea, lentil, and faba bean, have greater amylose concentrations (38.0-41.1%) and longer amylopectin branch chains than significant commercial

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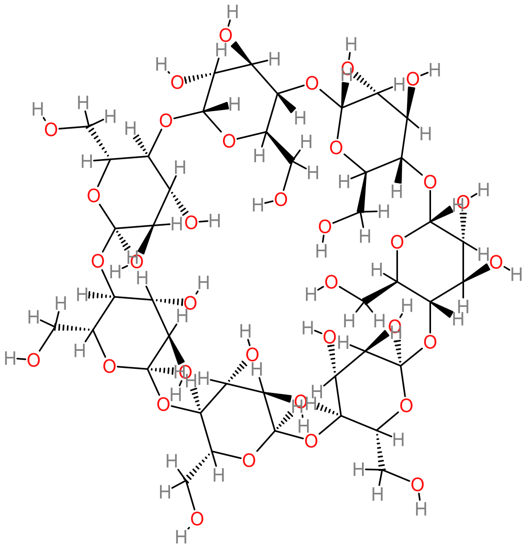
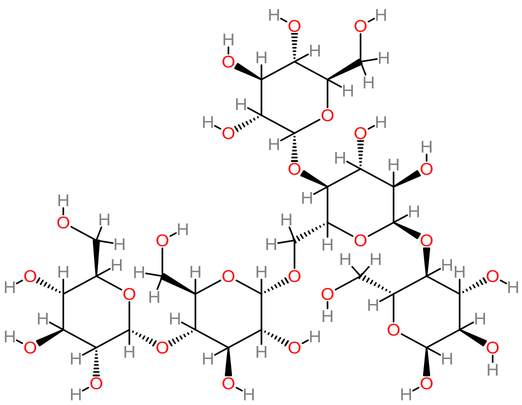
starches like waxy maize, regular maize, and tapioca [11].



Amylose $(C_6H_{10}O_5)_n$



Amylopectin $(C_{30}H_{52}O_{26})$

Starches play a crucial role in the food industry as they contribute to the texture, appearance, and stability of many foods. Their rheological properties, such as gelatinization and viscosity, are essential in determining their functionality in various food systems. [12]. Gelatinization is the process by which starch granules absorb water and swell, leading to the breakdown of their crystalline structure. As the granules expand, amylose molecules are released, which then form a three-dimensional network, resulting in the formation of a gel. The amylose content of starch influences the gelatinization process, with higher amylose content leading to a more rigid and stable gel.

Viscosity is another crucial property of starches. Viscosity refers to a fluid's resistance to flow, and it can be influenced by factors such as temperature, concentration, and shear rate. The viscosity of starch is determined by its amylose and amylopectin content, molecular weight, and branching. Different starches exhibit distinct viscosity behaviours. For instance, pulse starches, which come from legumes, tend to have lower peak and breakdown viscosities but higher final viscosities and more opaque pastes upon cooking and cooling. They also have higher retrogradation rates than other starches, meaning that they tend to become hard and gritty upon cooling. Pulse starches typically exhibit higher retrogradation rates, lower peak, and breakdown viscosities but higher final viscosities, and more opaque pastes upon cooking and cooling. The starch granule expands throughout the gelatinization process to several times its initial size, ruptures, and amylose concurrently leaks out of the granule. The amylose that has been leaked out creates a three-dimensional network during gelatinization process. The amylopectin content of starch determines how it will swell, and amylose functions as both a diluent and a swelling inhibitor. As a result of these structural characteristics, pulse starches may have fewer industrial applications [11,13]. However, the structural characteristics make pulse starches better suited for the creation of resistant starch (RS), a nutrient-rich dietary component that is gaining interest from the food industry [11]. The function of starches is dependent on their

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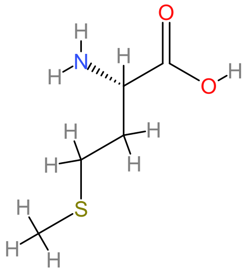
rheological and primarily gelatinization capabilities [12]. Those from various plant sources, including as grains, tubers, and legumes, have been significant in the food industry in respect to their characteristics and uses.

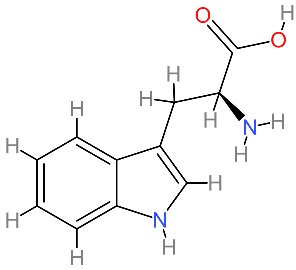
For a long time, scientists believed that starch was a simple carbohydrate that was completely absorbed and digested in the small intestine. Recent research has revealed that there is a resistant starch component that escapes enzyme digestion and makes its way to the colon, where it is fermented by the colonic microbiota. Resistant starch (RS) refers to the part of a carbohydrate that the small intestines of healthy persons are unable to absorb. There are 3 distinct forms of RS: In partially milled seeds and grains or densely packed structures like pasta, RS1 refers to physically inaccessible starch. RS2 is the indigestible starch fraction created by heating starch-containing meals in the presence of water and then cooling them; RS3, also known as Retrograded starch, is the native starch granules present in raw food. It can be found in meals like canned beans and peas, as well as boiled potatoes and other starches once they have cooled down. Health consequences vary depending on the rate and degree of starch digestion, and consequently the RS content of meals. (e.g., reduced glycaemic and insulinemic response to food, hypercholesterolemia effects, and protective effects against colorectal cancer). Due to the low digestibility of RS type 2 starch found in unprocessed foods, the rate and amount to which starch is digested are greatly influenced by the methods used to prepare those foods. Cooking, however, retrogrades part of the starch that has become gelatinized and accessible, making it resistant to enzymatic digestion after chilling. (RS3). In addition, the botanical origin of food affects how quickly its carbohydrates are digested. [14].

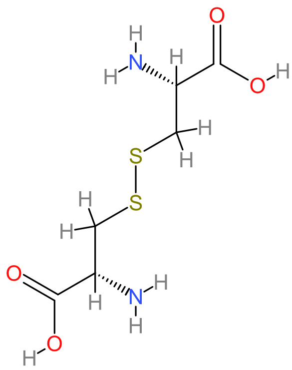
2.2 ***PROTEIN***

For huge portions of the global population, pulses are an essential source of dietary protein. Including lowering LDL cholesterol and lowering the risk of cardiovascular disease, cancer, diabetes, osteoporosis, hypertension, gastrointestinal problems, adrenal illness, and all the diseases, eating pulses may be beneficial for one's health [15,16]

Although pulses include a limited number of important amino acids like methionine, tryptophan, and cystine, they nonetheless have a protein content of between 21-25%. The variety, germination environment, and fertiliser use all affect the protein content and amino acid composition. Pulses have nearly twice the amount of protein as cereals do. Albumin and globulin were the two main fractions used to classify pulse proteins. The main storage proteins in pulse seeds are globulins, which make up 35-72% of the total protein while albumins make up most of the remaining protein component. More glutamine, aspartic acid, arginine, and lysine are present in the proteins of globulin [17]. Albumin typically plays a smaller physiological role than globulins, making up about 15–25% of the total protein in seeds. When compared to bean globulin fractions, albumins contain more cystine, methionine, and lysine.







Methionine

Tryptophan

Cystine

($C_5H_{11}NO_2S$)

($C_{11}H_{12}N_2O_2$)

($C_6H_{12}N_2O_4S_2$)

Due to the existence of disulfide bonds and hydrophobic interactions, globulins have a stiff, tightly packed structure. Albumins, one of the four main kinds of protein found in pulses, are distinctive because they are water - soluble. Albumins were able to interact and compete with starch for water because of their solubility. The main nutritional barrier to pulse protein's use in weaning food formulations is its poor digestion. Protein availability and proteolysis susceptibility are both determined by measuring a protein's digestibility. The nutritional value of highly digestible proteins is superior to those of poorly digestible proteins because they deliver more amino acids for absorption during proteolysis. The eligibility of proteins to be utilised as hydrocolloids in food formulations is determined by functional characteristics such as foaming qualities, water and oil absorption capacities, emulsification, and solubility. Due to their lower cystine content and consequently fewer disulfide linkages than albumin, globulins from lentils and horse gram were shown to be more digestible than albumin. Protein digestibility varies depending on the properties of starch such as gelatinization; when the starch is gelatinized, it becomes more accessible to digestive enzymes, which improve the digestion of the proteins present in the same food. Amylose to amylopectin ratio; starch have varying amount of amylose (linear molecule) and amylopectin (branched molecule) starch with higher amylose content generally have slower digestion rate when compared to starch with high amylopectin content. Slower starch digestion potentially affects protein digestibility. Processing methods such as cooking, soaking and fermentation, can modify the properties of starch in pulses which influence protein digestibility. For example, soaking pulses prior to cooking can help to reduce the anti-nutritional factors and improve starch digestibility, which indirectly effects on protein digestibility [8]. Albumins and globulins increased protein digestibility in the presence of starch was attributed to the compact protein structure's opening upon adhering to the starch granule surface and creating new linkages, which made it simpler for the proteolytic enzymes to reach the protein [18].

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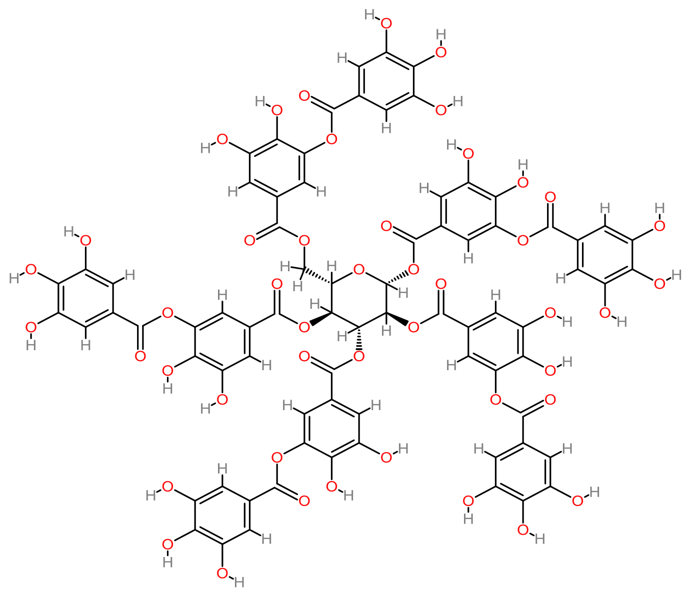
2.3 *POLYPHENOLS*

Pulses can offer the necessary amounts of minerals to meet dietary needs. The three types of phenolic substances are phenolic acids, flavonoids, and tannins. The antioxidant activity and phenolic content of various types of pulses also differed. Pulses with darker or more pigmented colours typically contain more phenols than their lighter counterparts. The amount of phenolics and flavonoids, particularly in the hull, varies depending on the colour of the grain. Different properties are added to the grain and its products because of these phenolics' interactions with the starch and protein components of the grain [18]. Tannin (Polyphenol) is known to form complexes with proteins under acidic pH (1-6) circumstances and prevent them from being absorbed by the human body. Tannin is also responsible for the decreased availability of amino acids and cellulose for enzyme digestion. Phosphorus is mostly stored as phytic acid in many plant tissues, particularly bran and seeds. Field bean polyphenols have been found to suppress salivary amylase activity and reduce the overall digestibility of carbohydrates in the rat digestive tract, according to in-vitro research. Additionally, it makes fats and proteins harder to digest. Before they are absorbed, minerals can be bound by phytic acid in the gut, which can also affect the digestive enzymes. Trypsin inhibitors are a subclass of serine protease inhibitors that lower trypsin's biological activity. Due to variables including plant genotypes, soil composition, growing conditions, and maturity state, the quality and amount of these components varies substantially [20].



Tannin ($C_{76}H_{52}O_{46}$)

Numerous studies have shown that the phenolic content of pulses higher in lentils, black beans, and red kidney beans was positively correlated with their ability to act as antioxidants. Ferulic acid, synaptic acid, and p-coumaric acid are three phenolic substances that were present in common beans in the highest amounts. Whole seeds of pulses as well as split-dehooked dhals are eaten. The hull region of the pulses contains the highest concentration of phenolic chemicals. The phenolic compounds were diminished because of milling the pulses used to make the dhals. Consuming pulses is particularly advised for lowering the risk of chronic illnesses including coronary heart disease, obesity, type 2 diabetes, etc. A significant section of the population in poor nations has reportedly had their nutritional needs met using pulses in the form of food.

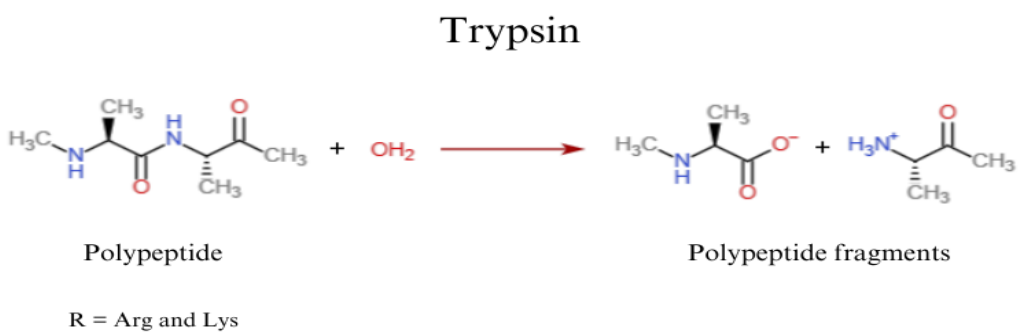
3.ANTINUTRITIONAL COMPONENTS OF PULSES AND THEIR EFFECT ON HUMANS

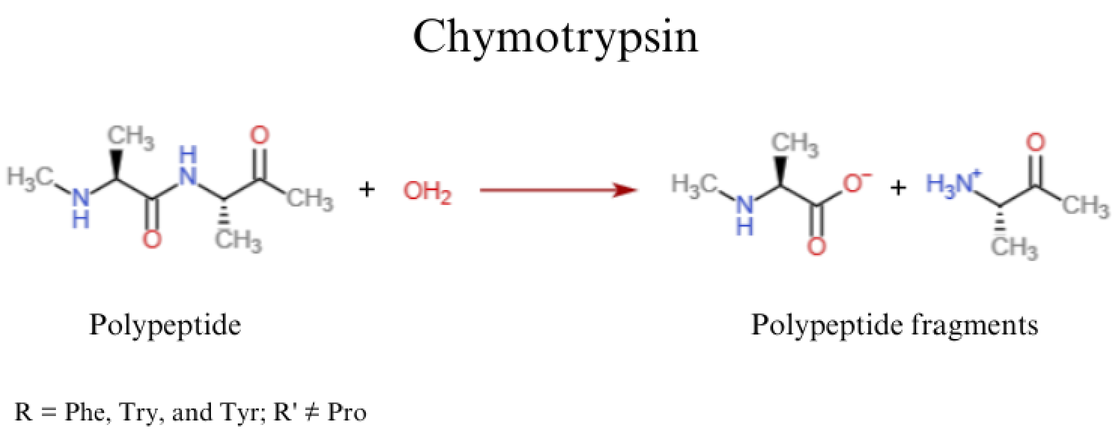
Pulses are important in terms of nutrition and global trade since they are simple to store and full of protein and fibre.

However, the presence of antinutritional elements like certain enzyme inhibitors (trypsin and chymotrypsin proteinase inhibitors), phytic acid, flatulence causes, lectins and saponins, among others, limit their nutritional value. However, no link was found between antinutritional factors (phytic acid-causing flatulence or lectins-saponins) and nutritious factors. (Protein - starch or protein - oil) [21]. The most important antinutritional components of pulses and their effects on feed rate are discussed below.

3.1 *Trypsin and chymotrypsin inhibitors*

Proteinase inhibitors, such as those found in trypsin and chymotrypsin, are present in some pulses. These can hinder the breakdown of protein, limiting the body's access to vital amino acids. Protease inhibitors can be found in every environment. Inhibitors have been the subject of extensive research due to their vital biological roles, which have been shown in everything from blood clotting regulation in humans to the coordination of receptors for chemical signals in animals to the prevention of insect damage in plants. Protease inhibitors are abundant in plants and can be broadly classified as either Bowman-Birk type or Kunitz type inhibitors. Among the Kunitz type protease inhibitors, at least nine are specific inhibitors of trypsin and chymotrypsin [21].





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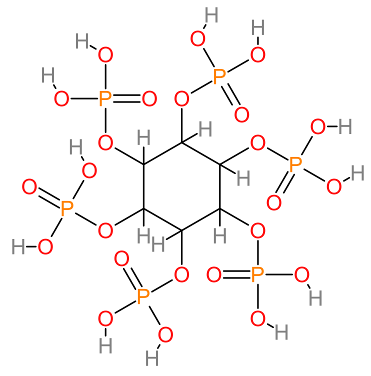
Animals grow more slowly when protease inhibitors are included in their diets because they cause the formation of the irreversible trypsin enzyme-trypsin inhibitor complex, which decreases intestinal trypsin levels and decreases digestibility of the protein in the diet. Pancreatic secretory activity is unregulated by the organism under these conditions, which can lead to hyperplasia and enlargement of the organ [22].

There has been researched on the role of trypsin and chymotrypsin inhibitors, which, if not adequately inactivated during processing, limit protein digestibility. Subsequent research established the involvement of trypsin inhibitors in defending against insect attacks. A protease inhibitor structure contains thirty to forty percent of the cysteine in bean protein. Protease inhibitors have no effect on small intestine digestion.

3.2 *Phytic acid*

Phytic acid is found in the outer layer or bran of pulses which is known as seed coat or hull. Phytic acid act as a storage form of phosphorus in plant seeds and is particularly concentrated in the bran or outer layer to protect the seed from premature germination and provides phosphorus to the growing plant and is known to reduce the absorption of minerals like iron, zinc, and calcium. This can lead to mineral deficiencies in the body, which can affect overall health. Foods having a plant origin contain phytic acid, which binds to dietary elements like calcium, zinc, iron, and magnesium to create a compound that prevents them from being absorbed biologically.[23].



Phytic acid ($C_6H_{18}O_{24}P_6$)

Additionally prevalent in legume seeds, phytic acid contributes almost 78% of the total phosphorus in pulses. Additionally, alpha-amylases and proteases, two digestive enzymes, have been shown to be inhibited by phytic acid. Dietary Minerals such as Zinc, calcium, magnesium, and iron become bound by phytic acid in the gastrointestinal tract, preventing the body from absorbing and using them. Additionally, it can interact with intestinal proteins, proteases, and amylases to form complexes that prevent proteolysis. [24].

Furthermore, because monogastric species are only partially able to hydrolyse phytate in the small intestine, it has been assumed that the phosphorus in phytate is mostly unavailable to the organism. The main factor affecting Zn absorption is phytic acid, particularly in diets with low levels of animal protein. In the digestive tract, it binds Zn tightly and decreases its availability for absorption and reabsorption. The absorption of Fe by humans may also be inhibited by phytic acid, according to some studies. Decomposition of phytic acid lead to increase the availability of calcium, which may also reduce the absorption of the calcium. However, despite the presence of phytic acid, it is challenging to link complete goods to a detrimental impact on Mg absorption. Exogenous phytic acid

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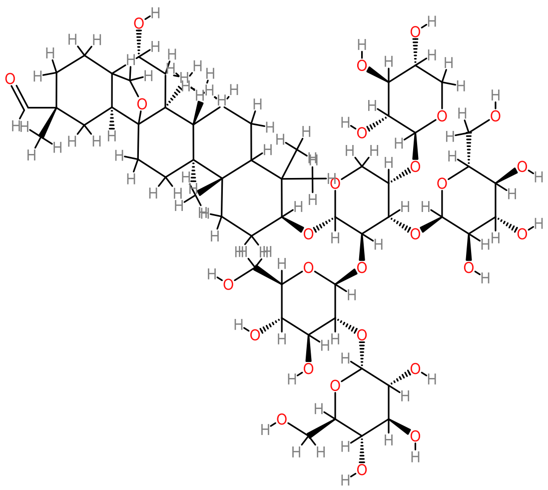
degrading enzymes can effectively reduce the amount of phytic acid [21].

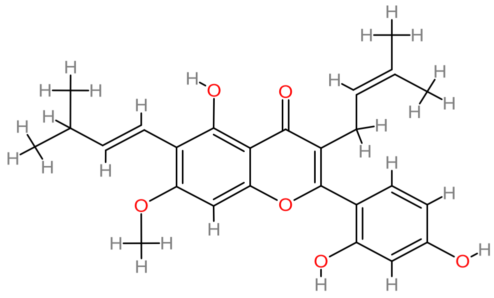
3.3 *Saponins and lectins*

Saponins are compounds found in some pulses that can form complexes with cholesterol and inhibit its absorption. However, they can also cause damage to the gut lining and reduce the absorption of nutrients like iron and zinc. Pulses include secondary plant metabolites known as saponins, which are aglycones that can have steroidal, or triterpenoid structures and a carbohydrate moiety (mono/oligosaccharide) connected to them [25]. They often have a bitter taste (the ones in liquorice are an exception; they are sweet), can foam in aqueous solutions, and can haemolyze red blood cells; the latter two characteristics are a result of their amphiphilic nature. Consuming foods containing saponin can have both negative and positive consequences. On the one hand, saponins produce negative results like a poor weight in animals and hypocholesterolaemia in people [26]. On the other hand, a diet high in dietary legumes containing saponins lowers the incidence of cardiac illnesses in people [27].



Saponin ($C_{58}H_{94}O_{27}$)

Lectins are a type of protein found in pulses that can bind to cells in the gut and interfere with nutrient absorption. They can also cause inflammation and damage to the gut lining, leading to digestive problems. Lectins are a type of non-immune protein found in nature. They are also known as hemagglutinins or phytohemagglutinins. They can be found in nature because they all can selectively and reversibly bind to carbohydrates, whether free-floating or embedded in more complex structures. Still Mark was the first to characterize castor bean extracts in 1888 [28]. Furthermore, many members of the lectin protein family agglutinate or clump red blood cells. Some pulse seeds that contain phytohemagglutinins (lectins) are lentils, beans, and peas [29]. These proteins have a strong preference for a variety of sugar molecules. Most lectins have 4–10% carbohydrate content. Grains (sometimes referred to as pulses or cereals), legumes, dairy products, and plants, from the nightshade family can all contain high concentrations of lectins, which are specialised proteins. Although they have not been as thoroughly examined and their lectin content is not believed to be as high or possibly harmful, many other foods also contain lectins [30]. The human digestive system can process a wide range of protein sources, from plants to animals, through the processes of digestion and elimination. Lectins are a type of protein found in plants and animals, and they can be fatal to humans if consumed. The primary toxic factor that prevents widespread use of pulses is their anti-nutritional value.



Lectin ($C_{26}H_{28}O_6$)

While pulse lectins tend to be more heat-resistant than other plant proteins, prolonged boiling can still render them inactive [31]. Due to the high cost and potential danger, heat processing is typically avoided whenever possible, and this holds true even for legumes. Even though pulse seeds contain anti-nutritional elements like lectins, enzyme inhibitors, substances that cause polyphenols, flatulence, tannins, saponins, and phytic acid that have already been highlighted (Table-1) Using different cooking methods, like pressure cooking or any other method can reduce or eliminate most of them [32,33].

Table – 1. Possible health benefits of various bioactive components found in pulses.

COMPOUND	PULSE	BENEFITS	REFERENCES
Phytates	Lupin	Type 2 diabetes patients may benefit from this because it decreases blood glucose response by slowing stomach emptying and reducing the pace of starch breakdown.	[34]
	Lentils	By the creation of an insoluble compound with cholesterol, hypolipidemic effects may lower cholesterol by inhibiting intestinal absorption; encourages the formation of the intestinal epithelium, which slows the growth of tumours.	[35]
	Dry bean	Anti – cancer; reduce oxidative DNA damage in cells to combat cancer.	[36]
	Lupin	Immuno- modulation	[37]
	Beans	Anti-obesity hypocholesterolaemia	[38,39]
Amylase inhibitors	Chickpea	Weight control Managing type 2 diabetes	[40]
Compound Saponins	Pulse beans	Hypolipidemic effects Antioxidant actions as well as platelet aggregation inhibition. Increasing bile acid excretion is one indirect way to lower cholesterol.	[41]
	Lentils	Prevent the formation of tumours in leukaemia, lung, and colon cancer cells as well as cancer cells' ability to reproduce.	[42]
Phenolic compound	Faba beans	Anti-cancer	[43]

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	Chickpea	By trapping nitrite, which lowers nitro sating species and prevents the endogenous synthesis of carcinogenic nitrosamines, the mutagenic effects of both directly acting carcinogens (such as benzo(a)pyrene diol epoxide) and carcinogens that need to activate metabolism (such as aflatoxin B1) trap nitrite.	[40]
	Beans	Reduce the obesity risk	[44]
	Lentils	By its anti-angiogenic activity and by altering adipose metabolism, they may prevent the growth of fat tissue. Potential defence against heart disorders Ability to produce effects that are both estrogenic and antiestrogenic. Potential defence against heart disease	[40]
Trypsin inhibitor	Beans	Anti-cancer Demonstrates in vitro antiproliferative properties. Can work through a variety of anticarcinogenic processes to prevent the malignant transformation of cells brought on by many types of carcinogens, but their exact target is still unknown.	[45] [46] [47]

4. PULSES BENEFICIAL IMPACTS ON HUMAN HEALTH

Beans are currently one of the most significant pulses in the world because of their high amounts of protein, fibre, and complex carbs [48]. Moreover, bean seeds are nutrient-dense, high in fibre, and excellent sources of protein. Eating dry beans is strongly linked to numerous physiological and health-promoting effects, including the avoidance of numerous diseases [49]. Fibre has emerged as a crucial part of any diet intended to treat or prevent chronic diseases. The metabolic benefits of eating dry beans have been shown to aid in weight management, and there is also evidence that they can help reduce blood cholesterol levels and improve various aspects of diabetes. That's why boosting your bean intake is one of the best things you can do to reduce your risk of multiple chronic diseases [21].

Because of their high nutritious content and low cost, lentils are a healthy and affordable alternative to meat. Furthermore, seeds are high in fibre. Increased fibre intake is linked to a variety of health benefits, including lower serum cholesterol, a lower risk of coronary heart disease, lower systolic pressure, better weight management, better glycaemic control, a lower risk of several cancers, and better gastrointestinal function. As a result, an increasing number of health organizations urge that people incorporate lentils into their diets to prevent nutritional deficiencies and diseases such as diabetes, heart disease, cancer, and cardiovascular disease.

Despite being a rich source of carbohydrates and protein, chickpeas have a low glycaemic index. It contains more protein than many other foods. Furthermore, except for the S-bond amino acids cysteine and methionine, chickpea contains high levels of all necessary amino acids. Cereals can be used to augment a healthy diet [50]. Oligosaccharides such as amylose and amylopectin, dietary fibre,

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and simple sugars like glucose and sucrose are second only to starch as a source of energy storage. Despite their low-fat content, chickpeas are a rich source of the important fatty acids linoleic and oleic. Three of the most significant sterols discovered in chickpea oil are stigmasterol, campesterol, and sitosterol. Chickpea seeds include Ca, Mg, P, and mainly K. Chickpeas are high in a variety of vitamins, including riboflavin, niacin, thiamine, folate, and vitamin A [51]. Pulses, an annual leguminous crop, are a mainstay in many diets due to their affordability and high nutrient density. Numerous nutrient pairs were found to have highly unfavourable associations (protein-carbohydrate and protein-fat). (Table-2)

Table-2: SOME POTENTIAL BENEFITS IN CONSUMING PULSES

Lowering LDL cholesterol	Pulses are high in soluble fibre, which can help reduce LDL cholesterol levels and improve overall heart health [52].
Reducing the risk of cardiovascular disease	Research has indicated that consuming pulses can help lower blood pressure [53].
Lowering risk of cancer:	Pulses are rich in antioxidants and other phytochemicals that may help protect against cancer [54].
Managing diabetes:	Minerals including calcium, magnesium, and others are abundant in pulses that are important for bone health and may help reduce the risk of developing type2 diabetes [55].
Improving bone health	Minerals including calcium, magnesium, and others are abundant in pulses that are important for bone health and may help reduce the risk of osteoporosis [56].
Reducing the risk of gastrointestinal disorders	Pulses are rich in fibre, which can help in reducing the risk of conditions like constipation, improve digestive health and diverticulitis [57].
Managing adrenal disease	Pulses also contain potassium, which is important for adrenal function and may help manage conditions like Addison’s disease [58].

5. EFFECT OF PULSES ON NORMAL HUMAN MICROBIOTA

Legumes, including pulses, are considered highly nutritious and are recommended in healthy dietary patterns due to their high dietary fibre and plant-based protein content, which is believed to have a positive impact on human gut microbiota. Pulses are also being used as a dietary strategy to address the protein gap while incorporating more plant-based foods in our diets to reduce the risk of chronic diseases and address the impact of food consumption on climate change. Research suggests that a diet with less animal-based protein and more plant-based protein, such as from pulses, can lead to higher microbiome diversity, which is associated with better health. This could be due to the fibre and other substrates present in pulses, which stimulate the growth of intestinal microbiota [59].

Some reviews demonstrated that only a few human studies have investigated the effects of pulses and pulse ingredients on the microorganisms in the human gut. These studies also did not explore how changes in gut microbial populations caused by pulses affect health. Although these studies showed changes in the amount and diversity of microorganisms, it is only useful if it results in a positive health outcome. To be considered a prebiotic, a substance must be selectively used by host microorganisms and confer a health benefit. However, it is difficult to determine a cause-and-effect relationship between changes in microbiota from specific foods and their health benefits [60].

Animal models can clarify the link between diet, which includes pulses, and changes in health outcomes related to microbiota which referes to the community of microorganisms, including bacteria, archea, fungi, viruses, and other microbes, that reside in or on a specific habitat or

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organism. They serve as a substitute for studying humans and can provide insights into how dietary changes affect microorganisms in the gut and ultimately impact health. In a randomized controlled trial of healthy adults, daily consumption of cooked lentils for six weeks resulted in a significant increase in the abundance of *Bifidobacteria* and *lactobacilli* in the fecal microbiota, as well as an increase in short-chain fatty acid (SCFA) concentrations in the colon [61]. Another study in healthy adults found that a high-fiber diet containing chickpeas and lentils led to significant changes in the gut microbiota composition, including an increase in the relative abundance of butyrate-producing bacteria such as *Roseburia* and *Faecal bacterium* [62]. A meta-analysis of 14 randomized controlled trials concluded that pulse consumption can significantly increase the abundance of *Bifidobacteria*, *lactobacilli*, and certain species of clostridia in the gut microbiota, as well as improve other markers of gut health such as fecal SCFA concentrations and pH [63]. In a study of overweight and obese adults, daily consumption of a lentil soup for six weeks led to significant increase in the beneficial gut bacteria, which include *bifidobacteria*, *lactobacilli*, and *Akkermansia muciniphila* [64]. These bacteria play a role in maintaining the integrity of the gut barrier and enhance the production of specialized proteins called mucins, which forms protective layer in gut lining. This strengthens the gut barrier and helps to prevent the passage of harmful substances into the blood stream. It also improves metabolic health like lower risk of obesity, insulin resistance etc and maintains intestinal health.

6. PROCESSING METHODS

Prior to eating, raw pulses are processed using a range of techniques such as grinding, dehulling, frying, etc. to eliminate or minimise the anti-nutritional elements. Even after the food has been heated, the inhibitory characteristics of the polyphenols and tannins are still present. Regarding the impact of variation on the anti-nutritional variables, there is a dearth of knowledge. Additionally, there were fewer investigations on the correlation between the content of tannin and polyphenols in domestic procedures and the digestion of protein and starch.

Different samples (pulses) are taken and processed i.e., uncooked, dehulling, cooked and soaked for 24hours and cooked. When compared to the raw sample, most treatments for pulses increased digestibility; only frying reduced it. The largest improvement was seen in germination and cooking, followed by soaking, dehulling, and cooking. Except for frying, all heat treatments improved digestibility. The beans with the highest digestibility were those that had been germinated and then cooked. Frying significantly reduced digestibility. Up to 4 hours, maltose liberation increased gradually in all legumes.

Under several experimental setups, Invitro digestibility of bean seeds was studied. Processing the seeds by following methods: Uncooked whole seeds, cooked whole seeds, Dehulled seeds, Soaked and cooked, and autoclaved.

7. INVITRO STARCH DIGESTIBILITY

Regardless of the processing method, processed legumes have been demonstrated to possess higher levels of RS than other dietary items like cereal and potatoes. Legumes have lower postprandial glycaemic and insulinemic reactions than cereal grains or potatoes because the rate of starch breakdown and, consequently, the release of glucose into the bloodstream is slower after the intake of pulses. Moreover, the considerable amounts of dietary fibre found in pulses strengthen the resilience of cells to cellular disintegration during cooking. This could be the leason for the restricted digestion of

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bean starch as well as the presence of several antinutrients.

The amount of total starch (TS), resistant starch (RS), and rapidly digestible starch (RDS), as determined by enzyme analysis, in raw and processed seeds. RDS causes a faster rise in postprandial plasma glucose and is easily and completely absorbed in the small intestine. The lowest RDS and TS, 2.1 and 29.9%, were found in the raw samples. The RDS content of mung beans was enhanced using a variety of processing methods, with the autoclaving method having the greatest concentration (49.3%). Even though heating dramatically increased vulnerability to pancreatic amylase attack, legumes are generally remarkably resistant to this enzyme. Gelatinization and antinutrient degradation during boiling increase the digestibility of starch. SDS (Slowly Digestible Starch) lowers postprandial plasma glucose and insulin levels and slows small intestine digestion. It is commonly used as a dietary starch. SDS content was found to be highest in soaking samples and lowest in cooked samples. When compared to raw and soaked samples, germination significantly enhanced ($P<0.05$) the in vitro starch digestibility of pulse. It has been shown that activating amylolytic enzymes during legume germination increases protein and starch digestibility.

The term “RS” refers to the amount of ingested starch and broken-down starch that is not absorbed when it passes through the small intestine. Pulses' high RS content (8.9%), particularly RS2, contributed to their poor starch digestibility; however, heating and autoclaving greatly reduced their RS level. (P0.05). The elimination of soluble components such as oligosaccharides and phenolic compounds could explain the reduction. Raw legumes have a greater RS concentration because their starch is concentrated in granules that were only mildly affected by Saccharolytic enzymes and hence are the least digestible. (RS2). A variety of reasons contribute to the limited bioavailability of legume starches. The presence of intact cell/tissue structure reduces the development of retrograded starch (RS3) as well as the swelling and solubilisation of starch granules, all of which slow the rate of in vitro digestion (Table-3). Furthermore, the high amylose/amylopectin ratios and the presence of several antinutrients, such as polyphenols, phytic acid, and other antinutrients, impact the digestion of legume starch. [65]

Table-3: Invitro starch digestibility

S.no	pulses	Invitro starch digestibility (%)				
		unprocessed	cooked	Soaked - cooked	Soaked - dehulled	References
1.	Black gram	58.6	41.4	25.6	17.1	[66]
2.	Chickpea	44.8	31.4	16.9	11.7	[67]
3.	Common bean	57.8	36.9	19.1	13.3	[68]
4.	Cow pea	55.1	42.3	25.1	19.3	[69]
5.	Lentil	47.6	32.7	15.6	9.9	[67]
6.	Lima bean	60.6	43.3	25.2	16.2	[68]
7.	Mung bean	57.4	40.4	25.5	18.0	[66]

8.	**Pea**	48.5	33.5	16.7	10.8	[67]
9.	**Pigeon pea**	60.3	44.6	31.1	21.3	[69]
10.	**Soya bean**	65.3	32.9	16.4	7.4	[67]

8. *IN VITRO* PROTEIN DIGESTIBILITY

Pulses are an excellent source of protein for human nutrition. However, the availability of this protein to the human body depends on its digestibility, which can vary among different pulses. In vitro protein digestibility is a commonly used method to assess the digestibility of proteins in food. It involves simulating the digestive process in a test tube or a laboratory model of the human digestive system. According to research, the in vitro protein digestibility of pulses can range between 50 and 90%, depending on the kind of pulse and the way of preparation. Chickpeas, for example, have been reported to have higher in vitro protein digestibility than lentils and kidney beans. The presence of anti-nutritional substances such as phytates and trypsin inhibitors, as well as the processing method utilized, can alter the in vitro protein digestibility of pulses. Soaking, heating, and germination can all serve to minimize anti-nutritional agents and enhance pulse protein digestibility in vitro. While in vitro approaches can provide valuable information on protein digestibility, they may not always reflect the genuine bioavailability of protein in the human body. Other factors that influence the nutritional value of pulses include variants of gut bacteria and protein quality.

Protein nutritional quality is thought to be significantly influenced by protein digestibility. According to research on protein digestibility based on pH variation, concentrates had significantly higher values (82.84% and 83.20%, respectively, for RPLC and GLPC) than flours (77.05% and 75.90%, respectively, for RLF and GLF). This might happen because the digestive enzymes will have less access to the labile peptide bonds in ours than in the concentrates. Moreover, during the protein extraction process, denaturation procedures may make proteins more accessible to digestive enzymes, which will enhance hydrolysis [1]. In addition to healthy proteins, pulse seeds may also include enzyme inhibitors (such as trypsin and chymotrypsin inhibitors), which, if not properly inactivated during processing, could negatively affect the digestion of proteins. Proteins that are easier to digest are preferred because they are more nutrient-dense. Chickpea, mung bean, and pea in vitro protein digestibility range from 65.3% to 79.4%, 67.2% to 72.2%, and 60.4% to 74.4%, respectively Black gram has a protein digestibility of 52% to 58%, while chickpea has a range of 48% to 53%. The variety and processing of chickpeas were also reported to affect differences in digestibility [70].

Soaking, boiling, autoclaving, and sprouting pulses all improve their protein digestibility. Cooking, sprouting, and autoclaving were found to be the most successful approaches. Protein digestion is slowed by substances called protease inhibitors, but heating and autoclaving legume grains get rid of them. Protein digestibility was also improved when cooked grains were soaked before consumption. Studies have also found that while cooking improved the in vitro digestibility of chickpea and common bean flour/concentrates, it had the opposite effect on lentil and faba bean flour. [71]. The nutritional value and digestibility of pulses can range widely depending on the type of pulse and other environmental factors [35]. Other studies have shown that

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thermal processing (like cooking or autoclaving) facilitates protein hydrolysis. This is due to the molecular rearrangements that take place during thermal denaturation, which involve the torsion and flexibility of protein secondary structures (the helix and sheet conformations) and thus make them more amenable to hydrolysis (1635 and 1650 cm^{-1}, respectively) [72].

Both pre-soaked and raw seed samples had their chymotrypsin inhibitor (90-100%) and trypsin inhibitor (92-99%) activities significantly reduced after being heated or cooked. Hydrothermal processing significantly reduced in trypsin inhibitor activity (76%) in several different lines of *L. sativus* and other common legumes. The trypsin inhibitor found in Brazilian velvet bean can be completely inactivated through regular heating or pressure cooking of pre-soaked samples (Table-4). It appears that dry heat treatment's loss of trypsin inhibitor (75-79%) and chymotrypsin inhibitor (56-63%), while still significant, is much lower than that of the other hydrothermal processing methods [22].

Table –4: Invitro protein digestibility of pulses

s.no	pulses	In vitro protein digestibility (%)				References
		unprocessed	cooked	Soaked cooked	Soaked - dehulled	
1.	Black gram	69.70	80.68	82.63	89.18	[73]
2.	Chickpea	67.7	81.5	85.2	91.1	[74]
3.	Cow pea	61.60	71.44	79.27	82.55	[75]
4.	Green gram	63.70	74.60	81.80	85.60	[73]
5.	Kidney bean	58.20	76.60	83.20	89.50	[76]
6.	Lentil	69.80	76.50	84.30	86.30	[74]
7.	Lima bean	53.20	70.20	77.40	81.50	[75]
8.	Mung bean	65.20	78.60	86.30	89.70	[76]
9.	Pigeon pea	61.20	73.50	80.80	86.30	[74]
10.	Soybean	65.20	82.60	86.30	92.70	[76]

9. TOTAL PHENOLIC CONTENT

Pulses also contain a range of phytochemicals, including phenolic compounds, which are known to have antioxidant and other health-promoting properties. The total phenolic content (TPC) in pulses can vary depending upon the type of pulse and the growing conditions. Studies have shown that some pulses have higher TPC than others. For example, black beans, navy beans, and lentils have been reported to have relatively high TPC compared to other pulses. In general, darker-coloured pulses tend to have higher TPC than lighter-coloured ones. The TPC in pulses also is affected by the factors such as soil type,

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weather conditions, and storage conditions. In addition to TPC, the specific phenolic compounds present in pulses can also vary. For example, some pulses are rich in flavonoids, while others are rich in phenolic acids. The specific phenolic compounds present in pulses may also have different health benefits. Therefore, it is important to consider both the TPC and the specific phenolic compounds when evaluating the health benefits of pulses.

Polyphenols and other bioactive substances in pulses tend to accumulate in the seed coat, while lesser amounts can be found on the cotyledons. However, cooking pulses significantly reduces both these compounds' quality and potential bioactivity quantity and potential bioactivity because they are heat sensitive. The total phenolic content of raw flours varied from 1.32 to 1.96 mg/g of gallic acid equivalent for broad bean and black bean, respectively. It is possible that the high temperatures employed in HMT diminished the bioactivity of the phenolic compounds present in flours. Values for the flours were like those of their natural counterparts after ANN was applied [72].

10. CONCLUSION AND FUTURE PERSPECTIVES

Pulses seeds contain an important amount of beneficial nutrients like, phytosterols, carbohydrates, polyphenols, proteins oligosaccharides, resistant starch, and dietary fibre. These nutrients have also been found to offer several health benefits and have been linked to a reduced risk of several chronic diseases such as heart disease, diabetes, cancer, and cardiovascular disease. Pulses are also a good dietary choice for individuals looking to maintain a healthy weight, as they are low in fat and have low glycaemic index. Additionally, pulses are a rich source of antioxidants, which can improve heart health and lower blood cholesterol levels. However, it is also true that pulses contain factors that are anti-nutritional, including polyphenols, saponins, lectins, lathyrogens, phytic acid, protease inhibitors and others. These antinutrients can interfere with the absorption of certain nutrients, leading to nutrient deficiencies, digestive issues, and other health problems. To minimize the impact of antinutrients, it is recommended to properly prepare and cook pulses before consumption. Soaking, dehulling, soaking plus cooking and cooking the seeds can help reduce the levels of antinutrients and improve their nutritional value. Additionally, consuming pulses as part of a balanced and varied diet can help ensure that you are getting all the necessary nutrients while minimizing the negative effects of antinutrients [21]. The study also revealed that different processing methods had varying effects on reducing anti-nutritional factors such as tannins, TIA, and phytic acid. The dehulling method was found to be the most effective in reducing these factors, followed by soaking and pressure cooking. The uncooked method was found to be the least effective in reducing anti-nutritional factors.

Pulses are a type of legume that included beans, lentils, and chickpeas, among others. These pulses contain anti-nutritional components such as tannins, phytic acid, and trypsin inhibitor activity (TIA), which can reduce the bioavailability of nutrients in the body. Therefore, it is important to reduce the levels of these anti–nutritional components through processing techniques before consuming pulses. This review suggests that using a single processing technique may not be enough to eliminate all the anti-nutritional components through processing techniques before consuming pulses. Therefore, it is recommended to use at least three processing techniques, such as soaking and cooking, to eliminate tannins and phytic acid. Additionally, soaking and roasting followed by pressure cooking are efficient in eliminating TIA. The processing techniques not only decrease anti-

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nutritional components but also increase the nutritional values of pulses. The IVSD (in vitro starch digestibility) and IVPD (in vitro protein digestibility) of pulses increase during processing, with cooking producing the greatest increase. As the IVPD increases, the TIA value for such pulses decreases, indicating a negative correlation between the two parameters. In summary, using multiple processing techniques is recommended to eliminate anti-nutritional components in pulses, and cooking is the most effective technique for increasing the nutritional value of pulses.

11- CONFLICTS OF INTEREST: No.

12. References

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