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# Lectin – An astonishing protein that is both a boon and a bane for humanity

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**Abstract**
Lectins are special kinds of protein molecules, which are carbohydrate-binding protein on the glycoproteins of the cell surface. Lectins vary structurally from each other and might be differentiated into a plant, animal, and fungi lectin. Besides causing toxicity to humans after consumption, further research suggests that they play a vital role as an anti-cancer, crop defense agents, application in forensic serology, determination of blood group, immuno-modulation therapy, and many more. Since lectins show a varied application in several fields, more research work in terms of isolation of lectin from different sources as well as investigating their application or uses in many fields and sources is required. This analysis focuses totally on lectin structure, its various forms, specificity, mode of action in humans, application in various fields, their methods of isolation and purification, and eventually, their major negative health issues on human beings and the way avoidance of lectin diet can aid within the prevention of disease-associated. Thus, it is suggested that lectins can be used as a powerful weapon for various diseases as an anti-causative agent and might be used as an efficient pharmaceutical agent if more efficient research is carried out.

**Keywords:** lectins, carbohydrate-binding, glycoprotein, anti-causative

## 1. Introduction
Plants are often under intense attack from pathogens and herbivorous insects. A multi-layered defense network, referred to as the innate immune system, has evolved to protect and defend themselves. Cell surface and intracellular immune receptors help plants feel their experiences when perceiving preserved microbial structures and associated patterns of damage. Key receptor components comprise of plant lectins and proteins with one or more lectin domains. The complete community of plant lectins contains a binding mechanism for a complex set of proteins capable of recognizing and interacting with specific carbohydrate structures, either from invading species or from weakened plant cell wall structures [1].
"Lectin" was derived from the Latin word "Legere", which means "to select", by William Boyd [2]. This idea was extended to incorporate all non-immune-derived sugar specific agglutinins, regardless of the specificity of the source and form of blood [3]. According to Goldstein's widely accepted definition, "A Lectin is a non-immune carbohydrate-binding protein or glycoprotein that agglutinates or precipitates glycoconjugates or both" [4]. It means that the lectins are assumed to be multivalent and therefore the specificity depends largely on termini of monosaccharide. Some plant lectins can agglutinate different erythrocytes blood groups and are, therefore, called phytohemagglutinins [4]. Structurally, these lectins have a varied class of proteins, that are capable of binding carbohydrates with great specificity [5]. Lectins are majorly found in various plants, animals and mushrooms species. The lectin content varies from species to species. They are mainly classified based on carbohydrate specificity.
Generally, various lectins are accountable for major negative health problems that arise in humans and after consumption, varied plant and dietary lectins show negative health effects on humans. Nevertheless, the application of various lectins depends upon their properties. Since of their antifungal and anti-insecticidal properties, they can be directly used for protection against pathogens. Another application also involves the production of anti-tumor and antiviral drugs based on the properties and type of lectins.

## 2. History
Evidence for the presence of proteins in nature that possess the ability to agglutinate erythrocytes began to accumulate within the late 19th century. Such proteins were generally

referred to as hemagglutinins or phytoagglutinins, as they were originally found in plant extracts. The earliest explanation of such a hemagglutinin is usually believed to have been given by Peter Hermann Stillmark in his doctoral thesis presented in 1888 to the University of Dorpat (now Tartu, Estonia), one among the oldest universities in czarist Russia [6].

**Table 1:** History of lectins

| Sr. No. | Year | Title of research paper | Research findings | References |
|---|---|---|---|---|
| 1. | 1999 | Lectin histochemical localization of N- and O-linked oligosaccharides during spermiogenesis of the urodele amphibian (Pleurodeles waltl) | Glycoconjugate characterization of the spermatids during spermiogenesis of urodele amphibian testis | [7] |
| 2. | 2000 | Mucosal immunogenicity of plant lectins in mice | Investigation of the mucosal immunogenicity of various plant lectins with different specificities of sugar in mice | [8] |
| 3. | 2001 | Carbohydrate binding properties of banana (Musa acuminata) lectin | Examination of lectins of banana (Musa acuminata) and the closely related plantain (Musa spp.) by the techniques of quantitative precipitation, hapten precipitation suppression, and isothermal calorimetry with titration showing that they are proteins which bind mannose/glucose | [9] |
| 4. | 2002 | Purification of Cajanus cajan root lectin and its interaction with rhizobial lipopolysaccharide as studied by different spectroscopic techniques | Isolation and purification of the lectins present in the roots of Cajanus cajan by affinity chromatography and showing C. cajna root lectin lipopolysaccharide interaction is unique. | [10] |
| 5. | 2002 | Evidence of an endogenous lectin receptor in seeds of the legume Cratylia floribunda | Cratylia floribunda lectin recognizes an endogenous soluble glycosylated receptor mediated by its carbohydrate-binding site through an interaction. | [11] |
| 6. | 2003 | Purification and acute toxicity of a lectin extracted from Tepary bean (Phaseolus acutifolius) | Assessed the acute toxicity of a lectin isolated and purified from tepary bean (Phaseolus acutifolius, G-400-34) on CD-1 mice and thus lectin showed affinity towards fetuin, with high agglutination values and low acute toxicity. | [12] |
| 7. | 2003 | Preparative purification of soybean agglutinin by affinity chromatography and its immobilization for polysaccharide isolation | Purification of the affinity of soybean agglutinin (SBA) from soybean flour and its further immobilization development. | [13] |
| 8. | 2004 | A new Ralstonia solanacearum high-affinity mannose-binding lectin RS-IIL structurally resembling the Pseudomonas aeruginosa fucose-specific lectin PA-IIL | Discovery of RS-IIL (subunit M(r) 11.6 kDa), a tetrameric lectin, with high sequence similarity to the Pseudomonas aeruginosa fucose-binding lectin PA-IIL. | [14] |
| 9. | 2005 | Characterization of the lectin purified from Canavalia ensiformis shoots | Purification of lectin of Canavalia ensiformis shoot with specific affinity ford-glucose by affinity chromatography using Sephadex G-100, and evaluation of some of its biochemical characteristics. | [15] |
| 10. | 2006 | Integration of affinity precipitation with partitioning methods for bioseparation of chitin-binding lectins | The applications of affinity precipitation and aqueous two-phase affinity extraction (ATPAE) for purification of lectins from wheat germ, potato, and tomato. | [16] |
| 11. | 2006 | Analyzing the dynamic bacterial glycome with a lectin microarray approach | Development of a lectin microarray for the analysis of glycoproteins and a rapid analytical system based on this technology for the examination of bacterial glycans. | [17] |
| 12. | 2007 | A novel strategy for mammalian cell surface glycome profiling using lectin microarray | Development of a simple and sensitive procedure based on lectin microarray technology for direct analysis of the live mammalian cell-surface glycome. | [18] |
| 13. | 2007 | A lectin array-based methodology for the analysis of protein glycosylation | Development of a lectin array-based method, Qproteome GlycoArray kits, for rapid analysis of glycosylation profiles of glycoproteins. | [19] |
| 14. | 2007 | A lectin from Ganoderma lucidum | Purification of a novel 114 kDa hexameric lectin from the fruiting bodies of mushroom Ganoderma lucidum and revealing its biochemical characterization. | [20] |
| 15. | 2007 | In vitro inhibition of oral streptococci binding to the acquired pellicle by algal lectins | Evaluation of the potential of two algal lectins to inhibit the adherence of five streptococci species to the acquired pellicle in vitro. | [21] |
| 16. | 2007 | Characterization of Con C, a lectin from Canavalia cathartica Thouars seeds | Isolation of lectin Con C from Canavalia cathartica and its partial characterization as a legume having high nutritional value and possessing less anti-nutritional factors. | [22] |
| 17. | 2007 | Isolation and characterization of a lectin with antifungal activity from Egyptian Pisum sativum seeds | Isolation of lectin from the Egyptian seeds of Pisum sativum (PSL) by gel filtration chromatography on Sephadex G-100 showing inhibition of growth of Aspergillus flavus, Trichoderma viride, and Fusarium oxysporum. | [23] |
| 18. | 2008 | An efficient method for the purification and quantification of a galactose-specific lectin from vegetative tissues of Dolichos lablab | Use of lectin specific antibodies to develop a simple and effective matrix of immuno-affinity, which allowed the lectin to be isolated and purified from stems and leaves of the D. lablab. | [24] |
| 19. | 2008 | Purification and characterization of an N-acetylglucosamine specific lectin from marine bivalve Macoma birmanica | Isolation of calcium-independent lectin from the foot muscle of marine bivalve Macoma birmanica by ammonium sulphate precipitation followed by affinity chromatography on immobilized GlcNAc column. | [25] |
| 20. | 2009 | Purification and characterization of a novel lectin from the toxic wild mushroom Inocybe umbrinella | Isolation and purification of lectin Inocybe umbrinella by ion-exchange chromatography on DEAE-cellulose, and CM-cellulose, and gel filtration on Superdex 75. | [26] |

| | | | | |
|---|---|---|---|---|
| 21. | 2009 | A lactose specific lectin from the sponge Cinachyrella apion: Purification, characterization, N-terminal sequences alignment and agglutinating activity on Leishmania promastigotes | A novel lectin. C. apion lectin (CaL) from the sponge Cinachyrella apion showed cross-reactivity with the polyclonal antibody IgG anti-CvL (Cliona varians lectin) and also a strong haemagglutinating activity towards human erythrocytes of all ABO groups. | [27] |
| 22. | 2010 | Extraction and Purification of a Lectin from Red Kidney Bean and Preliminary Immune Function Studies of the Lectin and Four Chinese Herbal Polysaccharides | Using of Reversed micelles to extract lectin from red kidney beans and studying of factors affecting reverse micellar systems (pH value, ionic strength and extraction time) | [28] |
| 23. | 2011 | Cytotoxic Effects of Native and Recombinant Frutalin, a Plant Galactose-Binding Lectin, on HeLa Cervical Cancer Cells | Study and compare the effect of native and recombinant frutalin on HeLa cervical cancer cell proliferation and apoptosis. | [29] |
| 24. | 2012 | Mannose-binding Lectin binds to Amyloid ***β*** Protein and modulates inflammation | Calcium-dependent evidence for MBL binding to amyloid β peptides and other known carbohydrate ligands has been attributed to the carbohydrate-recognition domain, a common feature of other C-type lectins. | [30] |
| 25. | 2013 | Effects of an extracted lectin from Citrullus colocynthis L. (Cucurbitaceae) on survival, digestion and energy reserves of Ectomyelois ceratoniae Zeller (Lepidoptera: Pyralidae) | Extraction and purification of lectins from Citrullus colocynthis seeds by Sepharose 4B-Galactose and DEAE-cellulose fast flow chromatographies | [31] |
| 26. | 2014 | Macrophage-inducible C-type lectin underlies obesity-induced adipose tissue fibrosis | Macrophage inducing C-type lectin (Mincle), a pathogen sensor for Mycobacterium tuberculosis, is found in CLS to macrophages, the amount of which is associated with the interstitial fibrosis | [32] |
| 27. | 2015 | Purification and characterization of a novel lectin from Chinese leek seeds | Purification of a novel lectin ‘CLSL’ using ion-exchange chromatography on SP Sephadex C-25 and gel-filtration chromatography on Sephadex G50 | [33] |
| 28. | 2016 | Effects of plant lectins on human erythrocyte agglutination | Blood agglutination activity against A, B, AB, and O groups was shown after blood exposure to extracts collected from 55% of the plants studied, while agglutination was absent in 45% of plants. | [34] |
| 29. | 2017 | A standardized method for lectin microarray-based tissue glycome mapping | A standardized method of lectin-assisted glycome tissue mapping - Formalin-fixed, paraffin-embedded tissue sections of two C57BL/6J mice were prepared from brain, liver, kidney, spleen, and testis. | [35] |
| 30. | 2018 | Fluorescent neoglycoprotein gold nanoclusters: synthesis and applications in plant lectin sensing and cell imaging | Preparation of functionalized fluorescent gold nanoclusters of neoglycoprotein, containing a biantennary N-glycan G0 as targeting receptor, ovalbumin as carrier/model antigen. | [36] |
| 31. | 2019 | Lectin-based method for deciphering human milk IgG sialylation | In lectin-IgG-ELISA biotinylated lectins were used to analyze the sialylation and galactosylation pattern of skim milk IgG of mothers who delivered prematurely at term. | [37] |
| 32. | 2020 | Molecular dynamics and binding energy analysis of Vatairea guianensis lectin: a new tool for cancer studies | Characterization by molecular dynamics and molecular mechanics/Poisson-Boltzmann solvent-accessible surface area analysis of the interaction of Vatairea guianensis seed lectin with N-acetyl-D galactosamine and the Tn antigen. | [38] |

## 3. Types of lectins

The lectins are specially categorized into 3 groups, depending on the distribution.

a. Animal lectins
b. Plant lectins
c. Fungal lectins (particularly mushrooms)

### 3.1 Animal lectins

In general, animal lectins are categorized into different groups based on the requirements for divalent cation or reducing environment, the conserved sequence for sugar-binding, cation coordination, structural folds, and their nominal carbohydrate specificities.

**Table 2:** Types of animal lectins

| Sr. No. | Type | Function | Reference |
|---|---|---|---|
| 1. | Calnexin | It comprises of an ER chaperone system that ensures the proper folding and quality control of newly synthesized glycoproteins. | [39] |
| 2. | M-type lectins | They function in the trafficking, sorting, and targeting of maturing glycoproteins. | [40] |
| 3. | L-type lectins | They function in the trafficking, sorting, and targeting of maturing glycoproteins. | [40] |
| 4. | P-type lectins | It plays a very important role in the generation of functional lysosomes within the cells of higher eukaryotes. | [41] |
| 5. | C-type lectins | In many immune functions such as inflammation and immunity to a tumor and virally infected cells, it acts as adhesion and signaling receptors. | [42] |
| 6. | Galectins | It helps in crosslinking of glycan in the extracellular matrix | [43] |
| 7. | I-type lectins | They are involved in protein-protein binding as receptors, antibodies or cell adhesion molecules | [44] |
| 8. | R-type lectins | It facilitates the glycoprotein hormone turnover as well as involved in enzyme targeting | [45] |
| | F-type lectins | They function in self‒/nonself-recognition which includes pathogenesis, fertilization, microbial adhesion, and innate immunity. | [46] |
| 9. | Ficolins | It plays a very important role in innate immunity. | [47] |
| 10. | Chitinase like lectin | Metabolism of collagen (YKL-40) | [48] |
| 11. | F-box lectin | It helps in the degradation of misfolded or unassembled glycoproteins. | [49] |
| 12. | Intelectins | It has the carbohydrate-binding capacity and plays a role in innate immunity. | [50] |

### 3.2 Plant lectins
Various species of lectins are found in diverse plant species. They are majorly found in plant seeds. Besides the seeds, tubers, roots, leaves, fruits, bulb, rhizomes, bark, stems, heartwood, coleoptiles, cotyledons, and phloem are seen. Plant lectins are classified into seven families of proteins based on structure and evolution [51]. They are as follows:

1. Legume lectin
2. Monocot mannose-binding lectin
3. Chitin binding lectin
4. Type 2 ribosome-inactivating protein
5. Cucurbitaceae phloem lectins
6. Jacalin family
7. Amaranthaceae lectins

Based on the overall structure, plant lectins are generally classified into mainly four distinct classes [52]:

**Table 3:** Types of plant lectins

| Sr. No. | Type | Structure | Cell agglutination and glycoconjugate precipitation properties | Example |
|---|---|---|---|---|
| 1. | Merolectins | Small monovalent protein with a single polypeptide, having one carbohydrate-binding domain. | No | Monomeric mannose-binding proteins from orchids [53]. |
| 2. | Hololectins | They consist of many carbohydrate-binding domains in which two or more are similar and possess multiple binding sites | Yes | Soya bean lectin. |
| 3. | Chimerolectins | They are fusion proteins composed of a carbohydrate-binding domain tandemly arrayed with an unrelated domain. | Yes | Type 2 RIP (Ribosome inactivating protein) |
| 4. | Superlectins | They are fusion proteins built up of two tandemly arrayed carbohydrate-binding domains which are structurally different | Yes | A lectin from tulip bulbs (TxLc-I) [54] |

### 3.3 Mushroom lectins
In general, lectins are present in different types of mushrooms. About 336 mushroom lectins have been described and documented based on the literature. Mushroom lectins are equipped with antitumor, antiviral, immune-stimulating, mitogenic, antiproliferative potential [55]. These lectins play a major role in the early stages of mycorrhization in mushroom physiological processes such as dormancy, growth, morphogenesis, morphological changes, and molecular recognition. They also consider the application in work on the isolation and structure of cell glycoconjugates as well as tracking changes occurring on the surface of the membranes of cells at various stages of physiological or pathological development [56].

**Mushroom lectins are generally classified based on [55].**

1. Biological action
2. Sugar specificity
3. Mitogenic potentiality.

### 4. Structure
A conserved amino acid profile shows the structure of lectins involving the specificity of lectins to certain carbohydrates. Monosaccharide binding lectin molecules generally show high similarity in their residues, which coordinate metal ion for the integrity of subunits and proper positioning of residues. The structure involves the association of lectins with metal ions and interaction with water molecules and carbohydrates. Structurally lectins differ in amino acid sequence, change in the number of subunits, and the nature of the polypeptides. Associated sites have hydrogen bridge specificities and affinities by including van der Waals and hydrophobic interaction. Proper lectin-carbohydrate interaction depends on the presence of ions within the environment [51].

### 5. Receptor location and specificity
Due to the presence of at least one non-catalytic domain, lectins are capable to selectively recognize and bind in a reversible way to specific glycans, having free form availability, or are part of glycoproteins and glycolipids [57]. The specificity of interaction of lectins with particular carbohydrates is often almost like the interaction between those of antigen-antibody or substrate-enzyme [58]. Binding of lectins facilitates both oligosaccharides on cells as well as to free-floating glycans including monosaccharides. Relatively weak lectin-monosaccharide interactions are associated with dissociation constants often on the order of micromolar to the millimolar range [59, 60]. In the case of animal lectins, the carbohydrate-binding activity of most lectins was generated by limited amino acid residues designated as the carbohydrate recognition domain (CRD) [6], which helps in recognizing the terminal non-reducing carbohydrate residues of cell membrane glycoproteins and glycolipids [61].

### 6. Mode of action of lectins in humans
In human intestine mucosal wall lining of consists of tight junctions between the cells. The surface area of the intestinal lining is equal to the half size of the badminton court [62] but only one cell is large. Within the intestinal wall, lectins move through these tight junctions in intestinal walls by binding with receptors with specific cells through producing a chemical compound called ‘Zonulin’. This Zonulin compound helps to open the tight junctions between the intestinal lining cells that opens the access to lectins for lymph nodes and glands, underlying tissue, and bloodstream [63, 64].

Due to molecular mimicry, lectins in the human body hardly differentiate themselves from other proteins. Mimicry normally causes host immune system fooling which ultimately ends up attacking the body’s proteins [65]. In general, lectins create disruptions between cell communication by mimicking or blocking hormonal signals. They bind to docking ports cell wall ports (docking port helps to convey information by a hormone for a cell to perform a specified task) leading to misinformation being transmitted to the cell or restricting the correct information. For example, WGA (Wheat germ agglutinin) is analogous to insulin and so binds to insulin docking ports leading to reduced muscle mass, starved brain, and nerve cells [66, 67].

## 7. Purification and isolation of lectin

Lectins are usually extracted and purified primarily by chromatography techniques with the aid of different types of purification methods. This involves bio-specific affinity chromatography [68], affinity chromatography, ionic exchange chromatography, hydrophobic interaction chromatography, and gel filtration. For lectin production, the first step involves selecting the material with a high lectin content and then using simple, specified purification protocol methods [69].

**Table 4:** Isolation and purification method of various lectins

| Sr. No. | Types of Lectin | Purification and isolation methods | Reference |
|---|---|---|---|
| 1. | Plant lectin isolated from Artocarpus sps. (Jackfruit) | Sodium Dodecyl Sulfate (SDS) - polyacrylamide gel electrophoresis | [70] |
| 2. | A Lectin from the seed of Moringa oleifera | Guar gel column chromatography | [71] |
| 3. | A lectin from seeds of a Bauhinia Variegata Candida (BvcL) Seeds | Gel-filtration and affinity chromatography | [72] |
| 4. | Novel Lectin from the Toxic Wild Mushroom Inocybe Umbrinella | Ion exchange chromatography. | [26] |
| 5. | A lectin from Glycine max (L.) | SDS - PAGE (3OkDa) and gel filtration chromatography on Sephadex G-100, | [73] |
| 6. | A lectin from Eugenia uniflora L. seeds | Ion-exchange chromatography in DEAE-Sephadex | [74] |
| 7. | Lectin from Phaseolus vulgaris cv. (Anasazi Beans) | Affinity chromatography, fast protein liquid chromatography (FPLC)-ion exchange chromatography. | [75] |
| 8. | A lectin from the wild edible mushroom (Agaricus arvensis) | Fast protein liquid chromatography-gel filtration on Superdex 75. | [76] |
| 9. | A lectin from the Edible Mushroom Stropharia rugosoannulata | Ion exchange chromatography on CM-cellulose | [77] |
| 10. | A lectin from the Mushroom, Flammulina veltipes | Gel filtration and polyacrylamide gel electrophoresis | [78] |

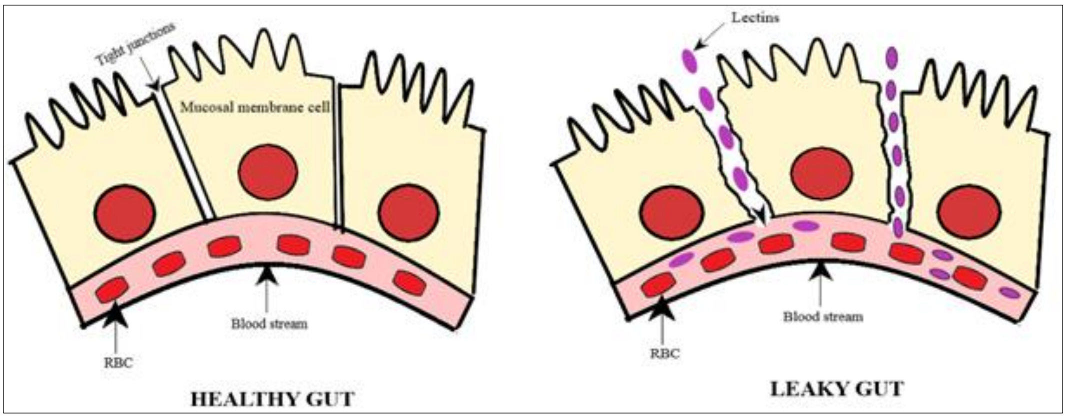


**Fig 1:** Effect of lectin on the mucosal wall lining of the human intestine

## 8. Application of lectins

**Table 5:** Application of lectins

| Sr. No. | Applications | References |
|---|---|---|
| 1. | Detection of goblet cell carbohydrates of the human conjunctiva. | [79] |
| 2. | In bacteriology, mycology, mycobacteriology, and virology for the identification and/or differentiation of various microorganisms through epidemiologic as well as taxonomic markers. | [80] |
| 3. | In serology and blood group determination | [80] |
| 4. | Helps in the detection of polysaccharide additives in foods. | [81] |
| 5. | Induction of mitosis and specific proteins or cellular processes | [82] |
| 6. | Diagnostic tool for tracing of aberrant glycosylation of glycoproteins | [82] |
| 7. | Diagnostic for stimulation of lymphocytes for chromosome analysis | [82] |
| 8. | Therapeutic for immunomodulation | [82] |
| 9. | Structural basis of calcium and galactose recognition by the lectin PA-IL of Pseudomonas aeruginosa | [83] |
| 10. | Tool for glycoconjugate research. | [84] |
| 11. | Lectins act as potent antimicrobials that bind to carbohydrates on microbial surfaces. | [85] |
| 12. | A D-mannose-specific lectin from Gerardia savaglia help in avoiding infection of H9 cells with human immune deficiency virus (HIV)-1. Flammulina velutipes hemagglutinin and dark red kidney bean hemagglutinin prevents the proliferation of leukemia L1210 cells | [69] |
| 13. | Forensic serology | [86] |
| 14. | Insecticidal activity and potential for crop protection | [87] |
| 15. | Diagnostic and therapeutic tools for cancer | [88] |
| 16. | Pharmaceutical application as targeted drug delivery systems | [89, 90] |

## 9. Impact of lectins on human health

Lectins are majorly responsible for occurrence of various diseases in humans,

**Table 6:** Impact of lectins on human health

| Sr. No. | Type of lectin | Impact of lectin on human health | Reference |
|---|---|---|---|
| 1. | Plant lectins | Agglutination of erythrocytes of A, B, AB, and O blood groups of the human being. | [91] |
| | | Affect the turnover and loss of gut epithelial cells, interfere with digestion and absorption of nutrients, and also modulate the digestive tract's immune response. | [92] |
| | | Activate the NLRP3 inflammasome to promote inflammatory disorders | [93] |
| | | Affects the in vitro fibroblast proliferation | [94] |
| | | Causes systemic effects such as increased protein catabolism and breakdown of stored fat and glycogen, and disturbance in mineral metabolism | [92] |
| 2. | Dietary lectins | Responsible for severe intestinal damage disrupts digestion and causes nutrient deficiencies and can cause IgG and IgM antibodies that cause food allergies and other immune reactions | [95] |
| | | It influences pancreatic growth that eventually has the potential for pancreatic cancer development in humans. | [96] |
| | | Modulation of immune function by dietary lectins in rheumatoid arthritis | [97] |
| | | Induces in vitro release of IL-4 and IL-13 from human basophils | [98] |
| | | Leads to endogenous loss of nitrogen and protein utilization | [99] |
| 3. | Peanut lectin | Acts as a mitogen for colorectal cancer cell line and increases crypt cell proliferation rates in the normal colonic epithelium in vitro | [100] |
| | | Stimulates proliferation of Human HT29 Colorectal Cancer Cells. | [100] |
| | | Increases rectal epithelial proliferation | [101] |
| | | Stimulates proliferation in colonic explants from patients with inflammatory bowel disease and colon polyps | [102] |
| 4. | Wheat lectins | Responsible for inflammation of the intestine in humans | [103] |
| 5. | Wheat germ agglutinin | Responsible for the occurrence of celiac disease in children | [104] |
| 6. | Wheat gliadin | Coeliac disease | [105] |
| 7. | Potato Glycoalkaloids | Affect intestinal permeability and aggravate inflammatory bowel disease | [106] |
| 8. | Mannose-binding lectins | Increases risk of severe atherosclerosis | [107] |
| | | Role in hepatitis B virus (HBV) infection | [108] |
| | | Increases the risk of developing asthma in children. | [109] |
| 9. | Phaseolus vulgaris lectin | Exerts toxic effects of recipient animals by interfering with their digestion and absorption | [110] |
| | | Causes nausea, vomiting, and diarrhoea | [111] |
| 10. | Vegetable lectins | Responsible for acute GI tract distress | [112] |
| 11. | Tomato lectin | Resist digestion | [113] |
| 12. | Beta-galactoside specific lectins. | Stimulates vascular cell proliferation | [114] |
| 13. | Mannan-Binding Lectin | Responsible for cardiovascular diseases. | [115] |
| 14. | Lectins | Reduces salivary and pancreatic Amylase activities and the rate of starch digestion | [116] |
| 15. | Soybean lectins | Induce pancreatic growth in rats. | [117] |

## 10. Benefits of Lectin limited diet on human health

**Table 7:** Benefits of Lectin limited diet on human health

| Sr. No. | Type of Diet | Effect | Reference |
|---|---|---|---|
| 1. | Polyphenol rich food and supplements | Reversal of endothelial dysfunction | [118] |
| 2. | Nutrigenomics based diet and Supplement | Management of coronary artery disease | [119] |
| 3. | High dose olive oil and polyphenol-rich diet | Stabilizes advanced coronary artery disease. | [120] |
| 4. | Diet Supplemented with Probiotics, Prebiotics, and Polyphenols | Helps to cure the Autoimmune Diseases | [121] |
| 5. | Polyphenol rich diet | Improving the gut microbiome | [122] |
| 6. | Lectin and gluten limited diet | The normal level of Adiponectin and Tumour Necrosis Factor-alpha (TNF alpha). | [123] |

## 11. Conclusion

Besides the potential of lectins to cause significant negative health problems in terms of human activation of various diseases, they find numerous applications in forensic serology, identification of blood groups, immunomodulation therapy, anti-cancer agents, crop defense agents, and many more. Research on the isolation and purification of lectin is minimal and further research work is required on more methods of purification and isolation of lectins from various sources. It can act as a powerful tool as an anti-causative disease agent as well as an effective pharmaceutical agent in terms of future aspects. Since lectins are responsible for causing various diseases, lectin limited diet can help keep the associated disease at bay and more work is required to seek out alternatives to lectin diet. Further research and study will help to seek out further potential and application of lectins.

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