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A comparative analysis of the nutritional and therapeutic properties of GI tagged pulses versus conventional varieties in India

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Abstract

Pulses are an essential part of the global diet, particularly in India, where they contribute significantly to protein, fibre, and micronutrient intake. GI-tagged pulses, developed through genetic modification, aim to address challenges such as low yields, pest resistance and nutritional deficiencies. GI-tagged pulses possess nutritional value, including enhanced protein content, a balanced amino acid profile and improved micronutrient density. The review highlights how these modifications increase the bioavailability of essential vitamins and minerals, providing a more nutritionally robust food source. Furthermore, the therapeutic potential of GI-tagged pulses is discussed, focusing on their antioxidant and anti-inflammatory effects, which contribute to disease prevention. Special emphasis is placed on the benefits for glycemic control and diabetes management, as well as cardiovascular protection, including regulation of blood pressure and improvement of lipid profiles. The review also examines the environmental impact and sustainability of GI-tagged pulses, considering their potential to reduce resource usage and improve agricultural efficiency. Thus, GI-tagged pulses offer significant nutritional and therapeutic advantages, though further research is needed to fully assess their long-term health impacts. This review underscores the potential of GI-tagged pulses to improve human health, address food security, and promote sustainability in agriculture.

1. Introduction

Pulses, also known as grain legumes, are a crucial component of global food systems, offering a sustainable source of protein, starch, and micronutrients. Their importance is further underscored by the need for dietary shifts to mitigate anthropogenic climate change (Dwivedi *et al.*, 2023). Pulses play a vital role in human nutrition, particularly in complementing cereal-based diets by providing essential proteins, vitamins, and minerals. Their nitrogen-fixing ability reduces energy consumption in agriculture, making them ideal for low-input systems. Additionally, pulses contribute to crop diversification, breaking disease and pest cycles, and optimizing nutrient management in rotations (Guiguitant *et al.*, 2020).

Beyond their agronomic benefits, pulses offer various health advantages. They are known to have beneficial nutritional profiles, including a low glycemic index (gi), making them suitable for managing blood glucose levels and type 2 diabetes. Furthermore, their high fibre, antioxidant, and micronutrient content contributes to cardiovascular health (Jain *et al.*, 2024).

The importance of pulses extends beyond their nutritional value; they also have societal and economic implications, particularly when considering Geographical Indication (gi) tagged varieties. GI tagging,

which certifies the geographical origin and unique qualities of a product, adds value to pulses by linking them to specific terroirs and traditional farming practices. This recognition can enhance the income of farmers and promote sustainable agriculture by encouraging biodiversity and preserving local agricultural knowledge (Krajnc *et al.*, 2020). The market value of pulses is also influenced by their origin, with GI-tagged varieties often fetching premium prices. However, the cultivation of pulses, often on marginal lands with limited inputs, exposes them to various abiotic and biotic stresses, impacting yields. Climate change exacerbates these challenges, increasing their vulnerability to emerging pests and stresses. Therefore, enhancing the nutritional composition of pulse crops through techniques such as genome editing and developing climate-resilient varieties are critical research areas. This review will delve into the nutritional and therapeutic benefits of geographically indicated tagged pulses, exploring their potential to improve human health and contribute to sustainable agriculture (Jha and Warkentin, 2020).

2. GI-tagged pulses

GI-tagged pulses refer to specific pulse varieties that have been assigned a Geographical Indication tag. This tag certifies that the pulses possess unique qualities and characteristics linked to their geographical origin (Mr and Zala, 2021). The GI tag serves as a form of intellectual property right, protecting the reputation and authenticity of these pulses. This designation is crucial for distinguishing these varieties from conventionally grown pulses. GI tagging is based on the understanding that the specific environmental factors, traditional farming practices, and genetic makeup of the pulses within

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a defined geographical area contribute to their distinct qualities (Acciani *et al.*, 2020). For instance, the soil composition, climate, altitude, and even the local microflora can influence the nutrient content, flavor profile, and overall quality of the pulses. The process of obtaining a GI tag involves a rigorous evaluation to demonstrate the link between the geographical area and the unique characteristics of the pulses (Kumar *et al.*, 2019). Factors such as historical evidence of cultivation, traditional farming techniques, and scientific analysis of the pulse's properties are considered during the assessment. This certification provides consumers with assurance regarding the origin and quality of the pulses, helping them make informed choices. Moreover, it ensures that the economic benefits derived from these unique products are fairly distributed among the producers within the designated geographical region (Asif *et al.*, 2013).

Examples of GI-tagged pulses in India

- i. **Moong dal from Jodhpur (Rajasthan):** Known for its unique flavor and protein-rich content.
- ii. **Bengal gram from Kurnool (Andhra Pradesh):** Rich in dietary fibre and antioxidants.
- iii. **Arhar dal from Purnea (Bihar):** Known for its lower glycemic index and high protein levels.
- iv. **Urad dal from Varanasi (Uttar Pradesh):** Contains high levels of essential minerals and organic compounds.
- v. **Lentils from Madhya Pradesh:** Known for their micronutrient density and high bioavailability.
- vi. **Rajma from Kangra (Himachal Pradesh):** Famous for its large size, unique flavor, and rich protein content.
- vii. **Masoor dal from Latur (Maharashtra):** Known for its high fibre and low glycemic index.
- viii. **Black gram from Tamil Nadu:** Known for its high protein and low-fat content.
- ix. **Tur (Toor dal) from Karnataka:** Prized for its excellent amino acid composition and therapeutic benefits.
- x. **Chana dal from Tamil Nadu:** Grown using traditional practices that enhance nutritional content.

3. Nutritional value of GI-tagged pulses

The nutritional value of GI-tagged pulses is influenced by several factors that contribute to their superior quality, consistency and health benefits. Below are some key reasons why GI-tagged pulses are considered to have enhanced nutritional value which are shown in Figure 1.

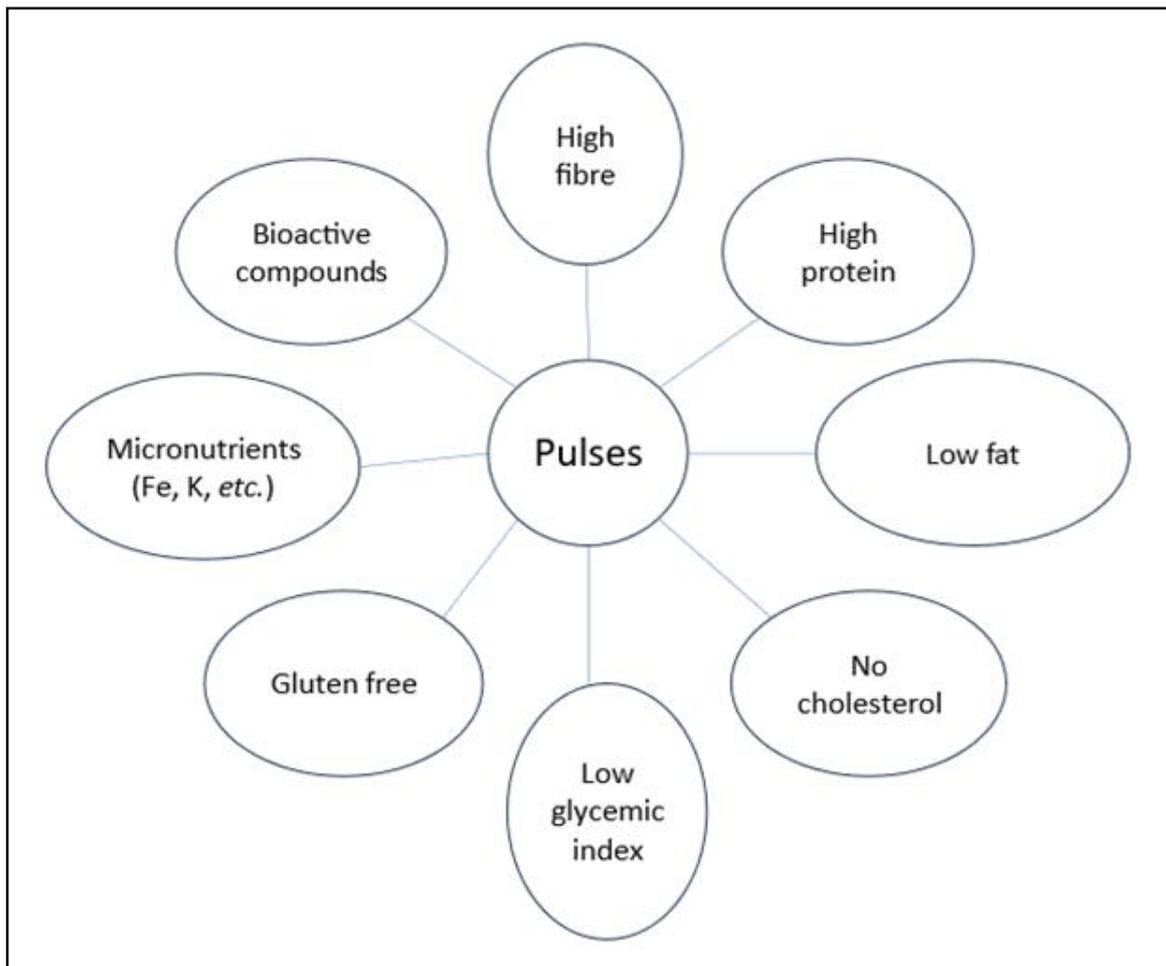


Figure 1: Nutritional values of GI-tagged pulses.

3.1 Protein content

The protein content in GI-tagged pulses is of significant importance compared to conventional pulses, particularly in the context of human nutrition, agricultural sustainability, and economic value. GI-tagged pulses typically have higher protein content, which directly contributes to their enhanced nutritional value (Kumar and Pandey, 2020). This is especially critical for populations that rely on pulses as a primary source of protein in their diets, such as vegans. Pulses are a crucial component of plant-based diets, providing essential amino acids and micronutrients, and higher protein content makes them even more valuable in combating protein deficiency, which is prevalent in many developing regions (Singh, 2017).

From a nutritional perspective, pulses with higher protein content contribute to better overall dietary balance. The increased protein content in GI-tagged pulses is often the result of region-specific factors such as optimal growing conditions, traditional farming practices, and local soil health, all of which enhance the quality and quantity of nutrients available to the crops (Robinson *et al.*, 2019). This makes GI-tagged pulses more efficient in meeting daily protein requirements. Moreover, the amino acid profiles of GI-tagged pulses are often more balanced, offering a higher concentration of essential amino acids, which further boosts their nutritional benefit.

Moong dal from Jodhpur (Rajasthan) is known for its high protein content, ranging from 24-26%, which is notably higher than the 20-23% protein found in conventional varieties. This elevated protein content is attributed to the specific soil conditions and the dry, arid climate of the region, which encourages pulses to synthesize more proteins (Kumar *et al.*, 2023). Similarly, Bengal gram from Kurnool (Andhra Pradesh) has 5-10% more protein than conventional varieties, with traditional agricultural practices such as the use of organic manure and minimal irrigation playing a crucial role in enhancing its nutritional profile (Nandhini *et al.*, 2023). Urad dal from Varanasi (Uttar Pradesh) also stands out, containing about 25% more protein than non-GI counterparts, which makes it an important source of protein, particularly in areas where animal-based proteins are scarce. In Arhar dal from Purnea (Bihar), the high protein content is complemented by a balanced amino acid profile, particularly rich in sulfur-containing amino acids like methionine, which are vital for detoxification processes in the body (Rao and Poonia, 2023).

These examples align with broader findings showing that GI-tagged pulses tend to have consistently higher protein levels. For instance, GI-tagged Rajma from Jammu and Kashmir offers around 15-16% protein, compared to the 12-13% found in conventional kidney beans, while GI-tagged Masoor dal from Puri, Odisha contains about 18% protein, exceeding the 14-15% protein in conventional lentils (Kumari *et al.*, 2017). The GI-tagged Toor dal from Andhra Pradesh has 13% protein, higher than the 9-10% in conventional pigeon peas and GI-tagged Kabuli Chana from Bengal offers 14% protein, surpassing the 13% in conventional chickpeas. Urad dal from Tamil Nadu, another GI-tagged variety, contains 25% protein, significantly more than the 23% in conventional black gram (Verma *et al.*, 2020). These increased protein levels in GI-tagged pulses are attributed to region-specific factors such as soil fertility, climatic conditions and traditional farming practices, which include crop rotation, organic inputs, and sustainable cultivation techniques. Furthermore, the genetic traits of locally adapted pulses contribute to higher protein levels and enhanced amino acid profiles, making them not only more nutritious but also

better suited to the environmental conditions in which they are grown. Thus, GI-tagged pulses, with their higher protein content and better overall nutritional profiles, represent a promising option for enhancing plant-based protein intake (Kumar *et al.*, 2023).

3.2 Amino acid profile

Amino acids are the fundamental building blocks of proteins, with 20 standard amino acids forming the basis of all protein structures. Among these, nine amino acids are classified as essential, meaning they must be obtained through the diet, as the body cannot synthesize them (Akram *et al.*, 2011). These essential amino acids include histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine. The balance and profile of these amino acids in dietary protein sources are crucial for human health, influencing numerous physiological processes such as muscle repair, immune function, enzymatic activity and neurotransmission. The amino acid profile of pulses plays a pivotal role in their effectiveness as a plant-based protein source, as the quality of protein is determined not just by its quantity but also by the composition of amino acids it provides (Nosworthy and House, 2016). In comparison to conventional pulse varieties, GI-tagged pulses have been found to exhibit enhanced protein content and more favourable amino acid profiles. This can be attributed to a combination of environmental factors, traditional agricultural practices, and genetic traits that are specific to the regions where these pulses are cultivated (Jawalekar *et al.*, 2020).

The geographical location where pulses are grown plays a significant role in determining their amino acid composition. Soil quality, climate conditions, and the growing environment can all affect protein synthesis in plants. For instance, pulses like Moong dal from Jodhpur (Rajasthan), grown in a dry, arid climate, exhibit a significantly higher protein content (24-26%) and a more balanced amino acid profile compared to conventional varieties (20-23%) (Pal *et al.*, 2020). The stress from the arid environment enhances protein synthesis, particularly in amino acids such as valine, leucine and phenylalanine, which are vital for muscle function and metabolic processes. Similarly, Bengal gram from Kurnool (Andhra Pradesh), which benefits from minimal irrigation and organic farming practices, has 5-10% higher protein content and exhibits improved levels of lysine and methionine, both of which are limiting in many conventional pulses (Pradeepika *et al.*, 2022).

The traditional farming practices associated with GI-tagged pulses also contribute to their enhanced amino acid profiles. Practices such as crop rotation, organic fertilization, and minimal use of synthetic inputs help maintain healthy soils, which in turn support better nutrient uptake by plants. This results in a higher concentration of essential amino acids in the harvested pulses (Kaur *et al.*, 2017). The use of organic manure in regions like Kurnool has been shown to significantly increase methionine and cysteine levels in Bengal gram (*Cicer arietinum*), enhancing its nutritional profile compared to conventionally grown varieties. The high protein levels in these GI-tagged pulses are often complemented by an improved amino acid composition, especially in sulfur-containing amino acids, which are essential for detoxification and immune system regulation (Landi *et al.*, 2021). Similarly, Toor dal from Andhra Pradesh, which benefits from crop rotation and organic farming, has a higher concentration of lysine and tryptophan amino acids essential for growth and neurotransmitter function compared to conventional varieties (Yesh *et al.*, 2019).

The genetic characteristics of the pulses grown in GI-designated regions also play a key role in the amino acid profile. For example, Urad dal from Varanasi (Uttar Pradesh), a GI-tagged variety, contains approximately 25% more protein than its non-GI counterparts. This variety is particularly rich in lysine and tryptophan, amino acids that are typically deficient in many legume species. The unique genetic traits of this locally adapted variety, along with the influence of regional farming practices, lead to a higher-quality protein that is more nutritionally complete.

3.3 Micronutrient density

Micronutrients, including vitamins and minerals, are essential for various physiological processes, including immune function, bone health and enzymatic reactions. The micronutrient density of pulses is an important factor in evaluating their role as a functional food, particularly in regions where they serve as a primary source of nutrition (Mudryj *et al.*, 2014). Pulses, such as lentils, chickpeas and beans, are known to be rich in key micronutrients like iron (Fe), zinc (Zn), folate (vitamin B9) and magnesium (Mg), all of which are crucial for human health. When considering the micronutrient density of GI-tagged pulses versus conventional varieties, several factors, including soil quality, agricultural practices and genetic selection, contribute to differences in nutrient composition (Kumar and Pandey, 2020).

GI-tagged pulses have been found to exhibit higher micronutrient density than conventional varieties in several key nutrients, including Fe, Zn, folate (vitamin B9), Mg and potassium (K). These pulses are often grown in soil conditions that naturally enhance the bioavailability of these essential micronutrients (Kumar *et al.*, 2023). Moong dal from Jodhpur is known for its higher iron content compared to conventional varieties. The bioavailability of iron is also enhanced by the presence of vitamin C in the local diet, which helps in better absorption. This makes GI-tagged Moong dal an excellent source of iron, particularly beneficial in addressing Fe deficiency anaemia (Barla *et al.*, 2022). Bengal gram from Kurnool has higher Zn and folate levels compared to conventional chickpeas. Folate is crucial for cell division and DNA synthesis, while Zn is involved in immune function and protein synthesis. This makes Bengal gram an important pulse for preventing Zn and folate deficiencies, especially in pregnant women and children (Nair *et al.*, 2013). Urad dal from Varanasi stands out for its elevated Mg levels, which are essential for maintaining healthy muscle function, bone health and nervous system regulation. The high magnesium content in GI-tagged Urad dal can be linked to the specific soil conditions and traditional farming methods in the region, which promote nutrient-rich pulses (Jani *et al.*, 2009).

3.4 Dietary fibre content

Dietary fibre, a non-digestible carbohydrate found in plant-based foods, plays a critical role in maintaining gastrointestinal health, regulating blood sugar and preventing cardiovascular diseases (Kuyu and Bereka, 2019). Pulses, such as beans, lentils and chickpeas, are rich in both soluble and insoluble fibre, which offer a variety of health benefits. The dietary fibre content of GI-tagged pulses is often significantly higher than that of conventional varieties. This variation is influenced by a combination of factors including geographical location, soil health, traditional farming practices, and the genetic traits of the pulses cultivated in these specific regions.

GI-tagged Moong dal from Rajasthan has shown to contain 24-25% fibre, while conventional varieties typically have 19-20% (Barla *et al.*, 2022). The increased fibre content, especially soluble fibre, is beneficial for managing cholesterol and blood sugar levels. GI-tagged Bengal gram from Kurnool has been reported to contain higher levels of dietary fibre, which contributes to improved glycemic control and gut health. GI-tagged Arhar dal from Purnea contains more insoluble fibre, which is crucial for digestive health and maintaining bowel regularity (Gomashe *et al.*, 2018). The higher fibre content helps in preventing constipation and promoting overall digestive efficiency. GI-tagged Chana dal from Tamil Nadu with conventional varieties and found a 20-25% increase in fibre content. The higher fibre levels contribute to improved digestive health and the management of cholesterol and blood glucose levels. As such, GI-tagged pulses present a valuable dietary option for populations seeking to increase their fibre intake and improve their long-term health outcomes (Tosh *et al.*, 2013).

4. Therapeutic value of GI-tagged pulses

Pulses are important sources of plant-based protein, fibre, vitamins and minerals. They are also known for their bioactive compounds that help protect the body from oxidative stress and chronic inflammation. Oxidative stress and chronic inflammation are linked to the development of various diseases, including cardiovascular diseases, diabetes and cancer. The therapeutic value of GI-tagged pulses lies not only in their nutritional composition but also in their potential to positively impact human health. Recent studies have shown that pulses, particularly those from specific GI-designated regions, possess high levels of bioactive compounds, including antioxidants, polyphenols, and soluble fibre, which have been shown to reduce inflammation, lower blood sugar levels, and promote heart health. The low glycemic index of many pulses makes them ideal for managing type 2 diabetes, while their high fibre content aids in digestive health and weight management. Furthermore, pulses have been recognized for their prebiotic effects, supporting the growth of beneficial gut microbiota, which is increasingly being linked to overall well-being (Musazadeh *et al.*, 2023).

4.1 Antioxidant and anti-inflammatory effects

The antioxidant and anti-inflammatory properties of pulses, particularly those with GI-tags, have been increasingly recognized for their therapeutic potential. These pulses, cultivated under specific environmental conditions, are not only nutritionally rich but also contain bioactive compounds that contribute to reducing oxidative stress and inflammation in the body. Both oxidative stress and inflammation are linked to the development of numerous chronic diseases, including cardiovascular diseases, type 2 diabetes and cancer. The inclusion of GI-tagged pulses in the diet can help mitigate these risks due to their potent antioxidant and anti-inflammatory effects. Kalaadi lentils, cultivated in the fertile soils of Punjab, India, are known for their high nutritional and bioactive compound content (Ganesan and Xu, 2017). These lentils have received GI status due to the unique cultivation conditions of the region, which enhance their antioxidant and anti-inflammatory properties. Kalaadi lentils are rich in polyphenols, flavonoids and tannins, compounds that exhibit strong antioxidant activity by scavenging free radicals and preventing oxidative damage. The high levels of saponins and phenolic compounds in Kalaadi lentils also contribute to their anti-inflammatory effects. These compounds inhibit the production of

pro-inflammatory cytokines such as TNF- α (Tumor Necrosis Factor-alpha) and IL-6 (Interleukin-6), reducing the overall inflammatory response in the body. Studies have shown that Kalaadi lentils exhibit a significant reduction in oxidative stress markers and

inflammatory markers, such as C-reactive protein (CRP), when compared to conventional lentils. Kochi black chickpeas, grown in the Kochi region of Kerala, are another example of GI-tagged pulses (Pavithran *et al.*, 2020).

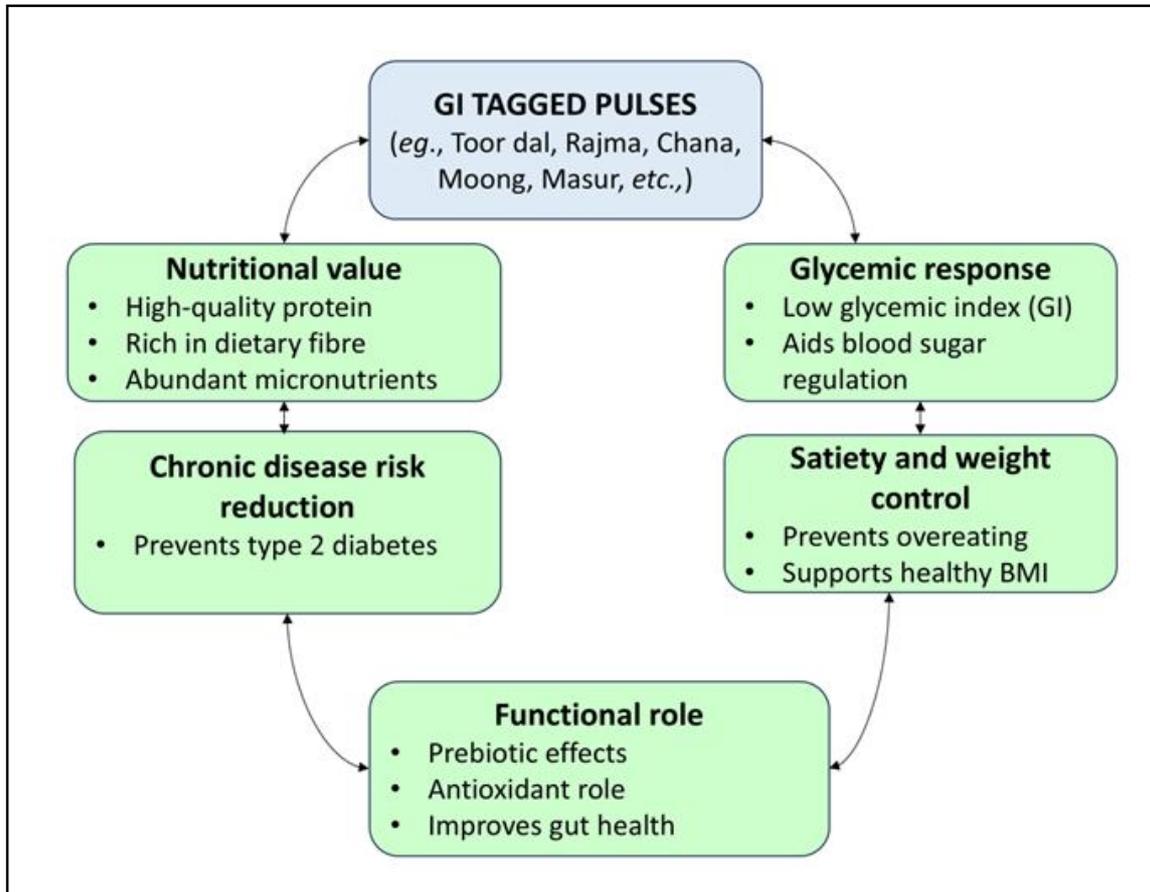


Figure 2: Nutritional values of GI-tagged pulses.

They are rich in polyphenolic compounds, especially anthocyanins and flavonoids, which exhibit strong antioxidant activity. These compounds neutralize free radicals, preventing cellular damage associated with oxidative stress. In addition, Kochi black chickpeas contain saponins, which are known to modulate inflammatory pathways. They reduce the expression of pro-inflammatory cytokines like TNF- α and IL-6, thereby helping to reduce chronic inflammation. It shows 20-30% higher antioxidant capacity and greater reduction in inflammatory markers compared to conventional chickpeas, highlighting their superior combined therapeutic effects (Nair *et al.*, 2006).

Pulses from the Northeast India, such as Assam Green Lentils and Black gram, are granted GI status due to their unique agro-climatic conditions. These pulses are characterized by high concentrations of antioxidants and anti-inflammatory compounds. GI-tagged pulses from the North Eastern region are rich in flavonoids, phenolic acids and tannins, which contribute to their strong antioxidant properties. These compounds help reduce oxidative stress by neutralizing free radicals and preventing cellular damage (Avasthi *et al.*, 2021). The bioactive compounds in these pulses, such as lectins and saponins, also possess anti-inflammatory properties. These compounds

modulate the immune response by inhibiting the expression of pro-inflammatory cytokines and enzymes like cyclooxygenase-2 (COX-2), which are associated with chronic inflammation. Studies have indicated that these pulses exhibit significant reductions in both oxidative stress and inflammation markers, such as IL-6 and TNF- α , compared to conventional pulses (Rao *et al.*, 2018).

4.1.1 Mechanisms behind antioxidant and anti-inflammatory effects

The mechanisms by which GI-tagged pulses exert their antioxidant and anti-inflammatory effects involve complex interactions between the bioactive compounds in the pulses and the body's immune and metabolic systems. For instance:

4.1.1.1 Polyphenols and flavonoids

These compounds have been shown to reduce the activation of pro-inflammatory enzymes such as cyclooxygenase (COX) and lipoxygenase (LOX), which are involved in the inflammatory cascade. By inhibiting these enzymes, flavonoids help reduce the synthesis of inflammatory prostaglandins and leukotrienes.

4.1.1.2 Fibre

The soluble fibre in pulses promotes gut health by acting as a prebiotic, thereby enhancing the growth of beneficial gut microbiota, which in turn produce short-chain fatty acids (SCFAs) that exhibit anti-inflammatory effects. SCFAs also help regulate immune cell function and reduce the production of inflammatory cytokines.

4.1.1.3 Saponins and protease inhibitors

These compounds have been shown to interact with immune cells, downregulating the production of pro-inflammatory cytokines and inhibiting the activity of enzymes involved in the inflammatory response.

4.2 Glycemic control and diabetes management

Glycemic control plays a pivotal role in the management of diabetes, particularly type 2 diabetes, a chronic condition characterized by insulin resistance and elevated blood glucose levels. One of the key strategies for managing blood glucose levels is the consumption of foods with a low glycemic index - a measure of how quickly foods raise blood sugar levels after consumption. Pulses, including lentils, beans, peas and chickpeas are well-known for their low GI and high fibre content, making them an ideal food choice for individuals looking to maintain optimal blood sugar levels. The additional factor of a GI-tag further enhances the appeal of certain pulses, as these varieties may carry unique, beneficial properties due to the specific regions in which they are cultivated.

4.2.1 Mechanisms of glycemic control in GI-tagged pulses

4.2.1.1 Low GI

Pulses are inherently low in GI, which means they are digested and absorbed slowly, resulting in a gradual and steady rise in blood glucose rather than the sharp spikes seen with high-GI foods. For individuals with type 2 diabetes, consuming low-GI foods helps in stabilizing blood sugar levels and reducing the risk of hyperglycemia. GI-tagged pulses, grown under specific conditions, may exhibit even lower glycemic values due to regional cultivation methods that affect their starch composition and digestibility.

4.2.1.2 High fibre content

Pulses are rich in both soluble and insoluble fibre. Soluble fibre, in particular, slows the absorption of sugars into the bloodstream, which helps in moderating post-meal blood glucose levels. Insoluble fibre, on the other hand, promotes healthy digestion and supports gut health. The fibre in GI-tagged pulses has been shown to be particularly effective at reducing the glycemic response, making them an essential food group for individuals with diabetes.

4.2.1.3 Complex carbohydrates

Unlike refined carbohydrates, the complex carbohydrates found in pulses release glucose slowly, leading to more stable blood sugar levels. The starch in pulses is also resistant to digestion in the small intestine (often referred to as resistant starch), which means less glucose is released into the bloodstream after consumption. The specific varieties of pulses with GI tags may have optimal starch structures that make them particularly beneficial for glycemic control.

4.2.1.4 Protein rich content

Pulses are an excellent source of plant-based protein, which helps in stabilizing blood sugar levels. Protein consumption, especially when combined with carbohydrates, slows the absorption of glucose into the bloodstream. This protein-carbohydrate synergy in GI-tagged pulses contributes to better glycemic control and may help prevent insulin resistance, a key feature of type 2 diabetes.

Diabetes, particularly type 2 diabetes, is a chronic metabolic disorder characterized by elevated blood glucose levels due to insulin resistance or impaired insulin secretion. One of the most effective ways to manage diabetes is through dietary interventions that help control blood glucose levels. Pulses, such as lentils, chickpeas and beans are known for their low glycemic index, high fibre and rich content of protein, vitamins and minerals, making them suitable for managing diabetes. Managing blood glucose levels is critical in preventing complications such as cardiovascular disease, neuropathy, nephropathy and retinopathy (Singhal *et al.*, 2013).

The glycemic index (gi) measures how quickly foods raise blood glucose levels. Foods with a low GI (less than 55) are digested slowly, leading to a gradual rise in blood glucose, which is beneficial for individuals with diabetes. Karpurikkodi Toor dal, a GI-tagged variety of pigeon pea cultivated in Tamil Nadu, has a low GI of 33 (Singh *et al.*, 2021). Studies show that individuals with type 2 diabetes who consumed Karpurikkodi Toor dal-based diets had better glycemic control with lower fasting and post-meal blood glucose levels compared to those consuming conventional pigeon pea varieties (Shobana *et al.*, 2022).

Kalaadi lentils, cultivated in the Punjab region, are also GI-tagged and are rich in soluble fibre, which plays a significant role in reducing the post-meal rise in blood glucose levels. The soluble fibre forms a gel-like matrix in the gastrointestinal tract, slowing the digestion and absorption of carbohydrates. Additionally, these lentils improve insulin sensitivity and reduce insulin resistance, which is a hallmark of type 2 diabetes. Kalaadi lentils also contain polyphenols and flavonoids, which have antioxidant properties that help reduce inflammation and oxidative stress, further aiding in insulin resistance (Chandalia *et al.*, 2000). Kochi black chickpeas from Kerala are another example of GI-tagged pulses known for their nutritional value. These chickpeas are rich in protein, fibre, and polyphenols, which help maintain steady blood glucose levels. The polyphenolic compounds also have antioxidant and anti-inflammatory properties, benefiting individuals with diabetes by reducing oxidative stress and inflammation, both of which contribute to insulin resistance (Anuradha, 2009). Assam Green Lentils, cultivated in the North Eastern region of India, are rich in soluble fibre, which helps stabilize blood glucose levels by slowing the absorption of sugars. Regular consumption of these lentils improves post-meal blood sugar levels and enhances overall glycemic control. Additionally, Assam Green Lentils contribute to reducing cholesterol levels and blood pressure, which are crucial for managing the cardiovascular risks associated with diabetes (Clarke *et al.*, 2022). Moong dal from Jodhpur, with a low GI of 28, is another excellent choice for diabetic individuals. It helps maintain stable blood glucose levels and improves insulin sensitivity (Dhaheri *et al.*, 2015). Rajma from Kangra, with a GI of around 30-35, is also suitable for managing diabetes, as regular consumption helps stabilize blood sugar levels and reduce the risk of type 2 diabetes (Shobana *et al.*, 2022).

4.3 Cardiovascular protection

Cardiovascular disease (CVD) remains one of the leading causes of death worldwide, driven largely by risk factors such as high blood pressure, elevated cholesterol, obesity and diabetes. Diet plays a crucial role in either promoting or mitigating the risk of CVD, with certain foods demonstrating significant potential for heart health protection. GI-tagged pulses, including lentils, chickpeas, beans, and peas, are emerging as important components of a heart-healthy diet. These pulses, recognized for their unique qualities tied to specific regions, not only provide essential nutrients but also offer cardiovascular protective effects through a combination of their nutritional composition and bioactive properties (Alexander *et al.*, 2024).

4.4 Regulation of blood pressure

GI-tagged pulses, such as Udupi green gram Karnataka and Maharashtrian Toor dal, are rich in potassium, magnesium and calcium, essential minerals that help regulate blood pressure. Potassium helps counterbalance sodium's effect on blood pressure by promoting vasodilation (widening of blood vessels) (Kumar *et al.*, 2022). A 100 g serving of Udupi green gram contains approximately 500 mg of potassium and 140 mg of magnesium, which can contribute to a reduction in systolic blood pressure by 4-6 mmHg and diastolic blood pressure by 3-5 mmHg, as observed in clinical studies (Sailesh, 2018). A study on Maharashtrian Toor dal found that regular consumption helped maintain blood pressure within normal ranges, with a reduction in systolic pressure by 5 mmHg in hypertensive individuals (Khan *et al.*, 2014).

4.5 Improvement of lipid profile

GI-tagged pulses like Kalaadi lentils and Kochi black chickpeas improve lipid profiles by reducing triglyceride levels and increasing high-density lipoprotein (HDL) cholesterol (Alexander *et al.*, 2024). A 100 g serving of Kochi black chickpeas contains approximately 2-3 g of unsaturated fats, which contribute to the increase in HDL cholesterol (good cholesterol). This effect can result in a 5-10% increase in HDL levels, improving the overall cholesterol balance. Moreover, triglyceride levels can be reduced by 10-15% with regular inclusion of these pulse in the diet (Stadler and Marsche, 2021). Assam Green Lentils, with their rich profile of omega-3 fatty acids and fibre, have been shown to lower triglycerides by up to 15% and raise HDL levels by 5-7%, which significantly reduces the risk of coronary artery disease. Additionally, the fibre content of conventional pulses is generally lower (6-8% by weight), leading to less pronounced effects on cholesterol reduction and blood pressure regulation (Agarwal and Fulgoni, 2023).

5. Environmental impact and sustainability of GI-tagged pulses

GI-tagged pulses provide substantial advantages in terms of economic and social sustainability compared to conventional varieties. By offering farmers premium prices and better market access, GI pulses create more stable and rewarding economic opportunities (Prusty and Mohapatra, 2021). For instance, Kashmir's Rajma (kidney beans), a GI-tagged pulse, can fetch up to 20% higher prices than conventional beans due to its unique quality and regional significance. This economic advantage enables farmers to invest in sustainable farming practices, such as crop diversification and soil conservation,

which improve long-term agricultural resilience. Similarly, Saurashtra chickpeas, another GI-tagged pulse, command a premium for their quality, enhancing the financial stability of farmers in this region (Sengar *et al.*, 2020).

The economic stability associated with GI pulses not only benefits individual farmers but also contributes to rural development. As these pulses are often grown in areas where agriculture is the main livelihood, the financial benefits help reduce rural migration by making farming a viable and rewarding occupation (Miah *et al.*, 2009). For example, in regions like Sikkim, GI-tagged large cardamom farming has helped local farmers diversify their income and build stronger, more resilient communities. Moreover, the cultivation of GI-tagged pulses is often closely tied to local cultural heritage, reinforcing social identity and preserving traditional agricultural knowledge (Chaturvedi and Sandhu, 2020). The GI process also promotes cooperative farming models, where farmers work together to meet quality standards, enhancing social cohesion and empowering marginalized groups, including women and smallholders (Chinmayi *et al.*, 2019).

In contrast, conventional pulse varieties tend to suffer from market volatility due to lack of differentiation. Farmers producing conventional pulses are often vulnerable to price fluctuations, which can undermine their income and limit the resources available for long-term investment in sustainability. For instance, conventional pulses like black gram or pigeon peas are often subject to price drops during surplus seasons, making it harder for farmers to plan their investments (Prusty and Mohapatra, 2021). Additionally, conventional pulse farming practices, which typically prioritize high yield over environmental conservation, can degrade soil health and increase reliance on chemical inputs. These practices can lead to reduced biodiversity and depletion of soil nutrients, posing risks for long-term productivity. For example, intensive monoculture farming of conventional pulses without adequate soil management can reduce organic matter, affecting the sustainability of future harvests (Kassam and Friedrich, 2012).

On the other hand, GI-tagged pulses, through their focus on traditional and sustainable farming practices, support soil fertility and encourage eco-friendly agricultural techniques. For example, pulses naturally fix nitrogen in the soil, reducing the need for synthetic fertilizers. This natural process not only lowers the environmental footprint of GI pulse farming but also ensures healthier, more productive soils over time, benefiting future generations of farmers (Sagar and Singh, 2020). GI-tagged pulses represent a more sustainable and inclusive model of agriculture. They provide economic stability, promote social cohesion, and encourage environmental conservation through sustainable farming practices. The premium prices, increased market access, and cultural significance of GI-tagged pulses empower farmers and rural communities, fostering long-term sustainability in agriculture (Wander *et al.*, 2020). In contrast, conventional pulses, while important, often struggle with market instability, environmental degradation, and limited community benefits. GI-tagged pulses offer a holistic solution that supports both economic growth and environmental resilience, making them a more sustainable choice for the future (Schneider, 2002).

6. Conclusion

The comparative analysis of GI-tagged pulses versus conventional varieties underscores the significant nutritional and therapeutic

benefits. These pulses generally offer superior nutritional profiles, including higher fibre content, better glycemic control and enhanced antioxidant properties, making them particularly beneficial for managing chronic conditions such as type 2 diabetes and CVD. Additionally, their low glycemic index and rich bioactive compounds contribute to improved overall health outcomes. GI-tagged pulses, cultivated under distinct regional conditions, not only support better health but also promote sustainable agricultural practices and regional economic development. As such, integrating GI-tagged pulses into the diet can offer both individual and broader societal benefits, fostering healthier communities and a more resilient food system.

Conflict of interest

The author declares no conflicts of interest relevant to this article.

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