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EDITORIAL

Plant Lectins: The Next Frontier in Precision Glycan-Targeted Medicine

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Precision medicine is revolutionizing healthcare by shifting away from the traditional "one-size-fits-all" approach to treatments. This new approach focuses on developing therapies tailored to each individual. It takes into account a person's unique genetic makeup, environmental factors, and lifestyle choices [1]. To achieve effective precision medicine, highly accurate molecular tools are essential. These tools must be able to detect and target specific disease-related markers with very few errors. Among the promising options in this field are plant lectins. These proteins can bind reversibly to specific sugars [2]. Plant lectins are attracting considerable interest because they can attach accurately to certain sugar structures found on cell surfaces [3].

Glycosylation, the enzymatic process of anchoring glycans to proteins and lipids, is important in cellular communication, immune targeting, and disease progression. Numerous pathological conditions, such as cancer, infectious diseases, and neurodegenerative disorders, are characterized by abnormal glycosylation [4]. Given their notable ability to selectively recognize and bind specific carbohydrate assemblies, plant lectins have emerged as powerful tools to exploit these glycan alterations for both therapeutic and diagnostic applications [3,5]. These proteins present an exciting avenue toward precision medicine by utilizing their high specificity, which enables targeted therapies based on glycan modifications associated with disease [3,6].

The ability to recognize and take advantage of patient-specific molecular signatures is essential for the shift from traditional therapies to precision medicine. Carbohydrate-binding proteins, such as plant lectins, are essential tools for diagnosis and treatment because glycosylation plays a crucial role in disease mechanisms. The high glycan selectivity of these proteins makes them useful for immune modulation [7], targeted drug delivery [8], and biomarker identification [9]. The variety of their structure and function enables accurate interactions with cell-surface receptors, impacting immune responses and signaling pathways—a crucial aspect of tailored treatments. According to their preferences for binding carbohydrates, plant lectins are categorized as follows: lectins that bind mannose, such as Concanavalin A (ConA); lectins that bind galactose, such as Erythrina indica lectin; lectins that bind N-acetylglucosamine, such as *Griffonia simplicifolia* lectin; and lectins that bind fucose, such as *Lotus tetragonolobus* [10]. According to new research, some plant lectins may alter signaling pathways and cellular receptors involved in pain perception and the defense of the stomach mucosa. Lectins' specificity could be used to create customized antinociceptive treatments [11,12] and gastroprotective effects [13-15] that address individual differences in disease mechanisms. For example, lectins that selectively target sialylated glycans—which are overexpressed in neuropathic pain [16]—could deliver localized analgesia with fewer side effects than opioids. *Maackia amurensis* lectins (MAL-I and MAL-II), which bind specifically to α2,3-linked sialic acid (MAL-I) and α2,6-linked sialic acid (MAL-II), illustrate this potential [17]. Patients who take NSAIDs long term may benefit from lectins such as *Calotropis procera* Leaf Lectin (ProLec), which can help increase mucus secretion and protect the digestive tract [14]. This precision-based method may pave the way for new approaches for the treatment of gastrointestinal issues and chronic pain.

In conditions such as cancer, where tumor cells frequently exhibit altered glycan profiles, these proteins exhibit abnormal glycosylation patterns. They are perfect for therapeutic and diagnostic applications because of their binding specificity, which allows for targeted interactions [5]. By attaching to tumor-associated glycans,

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lectins such as ConA and Wheat Germ Agglutinin (WGA) can be used to differentiate malignant tissues for cancer biomarker detection, facilitating early diagnosis [18]. Lectins such as BanLec are used in infectious disease diagnostics to detect pathogen-specific glycans [19], which speeds up the identification of bacterial and viral infections. Using lectin-based assays, neurodegenerative disease screening can identify altered glycans in Parkinson's disease and Alzheimer's disease, potentially leading to early intervention [20]. By selectively binding to glycans specific to neurodegenerative diseases such as Parkinson's disease (PD) and Alzheimer's disease (AD), plant lectins can help with glycan-targeting precision medicine. For example, Concanavalin A (ConA) and Wheat Germ Agglutinin (WGA) can identify tau and amyloid-beta glycans in AD [21,22].

Targeted drug delivery systems are one area where the therapeutic potential of plant lectins is most noticeable. Glycan recognition, in which lectins bind disease-specific carbohydrates; cellular uptake via receptor-mediated endocytosis; and controlled release for intracellular drug delivery that reduces systemic toxicity are all components of their lectin-mediated targeting mechanism [23]. With distinct disease applications, several lectin-based delivery systems, such as lectin-drug conjugates, lectin-coated nanoparticles, and lectin hydrogels, have been created. T/Tn-specific lectins extracted from Artocarpus integrifola are used in cancer treatment to target aberrant O-glycans expressed on the surface of cancer cells [24]. Urtica dioica agglutinin (UDA), which is specific to N',N",N"'-triacetylchitotriose, inhibits SAR-CoV replication by blocking the ability of the virus to bind to the host cell spike protein [25].

To fully utilize plant lectins in clinical settings, several obstacles need to be overcome. The development of hypoallergenic lectins is necessary to address toxicity and immunogenicity concerns [26]. Glycan heterogeneity demands customized glycan profiling, and pharmacokinetic issues necessitate stability and controlled release optimization [27]. To improve clinical applicability, future studies should concentrate on lectin engineering, bioinformatics-driven glycan analysis, and nanotechnology integration [3].

In conclusion, plant lectins have great potential for precision medicine because they provide glycan-specific targeting, accurate diagnosis, and adaptable treatment options. Advances in protein engineering, drug delivery systems, and glycomics could unlock their full potential in treating cancer, infections, and immune disorders. For their clinical translation to be successful, however, issues with safety, bioavailability, and regulatory barriers must be resolved. With further development, plant lectins could soon transform personalized medicine and usher in a new era of patient specific, targeted treatments that harness the power of glycobiology to improve healthcare outcomes.

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