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REVIEW ARTICLE

Anti-Nutritional Factors in Legumes: Reduction Strategies and their Impact - A Review

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Abstract: ***Introduction*:** Pulses are increasingly consumed worldwide due to their affordability and rich nutritional profile. They are also a valuable source of bioactive compounds like phenolics and flavonoids, which contribute to health benefits. The presence of anti-nutritional factors in legumes can hinder nutrient bioavailability. Processing techniques such as soaking, cooking, germination, and fermentation help improve sensory and nutritional qualities while reducing these compounds.

***Methods*:** A structured literature review was conducted to identify and analyze recent findings related to the composition of legumes, with a particular focus on anti-nutritional factors and their reduction through different processing techniques. Key approaches to improving nutrient accessibility and potential applications in food systems were also examined.

***Results*:** The findings show that processing techniques, particularly fermentation and germination, can reduce anti-nutritional factors by up to 95% for phytates and 50% for tannins. These methods improve protein digestibility, mineral bioavailability, and functional properties. Additionally, combining treatments can enhance the overall nutritional profile, making legumes more suitable for diverse dietary uses and functional food development.

***Discussion*:** The differential impact of processing techniques highlights the importance of selecting tailored strategies based on the specific anti-nutritional targets and intended functional improvements. Optimizing these treatments can improve the bioaccessibility of nutrients and the techno-functional behavior of legumes in complex food systems.

***Conclusion*:** This review underscores the nutritional potential of legumes and the significant impact of processing techniques on reducing anti-nutritional compounds. It provides a unique perspective by linking anti-nutrient mitigation strategies with improved food functionality and health benefits.

Keywords: Pulses legumes, anti-nutritional factors, processing techniques, nutritional importance, fermentation, germination protein digestibility.

1. INTRODUCTION

Pulses are a part of the Fabaceae family, which is the third largest family of global flora, as per FAO in 2016 [1]. They are the second most important crop on the planet from an economic standpoint, behind grasses and *Poaceae* [2]. In 2021, FAO identified approximately 50 species of edible legumes, with lentils (*Lens esculenta*), beans (*Vicia faba*), chickpeas (*Cicer arietinum*), beans (*Phaseolus vulgaris*), and soybeans (*Glycine max*) being the most widely used [3, 4]. Over the past few years, there has been a remarkable rise in the production of pulses worldwide. According to the latest statistics made by the FAO in 2021 [4], the average global quantity produced of pulses is approximately 93 million tons, compared to a production of about 81 million tons in 2016 [1]. This production growth is dominated by Asia, no-

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tably by India and China. Pulse cultivation in Tunisia is highly important in both agronomic and economic terms, contributing to the increase in production over previous years, reaching approximately 120.4 thousand tons in 2021 [4, 5]. The recognition of legumes as environmentally sustainable plant protein sources with several benefits for human health has increased [6]. Not only do legumes contain high protein, but they also provide fiber, essential minerals such as magnesium, potassium, iron, and zinc, B vitamins, and other bioactive compounds. In addition, legumes are naturally low in saturated fat and contain low glycemic-index carbohydrates [7]. Nowadays, the trend towards vegetarian food is prompting food industries to increasingly focus on pulses, thus creating analogues to products of animal origin that function as functional foods [8]. Functional foods are food products that are consumed to promote a healthy and balanced diet containing bioactive substances that are beneficial for health [9-11]. This has increased the demand for vegetable protein derived from pulses and their processed products. Due to their high nutritional intake and their positive impact on human health, there has been an increase in demand. Consequently, these crops are often valued for flour, which will then be utilized in various types of food [2]. This review examined the nutritional value of the most essential legumes and addressed the various anti-nutritional factors and their elimination methods. In addition, the increase in the consumption of functional foods based on pulses, aimed at formulating new products that promote food diversity and create metabolic and nutritional benefits, was also reviewed.

2. METHODS

Extensive bibliographic research was conducted using scientific databases like Web of Science, PubMed, and Scopus, along with annual reports from organizations (e.g., FAO), covering publications from 1995 to 2023. The following keywords were used: legumes, pulses, anti-nutritional factors, valorization, nutritional importance, and processing technologies. To refine the search, additional terms were included: pulse processing, vegetable proteins, enzyme inhibitors, nutritional value, production, metabolic deterioration, fiber, energy, dietary proteins, nutritional quality, digestibility, human health, lectins, phytic acids, tannins, saponins, and alpha-galactosides.

Inclusion criteria included studies written in English or French, focusing on edible legumes and reporting experimental results or recent comprehensive reviews. Studies were excluded if they lacked full-text access, were unrelated to anti-nutritional factors, or did not provide relevant methodological or technological insights.

The screening process was conducted in two stages. First, titles and abstracts were reviewed to exclude irrelevant or incomplete publications. Then, all remaining articles underwent full-text screening to assess eligibility based on the inclusion and exclusion criteria. A total of 101 articles meeting the predefined criteria were analyzed in full text.

To minimize potential selection bias, the screening and selection were performed by two independent reviewers. Discrepancies were resolved through discussion and consensus. While this review did not include a formal risk-of-bias assessment due to the diversity of study designs, we acknowledged this as a limitation. Moreover, potential publication bias (*e.g.*, underreporting of negative or non-significant results) was considered and discussed in the limitations section.

The selected studies were then categorized based on the main identified anti-nutritional factors and the corresponding reduction or elimination methods, including physical, chemical, and biological processing technologies.

3. RESULTS

3.1. Nutritional Importance of Pulses

In sustainable agriculture, studies conducted by Sultani *et al.* [12] indicate that legumes play a crucial role by fixing atmospheric nitrogen, increasing soil fertility, and positively impacting soil properties and conservation [13]. That's why various policies are currently promoting the cultivation of legumes, and the FAO has designated 2016 as the International Year of Pulses (ONU A/RES/68/231) [1, 4, 14, 15].

From a nutritional perspective, according to Mullins and Arjmand [16], the recognition of legumes as environmentally sustainable plant protein sources is growing, offering several benefits for human health [6]. In fact, Smykal et *al.* [2] affirmed that about 33% of proteins in the human diet are derived from grain legumes, which are crucial for global food security [12]. Albumins and globulins are the major proteins in pulses. Albumins, which are water-soluble, include enzymatic proteins, protease inhibitors, amylase inhibitors, and lectins, have Molecular Masses (MM) ranging between 5000 and 80,000 Da [17]. Legumin (11S) and vicilin (7S) are examples of globulins that are soluble in salt. Multigene families encode polymorphic subunits that make up the 11S and 7S storage proteins of pulses [18]. Notably, 11S Hexameric quaternary structures with basic subunits (MM of 20,000Da) and acidic subunits (MM of 40,000Da) are found in legumins. The trimeric structure of the 7S vicilins has MMs ranging from 175,000 to 180,000 [17].

Both high energy density and high protein density are characteristic of legumes' nutritional content (Table **1**). Indeed, according to researchers such as Aguilera et *al.,* and Rubio and Molina [19-22], the high protein content of legumes is the most significant characteristic, both for animal feed and for balanced human consumption [19-21]. In terms of nutrition, legumes offer a range of bioactive peptides [22-24] that have beneficial effects on human health [25-29].

In addition, the nutritional quality of dietary proteins from legumes is determined by both the composition and digestibility of essential amino acids. Boye *et al.* [17] highlighted that legume proteins are particularly rich in Lysine, Leucine, Aspartic Acid, Glutamic Acid, and Arginine, which are among their main amino acid constituents [17]. Later, Remond and Walrand [30] demonstrated that legume amino

Table 1. Nutritional composition of pulses, compared to reference foods (Rice, meat).

	For 100 g	Energy kcal	Proteins g/ 100 g	Lipids g/ 100 g	Carbohydrates g/ 100 g	Fibers g/ 100 g	Iron mg/ 100 g	Zinc mg/ 100 g	Calcium mg/100 g
White bean	Dry	333	23.58	0.83	60.01	24.9	10.40	3.67	240
	Cooked	139	9.7	0.4	25.1	6.3	3.70	1.38	90
Lentils	Dry	352	31.4	1.15	56.53	10.7	6.51	3.27	35
	Cooked	116	9.0	0.4	20.1	7.9	3.33	1.27	19
Chickpeas	Dry	378	19.30	6.04	60.65	17.4	4.31	2.76	57
	Cooked	164	8.9	2.6	27.4	7.6	2.89	1.53	49
Carob	Dry	-	2.47	0.2–2.3	40–55	30-40	-	-	970-1120
Split peas	Dry	352	23.8	1.2	63.7	15.5	4.82	3.55	37
	Cooked	118	8.3	0.4	21.1	8.3	1.29	1.00	14
Beans	Dry	341	26.1	1.53	33.3	25	6.70	3.14	103
	Cooked	110	7.6	0.4	19.7	5.4	1.50	1.01	36
Corn	Dry	336	23.5	1.3	60.0	10.6	8.27	3.37	110
	Cooked	116	7.7	0.5	20.8	6.5	2.51	1.29	24
Lupine	Dry	371	36.2	9.7	40.4	18.9	4.36	4.75	176
	Cooked	119	15.6	2.9	9.9	2.8	1.20	1.38	51
Soy	Dry	446	34.5	19.2	20.8	13	15.70	4.89	277
Rice	Cooked	130	2.7	0.3	28.2	0.4	1.20	0.49	10
Meat (beef)	Cooked	142	26.4	4.1	-	-	2.90	5.60	-

Note: [16, 17, 23-29].

acid profiles tend to be deficient in Tryptophan and sulfur-containing amino acids such as Methionine and Cysteine (Tables **2** and **3**) [31]. This deficiency affects the overall protein quality but can be overcome through dietary complementation. Indeed, legume proteins complement cereal proteins, which are typically low in Lysine but relatively richer in Methionine [32-36]. Therefore, combining legumes and cereals in a diet contributes to a more balanced and complete amino acid profile, enhancing the overall nutritional value of plant-based diets.

3.2. The Investigation of Anti-nutritional Factors in Legumes

In addition to their nutritional affluence, legumes have Anti-Nutritional Factors (ANF) in the form of bioactive compounds like protease inhibitors, phytic acid, tannins, saponins, lectin, and alpha-galactosides that affect protein digestibility and favor intestinal discomfort (Table **4**). ANF also enhance the activity of mycotoxins and pesticide debris that can threaten human health [15]. Some ANF have positive effects at low doses and reveal their harmful effects at high doses.

Therefore, ANF are classified into two categories: those of a protein nature, including protease inhibitors (Trypsin, chymotrypsin and alpha-amylase) and lectins, and those of a non-protein nature, such as phytates, tannins, saponins, and alpha-galactosides. Alpha-galactosides, which are not hydrolysable, are responsible for colic fermentation [37]. Lectin, which is a glycoprotein, has adverse effects on the digestive mucosa, promoting diarrhea and malabsorption of nutrients [38]. Tannins can play a role in the precipitation of proteins and the formation of complexes that are more or less stable with them, as well as inhibit and diminish the absorption of certain minerals. The activity of these compounds can be decreased through pre-treatments and treatments such as soaking, cooking, and fermentation (Table **5**) [39, 40].

3.2.1. Protease Inhibitors (PI)

During digestion with trypsin and chymotrypsin, PI acts irreversibly. They have a molecular weight range of 7,000 to 20,000 Daltons, making them the most harmful proteolytic enzyme inhibitors. Inactivation is manifested by compensatory hypersecretion and hypertrophy of organs.

Cabrera-Orozco *et al.* [41] assert that the presence of protease inhibitors, particularly Antitrypsin Factors (ATFs), in the diet of monogastric animals leads to reduced growth and pancreatic dysfunctions [41]. These effects are mainly due to two mechanisms: first, a reduction in protein absorption caused by the disruption of pancreatic enzyme secretion; second, a limitation in amino acid assimilation due to the accumulation of partially digested oligopeptides in the intestinal mucosa, which interferes with nutrient uptake [41-45].

Table 2. Lysine composition, sulfur amino acids and tryptophan of legumes, relative to reference foods (Rice, meat).

-	For 100 g	Lysine(mg)	Methionine and Cysteine (mg)	Tryptophan (mg)
White bean	Dry	1.60	0.61	0.28
	Cooked	0.67	0.25	0.12
Lentils	Dry	1.72	0.53	0.22
	Cooked	0.63	0.20	0.08
Chickpeas	Dry	1.38	0.55	0.20
	Cooked	0.59	0.24	0.09
Split peas	Dry	1.77	0.62	0.28
	Cooked	0.60	0.21	0.09
Beans	Dry	1.67	0.55	0.25
	Cooked	0.49	0.16	0.07
corn	Dry	1.59	0.60	0.29
	Cooked	0.52	0.20	0.10
Lupine	Dry	1.9	0.70	0.29
	Cooked	0.83	0.30	0.13
Soy	Dry	2.71	1.20	0.59
Rice	Cooked	0.10	0.12	0.03
Meat (beef)	Cooked	2.2	1.82	0.26

Note: [30].

Table 3. Digestibility of different types of legumes relative to rice [1].

Pulse	Amino Acid Score	True Protein Digestibility (%)	Protein Digestibility Corrected Amino Acid Score (PDCAAS)
Pea	0.59	85.2	0.50
Lentil	0.71	87.9	0.63
Chickpea	0.61	85.0	0.52
Bean	0.83	80.0	0.67
Soy	0.92	83.5	0.77
Rice	0.54	92.0	0.50

Abbreviations: Amino Acid Score (AAS): A measure of the content of essential amino acids in a protein compared to a reference pattern established by the FAO/WHO. True Protein Digestibility (TPD): The proportion of ingested protein that is absorbed and retained in the body, accounting for endogenous losses. Protein Digestibility Corrected Amino Acid Score (PDCAAS): An index that combines the amino acid score with the true digestibility of the protein to assess [1].

Non-digestion of the protease-PI complex results in methionine degradation, favored by the two inhibitors, Bowman-Birk inhibitor (BBI) and Kunitz inhibitor (KI) [42]. Thermal treatments (cooking, autoclaving, *etc*.) as well as acids and alkalis can easily inactivate the action of these inhibitors [42, 46-49].

3.2.2. Lectins or Hemagglutinins

These glycoproteins have a large molecular weight, varying between 20,000 and 270,000 Daltons. They cause the clumping of red blood cells. Lectins associate with simple sugars, polysaccharides, glycolipids, and other glycoproteins, delaying growth and promoting the appearance of anemia and colitis [43]. They can also reduce the digestibility of starch and proteins in legumes [50-53].

However, since they are heat sensitive, these glycoproteins are denatured by heat treatments, such as cooking, autoclaving, and soaking pulses [43].

3.2.3. Phytates or Phytic Acids

Phytates are the primary compounds responsible for phosphorus and mineral accumulation in legume seeds, with concentrations reaching up to 20 g/kg [7, 47]. The complexation of divalent minerals, such as Ca^{2+}, $Zn^{2+,}$ and iron, by phytic acid, causes a lack of minerals in the body [54].

Table 4. Amino acid content of various legumes.

Amino acid (AA)	Pea (mg/ g) [32]	Chickpea (mg/g) [33-34]	Lentil (mg/g) [20, 35]	Soy Bean (mg/ g) [36]
Essential AA				
Isoleucine	3.89	4.1	5.06	0.54
Leucine	7.84	7.0	8.09	0.72
Lysine	6.25	7.7	5.69	0.83
Methionine	1.60	1.6	1.18	0.23
Phenylalanine	5.17	5.9	5.55	0.69
Threonine	4.46	3.6	5.62	0.26
Tryptophan	0.61	1.1	-	-
Valine	5.11	3.6	7.24	0.65
Arginine	7.93	10.3	9.10	0.42
Histidine	2.33	3.4	6.84	0.30
Non-essential AA				
Alanine	4.83	4.4	21.32	0.30
Aspartic acid	11.16	11.4	11.17	1.36
Cysteine	0.35	1.3	0.44	-
Glutamic acid	18.46	17.3	24.22	1.88
Glycine	4.82	4.1	10.22	0.4
Proline	4.64	4.6	8.88	0.38
Serine	5.71	4.9	11.20	0.61
Tyrosine	3.34	3.7	5.05	0.45

Table 5. Summary of the impact of common processing techniques on key antinutritional factors in legumes and their influence on nutrient bioavailability.

Antinutritional Factor	Processing Method	Observed Reduction (%)	Impact on Bioavailability	References
Protease Inhibitors (Trypsin, Chymotrypsin inhibitors)	Thermal treatment, fermentation	70–100%	Improved protein digestibility	[43-44]
Lectins	Thermal treatment, fermentation	90–100% (thermally inactivated)	Reduced toxicity and improved digestibility	[43-47]
Phytates	Fermentation, phytase	40–95%	Significant improvement in mineral absorption such as iron	[47-51]
Tannins	Fermentation, soaking, germination	30–70%	Improved protein availability and antioxidant potential	[49-53]
Saponins	Fermentation, soaking	10–50%	Reduced bitterness and potential cholesterol-lowering effects	[50, 51, 53]
Alpha-galactosides	Lactic fermentation, soaking	50–80%	Reduced flatulence effects and improved digestive tolerance	[48, 52]

Phytic acid reacts with proteins, creating complexes, which lower protein solubility and limit the access of proteases to labile peptide bonds [55]. This can also affect protein digestibility due to the globular structure and protein conformation, which can be influenced by treatments such as thermal processing that increase chain flexibility and accessibility to proteases [55].

It has been shown that soaking reduces the phytates content, as does heat treatment, which can either promote the enzymatic hydrolysis of the phytates or ensure their diffusion in the cooking water [56, 57].

Razafindrazaka [50] also demonstrated that germination, that triggers seed enzyme reactions, can reduce phytates [46, 49, 50]. Indeed, due to the activation of the endogenous

phytase enzyme by germination, phytic acids can be destroyed [58, 59].

Studies have reported that phytates can be effectively degraded by spontaneous fermentation of legumes using bacilli or fungal cultures such as *Rhizopus stolonifer*, *Aspergillus oryzae*, as well as lactic acid bacteria, with reductions reaching up to 95% in some cases [48-51].

3.2.4 Tannins

Like most ANFs, tannins' interaction with proteins reduces their digestibility, their enzymes' activity, the bioavailability, and the intestinal absorption of nutrients [17, 60].

Additionally, these phenolic compounds contribute to bitterness by reducing the digestibility of protein and starch due to the inhibition of pancreatic enzymes [61].

Similarly, tannins reduce the absorption of both macro- and micronutrients from food, which may lead to a decrease in overall caloric intake and the glycemic index of meals. In the context of diabetes management, tannins exert antidiabetic effects primarily through the inhibition of key digestive enzymes such as α-amylase and α-glucosidase, thereby slowing down carbohydrate digestion and glucose absorption. This enzymatic inhibition results in reduced postprandial blood glucose levels and improved glycemic control, highlighting the potential of tannin-rich foods in dietary strategies against type 2 diabetes [62].

However, research has shown that tannins have beneficial properties for human health, including anticancer and anthelmintic activities [63, 64].

These phenolic compounds, which are thermostable, can be reduced by dehulling, soaking, air classification, extrusion, steaming, and pre-gelatinization [52, 65, 66]. Moreover, it turned out that germination, enzyme treatments, and fermentation were more effective techniques, with a reduction of 50% in tannin content [44, 50, 52, 67, 68].

3.2.5 Saponins

Saponins are thermostable carbohydrate substances that can be divided into two groups: Steroidal and other triterpenoids, and are endowed with surfactant properties. A high dose of these substances can cause hemolysis, nausea following interaction with the mucous membranes of the stomach, and astringency or bitterness in products [43].

These substances can also promote the reduction of cholesterol absorption by the intestine [69].

Saponin activity can be reduced through heat treatment, soaking, and germination [70, 71].

3.2.6 Alpha-galactosides

Alpha-galactosides are oligosides of galactose, fructose, and glucose, characterized by the presence of osidic α 1- 6 bonds not hydrolyzed during human digestion. These substances are mostly: raffinose (α-galactose 1-6 β-glucose 1-2 β-fructose), stachyose (α-galactose 1-6 raffinose), and verbascose (α-galactose 1-6 stachyose) [72].

Thus, they lead to colic fermentation, followed by the phenomenon of flatulence and diarrhea [13, 52, 73].

However, partial elimination of these oligosides occurs through solubilization, enzymatic action during germination or fermentation [47, 53], or soaking [74, 75].

3.3. Interests of Pulses and their Different Ways of Transformation

Pulses are widely exploited in several fields such as cosmetics, packaging, feed, and food.

3.3.1. Miscellaneous Use

In cosmetics, studies have been conducted on the valorization of dried proteins and peptide hydrolysates of legumes in the form of skin moisturizers, soothing, and anti-itch substances [76]. It has been found that these proteins have the power to reduce body perspiration and whiten the skin [6].

3.3.2. Packaging

In the packaging sector, manufacturers are increasingly seeking new solutions for bio-based and biodegradable polymers that are less expensive, to meet the requirements of preserving food and cosmetics while maintaining their durability and biodegradability [8]. This leads to the use of bioactive substances from legume waste and by-products, including renewable and biodegradable natural fibers, in the production of polymer bio-composites [77].

3.3.3. Feed and Food Use

Legumes and their by-products play a vital role in both animal feed and human food systems, largely due to their rich nutritional profile.

According to the FAO, they are widely recognized as a key source of feed for animals, offering a sustainable and nutrient-rich ration [15].

In human nutrition, legumes have traditionally been valued. However, recent advances have focused on maximizing their functional potential through several extraction and fractionation technologies. These techniques allow the isolation of high-value components such as proteins, polyphenols, and fibers from both legumes and their processing by-products [78-81].

As the most advanced and effective technology for preserving protein quality and functionality, the wet or dry fractionation method was used for protein extraction from legumes [82].

A growing interest in plant-based diets has further intensified the demand for legumes, particularly as substitutes for animal-derived ingredients. This trend has prompted manufacturers to explore legumes such as chickpeas, lentils, and beans, not only for their macronutrient contents, including protein and starch, but also for their ability to support the development of functional foods [8, 83, 84].

As a result, legume-based flours are increasingly used across a variety of food products, aligning with consumer preferences for healthier, more sustainable diets [2, 85].

In addition to vegetarian and vegan lifestyles, consumers' awareness about nutrition and human health has also contributed to the rise of functional foods rich in fiber and bioactive components [86-89].

Legumes such as beans and peas have gained attention for their high dietary fiber content, making them valuable ingredients for promoting digestive and metabolic health [90, 91].

Among these, chickpea received particular focus. Their husks have been exploited in the manufacture of functional foods and in the bakery as a source of dietary fiber and phenolic compounds [92].

Moreover, chickpea protein is being investigated as a plant-based alternative in meat products such as merguez [63].

Its natural emulsifying and foaming properties even make it suitable for replacing egg yolk [93].

Additionally, chickpea-based ingredients offer antioxidant and antimicrobial benefits, supporting their use in 'green label' products that aim for more natural formulations [94].

Being the most used natural antioxidants by consumers and manufacturers, the phenolic compounds from legumes are commonly incorporated into meat production to prevent oxidative degradation, enhancing both shelf life and nutritional quality [95].

Carob is another promising legume-derived ingredient. Due to its richness in nutrients and functional compounds, carob is used in food products such as molasse, carob syrup, caffeine-free and low-calorie chocolate alternatives, and gluten-free dietary products [96-100]. Despite its potential, the industrial exploitation of carob remains limited [101], highlighting a need for further research and product development to fully realize its value.

CONCLUSION

After reviewing all the scientific evidence, it is clear that pulses are an excellent source of proteins, fibers, minerals, and other biologically active compounds. However, it is important to note that legumes may also contain Anti-Nutritional Factors (ANFs), which can have adverse effects on human health. Fortunately, various processing methods have proven effective in reducing or eliminating these compounds.

Among these, fermentation has emerged as one of the most effective strategies, with studies showing up to 95% reduction in phytates and approximately 50% reduction in tannins, depending on the microbial strains and fermentation conditions applied. This not only enhances the nutritional profile of pulses but also improves their functional and sensory qualities.

In addition to nutritional and anti-nutritional considerations, legumes contain compounds with health-promoting activities, supporting their valorization in various fields such as food, nutraceuticals, and biotechnology.

This review stands out by integrating nutritional, biochemical, and technological aspects of pulses in a unified framework, offering a multi-disciplinary perspective that is still scarce in the current literature.

This review aims to provide a comprehensive overview of the composition and characteristics of pulses, emphasizing recent scientific advancements and challenges in the development of pulse-based food products.

In particular, future research should focus on identifying optimized, low-cost, and sustainable processing techniques, as well as evaluating the synergistic effects of combined methods on both nutrient bioavailability and functional properties.

In conclusion, this review highlights not only the nutritional potential of pulses but also the importance of process optimization to unlock their full value, especially through biotechnological tools such as fermentation. Therefore, a better understanding of how these treatments affect beneficial bioactive compounds is needed to ensure an optimal nutritional balance.

AUTHORS' CONTRIBUTIONS

The authors confirm their contributions to the paper as follows. SS and AMG were responsible for writing, reviewing, and editing. IC handled data collection. LR and SB contributed to the methodology. AS worked on visualization. HG was responsible for conceptualization. All authors reviewed the results and approved the final version of the manuscript.

LIST OF ABBREVIATIONS

FA	=	Functional foods
FAO	=	Organisation pour l'alimentation et l'agriculture
MM	=	Molecular Masses
AA	=	Amino Acid
ANF	=	Anti-Nutritional Factors
PI	=	Protease Inhibitors

CONSENT FOR PUBLICATION

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CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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