**Antinutritional properties of dietary lectins**

**Author:**AsemKajal Devi1, OinamSangita Devi1, Ashem Anjali Devi1, Sanasam Yaiphabi1,Senjam Sunil Singh1,\*

*1Laboratory of Protein Biochemistry, Biochemistry Department, Manipur University, Canchipur, Imphal-795003, India*

\*corresponding author Email address- [sunil\_senjam@rediffmail.com](mailto:sunil_senjam@rediffmail.com)

Postal address: Biochemistry Department, Manipur University, Canchipur, Manipur, 795003, India

**ABSTRACT**

Lectins are a class of specialized proteins found in large quantities in nature that can recognize and bind to carbohydrates and glycoconjugates with selectivity and reversibility. Lectins have been identified from a variety of sources, including lower vertebrates' and invertebrates' bodily fluids, fungus, algae, and plants. The majority of regularly consumed edible plant foods contain lectins. When it comes to food, lectin comes under antinutritional factors since harmful local and systemic reactions might trigger during ingestion. However, the characteristic property of lectins being resistant to animal and insect proteases and their ability to recognize and affect other molecules in a distinct way makes them play a vital role in plant defense.

**Keywords**: Lectin, antinutritional factors, toxic substance, carbohydrate binding protein,

**I. INTRODUCTION**

Lectins are a class of natural bioactive proteins and glycoproteins of non-immune origin widely distributed in nature that reversibly bind to carbohydrates and glycoconjugates (Kennedy *et al.*, 1995; LIS and SHARON 1981). Lectins have been isolated from numerous sources such as plants, algae, fungi, and body fluids of invertebrates and lower vertebrates. (Mishra *et al.*, 2019; Peumans and Van Damme 1995). Plant lectins are referred to as phytohemagglutinins. When it comes to food, lectin comes under antinutritional factors (Thompson 1993; Vasconcelos and Oliveira 2004a). Because lectins are resistant to digestion by the gastrointestinal tract, they attach to the glycosyl groups in the membranes of the cells lining the digestive tract. This combination may result in a number of unfavorable local and systemic effects, designating this class of biomolecule as toxic or antinutritive. (Kumar *et al.*, 2012; Pusztai, Bardocz, and Ewen 2008a; Vasconcelos and Oliveira 2004a). The Public Health Laboratory Service first documented an epidemic of lectin poisoning in 1976 after a group of adults and schoolboys consumed uncooked Phaseolus vulgaris kidney beans after they had been soaked in water for a day. (Bender and Reaidi 1982). Later, Rodhousesurveyed the same poisoning incidents between 1976 and 1989, leading to the conclusion that lectin is responsible for all the events(Rodhouse*et al.,* 1990). Undigested and unabsorbed proteins and carbs make their way to the colon, where they are fermented by the colon's flora of bacteria to produce gases and short-chain fatty acids. These could be involved in some of the gastrointestinal symptoms that are common when lectin-associated foods are consumed. (Thakur *et al.*, 2019). Plant defense proteins are classified into five primary classes: lectins, chitinases, polyphenol oxidases, α-amylase inhibitors, and protein inhibitors (Fürstenberg-Hägg, Zagrobelny, and Bak 2013). Lectin is one of these classes.With these perspectives in mind, we want to consolidate information on the defense role of lectins in plants as well as their implications as antinutritional qualities for lectins found in human diets.

**II.CLASSIFICATION OF LECTINS**

Due to their extensive diversity, the ongoing development of lectin classification continues. Lectins are categorized based on their structure into two groups. First, there are Merolectins, which consist of small monovalent proteins with a single polypeptide and only one carbohydrate-binding domain. Merolectins are unable to induce glycoconjugate precipitation or cell agglutination (Macedo, Oliveira, and Oliveira 2015; Peumans and Van Damme 1995; Santos et al., 2016). Second, there are Hololectins, which exclusively possess carbohydrate-binding domains, with two or more domains being either identical or highly similar. Hololectins encompass all lectins with multiple binding sites and have the capability to induce cell agglutination or glycoconjugate precipitation (Santos et al., 2016).

(3) Chimerolectins are unique proteins that lack carbohydrate domains but are considered 'chimeric' as they combine a carbohydrate-binding domain with other domains possessing enzymatic activity. Importantly, the presence of the carbohydrate-binding domain does not interfere with the functions of the enzymatic domain. The classification of Chimerolectins as hololectins or merolectins depends on the number of sugar binding sites they possess (Mishra et al., 2019). On the other hand, Superlectins are molecules characterized by the presence of two or more distinct carbohydrate-binding domains. These multiple domains enable them to recognize sugars with varying structural characteristics (Santos et al., 2016).

Based on binding affinity to carbohydrate moiety,lectins are classified as (1) Glucose/mannose binding lectins; (2) Galactose and N-acetyl-D-galactosamine binding lectins; (3) L-fucose binding lectins; (4) N-acetyl-D-galactosamine binding lectins and (5) Sialic acids binding lectins(Bah, Fang, and Ng 2013; Mishra *et al.,* 2019).

Lectins are also categorized into 12 families based on the similarity of amino acid sequences in these proteins and the structure of their carbohydrate-recognition domains (CRD). These families encompass Agaricusbisporus homologs, the Amaranthin domain, class V chitinase homologs, the Euonymus europaeus family, the Galanthusnivalis agglutinin family, proteins containing hevein domains, Jacalins, Cyanovirin domain proteins with legume lectin domains, Lys M domain proteins, the Nicotianatabacum agglutinin family, and the ricin-B domain (Hendrickson and Zherdev 2018; Macedo, Oliveira, and Oliveira 2015).

Plant lectins can also be classified based on sequence data, and this categorization involves grouping them into four distinct categories based on their evolutionary relationships with other proteins. These categories are as follows: (1) Legume lectins; (2) Chitin-binding lectins; (3) Type 2 RIP (ribosome-inactivating proteins); and (4) Monocot mannose-binding lectins (Dammeet al., 1998).

**III. LECTINS IN FOODS**

Lectins are found in a variety of commonly consumed foods, including tomato, potato, beans, peas, carrots, soybeans, cherries, blackberries, wheat germ, rice, corn, garlic, peanuts, mushrooms, avocado, beetroot, leek, cabbage, tea, parsley, oregano, various spices, and nuts. Additionally, lectins can be found in several wild plant species (Vasconcelos and Oliveira 2004b). It is noteworthy that plant tissues tend to contain higher levels of lectins in comparison to animal tissues. (Hamid *et al.,* 2013). Lectin is under the category of antinutritional elements in diet. Due to their resistance to digestion in the gastrointestinal (GI) tract, lectins bind to the membrane glycosyl groups of the cells lining the digestive system. This interaction could cause several adverse local and systemic reactions in the GI tract, placing this class of biomolecule as an antinutritive substance (Kumar *et al.,* 2012; Pusztai, Bardocz, and Ewen 2008a). Several lectins from many vegetables and fruits have been discovered as potent food allergens. Only a small number of them have been identified by the WHO/IUIS Allergen Nomenclature Sub-Committee as possible food allergens. The list also includes contact allergens from Hev b 6 (hevein) and Hev b 11 (class I chitinase having a hevein domain) from the rubber tree Heveabrasiliensis, as well as a restricted number of proteins like Tri an 18 (Wheat Germ Agglutinin) and a few chitinases with a hevein domain like Mus a 2 (banana), Bra r 2 (turnip), Zea m 8 (corn), and Per a 1 (avocado). Based on their capacity to bind IgE, degranulate mast cells and basophils, and trigger interleukin responses in susceptible individuals, a few more plant lectins have also been recognized as possible food allergens (Barre et al., 2020).

The exposure of heterotrophic organisms, including humans, to functionally active lectins is a common event. The lack of public knowledge concerning the deleterious effects of dietary lectins on the gut and other part of GI tract has led to several ~~f~~ood poisoining outbreaks. The first outbreak of lectin poisoning was reported by the Public Health Laboratory Service in 1976 when some people ate raw kidney beans, *Phaseolus vulgaris*(Bender and Reaidi 1982). Later, the same poisoning incidents were surveyed between 1976 and 1989 concluding that lectin is responsible for all the events (Rodhouse*et al.,* 1990). Undigested and unabsorbed proteins and carbs make their way to the colon, where they are fermented and released as gases by the bacterial flora. These might be involved in some of the gastrointestinal complaints linked to eating lectin-containing foods (Thakur et al., 2019).

When consumed, lectins in human may causes vomiting, nausea, bloating and diarrhoea. It was also reported that, animal fed with lectins, show symptoms of appetite loss, decrease in body weight and even death of the animal (Liener*et al.*, 1986; Lajolo*et al.,* 2002).

Lectins are comparatively resistant to digestion in GI tract, and many of them may undergo further modification leading to remain as active throughout the digestive processes. And those bound to the mucosa become important as antinutritional lectins (Pusztai and Bardocz, 1996; Sunil *et al.,* 2012). After binding to the mucosal cells, lectins may cause changes in cellular morphology and intermediary metabolisms leading to frequent disruption of brush borders and other main absorptive cells. It may cause reduction in the absorptive surface area and absorption of essential nutrients and become hyperplasia (Otte*et al.,* 2001; Sasaki *et al.*, 2002). Another secondary toxic effect of accumulated lectins in the small intestine is the overgrowth of intestinal bacteria which ultimately lead to overproduction of bacterial toxins. This also may aggravate in the worsening of animal health (Grant, 1999; Ilka *et al.*, 2004; Sunil *et al.,* 2012).

**IV. LECTINS AS PLANT DEFENSE MOLECULE**

Against bacteria, fungus, and insects, plant lectin is essential (Souza Cândidoet al., 2011). Lectin is a member of the five main families of defense proteins, which also include lectins, chitinases, polyphenol oxidases, α-amylase inhibitors, and protein inhibitors. The glucose/mannose-specific concanavalin A (ConA) from Canavaliaensiforms (Jacobean) was the first defensive lectin to be found (Fürstenberg-Hägg, Zagrobelny, and Bak 2013). Proteins that bind carbohydrates make up a portion of a plant's nitrogen reserve and can be employed as passive defense (Peumans & Van Damme, 1995). Lectins play a major role in plant defense against herbivorous insects by penetrating, destroying, or modifying the peritrophic membrane (Konno and Mitsuhashi 2019). Chrispeels&Raikhelbalso closely analyzed the protective role of lectin and several chitin-binding proteins(Chrispeels& Raikhelb,1991). One of the most critical attributes of lectins is their capability to endure the digestive system of insects, which underscores their significant insecticidal potential. They function as antinutritive and/or toxic agents by binding to glycosyl groups lining the digestive tract's membranes, thereby inducing various harmful systemic reactions in insects (Belete 2018). Moreover, plant lectins possess the advantage of maintaining stability across a broad range of pH levels and temperatures, and they exhibit resistance to proteases from animals and insects (Souza Cândido et al., 2011). Numerous reports have documented how these bioactive defense proteins frequently disrupt digestion processes. Esch and Schaffrath explored the potential role of Jacalin-Like Lectin (JRL) domains as decoys in fusion proteins, aiding plants in detecting invading pathogens (Esch and Schaffrath 2017). Additionally, a compact-sized lectin derived from the rhizomes of stinging nettle effectively inhibits the growth of several chitin-containing phytopathogenic and saprophytic fungi (Broekaert et al., 1989). Oliveira and colleagues reported the insecticidal activity of Cratylia argentea lectin against Callosobruchus maculatus larvae, known to infest cowpea (Vigna unguiculata) seeds, further supporting the hypothesis that lectins play a role in defense mechanisms against herbivory (Oliveira et al., 2004).

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To defend against the wide range of harmful bacteria, viruses, fungi, oomycetes, and pest insects, plant genomes encode an abundance of RLKs (receptor-like kinases), RLPs (receptor-like proteins), and lectins. De Schutter and Van Damme (2015) have described a wide variety of membrane-bound, soluble PRRs (pattern recognition receptors) that carry lectin domains and are responsible for identifying the carbohydrate structures of pathogens and starting the stress response.

**V. EFFECT OF LECTINS ON HUMANS.**

The majority of plants appear to contain lectins, although most of them do not exhibit binding affinity to cells of higher animals (Damme et al., 1998; Van Damme, Lannoo, and Peumans 2008). Their susceptibility to heat-induced denaturation varies, as does their resistance to degradation by proteolytic enzymes during passage through the digestive tract. The latter factor also seems to be influenced by the specific animal species consuming them (Pustzai 1990). Given that many cellular receptors and other components within the intestinal epithelium possess carbohydrate-rich side chains, the ability of lectins to bind to these cells depends on their carbohydrate specificity. Consequently, lectins may trigger responses associated with the function of these receptors and components (Krogdahl and Bakke 2015). Some lectins can disrupt the mucosal barrier, while others may promote beneficial microflora, possess anti-inflammatory properties, or even contribute to cancer prevention (Pusztai, Bardocz, and Ewen 2008b).

Numerous epidemics of food poisoning have resulted from the general public's ignorance of the harmful effects of dietary lectins on the gut and overall health. When taken in excess by those who are sensitive to them, they can result in a variety of primary physiological reactions, such as severe intestinal damage that impairs digestion and depletes nutrients, the induction of IgG and IgM antibodies that lead to food allergies and other immune responses, and the simultaneous binding of immune factors to erythrocytes that results in hemagglutination and anemia.2014's FekaduGemede

Numerous lectins found in a wide range of fruits and vegetables have been identified as possible food allergies. A small number of proteins, such as Tri an 18 (wheat germ agglutinin, WGA) and a few chitinases with a hevein domain, such as Mus a 2 (banana), Bra r 2 (turnip), Cas s 5 (chestnut), Zea m 8 (corn), and Per a 1 (avocado), have been listed by the WHO/IUIS Allergen Nomenclature Sub-Committee as potential food allergens. These include contact allergens Hev b 6 (hevein) and Hev b 11 (class I chitinase with hevein domain) from the rubber tree Heveabrasiliensis. Based on their capacity to bind IgE, degranulate mast cells and basophils, and trigger interleukin responses in a variety of allergic individuals, a few more plant lectins have also been recognized as possible food allergens (Barre et al., 2020).

Cellular social behavior relies on membrane glycosylation, encompassing processes like cell communication, adhesion, and migration. Upon ingestion, various biological effects manifest at the biochemical and molecular levels. The interaction between lectins and cell surface molecules or their internalization into cells triggers a diverse array of signals crucial for cellular regulation. These signals encompass cell agglutination or aggregation, the induction of apoptosis or cell cycle arrest, the down-regulation of telomerase activity, the inhibition of angiogenesis, enhanced drug sensitivity in tumor cells, direct modulation of the immune system through alterations in interleukin production (Krogdahl and Bakke 2015), and the activation of specific protein kinases. The consumption of lectins also sequesters the body's polyamine reserves, effectively inhibiting the growth of cancer cells. Furthermore, certain lectins can bind to ribosomes, thereby inhibiting protein synthesis (Ferriz-Martínez et al., 2010), demonstrating their multifaceted impact on cellular processes.

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The overall impact of dietary lectins on human health is still an area of ongoing research and debate. While some lectins can have negative effects, others might have potential health benefits, such as their potential to modulate the immune system or act as prebiotics to support beneficial gut bacteria(Pusztai, Bardocz, and Ewen 2008b).

**CONCLUSION**

Lectins are poisonous or antinutritional chemicals that are harmful to a variety of creatures that consume plants. This characteristic is linked to their strong resistance to proteolysis in the gastrointestinal tracts of different organisms as well as their ability to bind and modify the small intestine's lining epithelial cells. Lectins are powerful defensive chemicals in plants, and it is already possible to create transgenic plants that are resistant to insects by expressing lectin genes. This strategy may lower the need for pesticides while increasing crop yield. However, as many food lectins have been shown to be poisonous and antinutritional, their impact on human intake also needs to be carefully studied.

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