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A REVIEW ON SOURCES AND APPLICATIONS OF CHITOSAN

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ABSTRACT

Taking into account of Chitosan and its potential for commercialization as well as their effects on the environment and their ranges of possible uses are explored in this review. A survey of the literature was used to conduct this investigation. Many types of aquatic crustaceans like crabs and shrimp, as well as numerous insects, as well as fungus, include chitin. One of the industries in the world that is growing the fastest is the shrimp industry. But the hard exoskeleton of shrimp, including the parts of the shrimp skin and head, is thrown away as bio-waste during the processing of shrimp. Chitin is present in significant amounts in the shrimp exoskeleton. The deacetylation process turns chitin into the bioproduct chitosan. The deacetylation process can be carried out by chemical or biological methods. A significant amount of bio-waste treated with chitin can be converted into chitosan.

Chitosan is a naturally occurring biodegradable, non-toxic, and biocompatible substance with a wide range of uses. Chitosan may possess antioxidant and antibacterial properties. Furthermore, it has a plethora of industrial applications, gene therapy, cancer therapy, agriculture, environmental protection, regenerative medicine, food technology, biotechnology, bio-nanotechnology, medicine, and many more. Chitosan is useful in almost every branch of biology. Even though it's not currently utilized in all of the afore mentioned industries, chitosan should have a big impact in these areas. Further studies ought to be conducted in order to turn chitosan into a chemical with a wide range of potential uses.

Keywords: Chitosan, Deacetylation, Antibacterial properties, Potential use.

INTRODUCTION:

Several environmental risks brought on by this threat that affect both people and animals. In addition to persistently endangering land and marine creatures, the fallout from different industrial wastes has had an impact on human health through a variety of diseases that humans

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have contracted from the decomposing wastes. It is vital to understand the significance of protecting the environment.

The usage of synthetic polymers is a source of worry due to the growing global population. Through the production of a bio-polymer chitosan from shell wastes of crustaceans, the environmental problems caused by synthetic polymers can be tackled (Bello and Olafadehan, 2021). To end this challenge, viable products are produced through the recycling of shell wastes by chitin production initially (chemical processes of demineralization and deproteinization) and chitosan formation (deacetylation) subsequently (Bello and Olafadehan, 2021).

Aquaculture industry waste is rich in chitin, minerals, oils, proteins, and lipids. These waste products serve as raw materials for the commercial synthesis of chitosan, chitin, and other useful compounds. Recycling is therefore vitally necessary in an effort to maintain a clean environment as well as a massively prosperous economy. Through the chemical deacetylation of previously formed chitin, recycling produces chitosan (Amoo et al., 2019; Kolawole et al., 2017).

Since the usage of synthetic polymers harms both the environment and consumers, numerous studies have been done to develop environmentally benign substitute materials. By using the shell wastes of crustaceans to produce a biopolymer chitosan, the environmental issues brought on by synthetic polymers can be addressed (Bello and Olafadehan, 2021). Viable products are created by recycling shell wastes to overcome this difficulty. First, chitin is produced through chemical processes of demineralization and deproteinization, and then chitosan is formed through deacetylation (Bello and Olafadehan, 2021).

CHEMICAL STRUCTURE OF CHITIN AND CHITOSAN:

Chitin:

According to Gbenebor et al. (2017), chitin is a naturally occurring polysaccharide that is the primary building block of the exoskeletons of a variety of organisms, including insects and shrimp. Although chitin is a structural polysaccharide with properties comparable to cellulose, its acetamide group—rather than the hydroxyl group at the C2 position inside the glucose unit distinguishes it from cellulose in terms of both its chemical structure and biological functions (Hajji et al., 2014).

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Chitin is a homopolymer that is easily observable in the environment and has a chemical structure made up of poly-(164)-N-acetyl-D-glucosamine, similar to the biopolymer cellulose (Annaduzzaman, 2015; Shahidi, 1995). According to Steve (2005), chitin has a high molecular weight of 1000–3000 units in NAG units connected by β-D(164) links. The molecular mass of chitin is 627.5928 g/mol, and its empirical formula is (C8H13O5N).

Chitosan:

Chitosan is a cationic amino polysaccharide that finds extensive use in the food industry (binder, gelling agent, thickener, antimicrobial agents, and antioxidants), medical, biomedical, and pharmaceutical industries (fibers, membranes, artificial organs), as well as the biological, agricultural, and environmental sectors (Razmi et al 2017). Although chitin and chitosan can be extracted using a variety of methods, chemical treatment is the most often used method (Al Sagheer et al., 2009).

Chitosan is a derivative of chitin produced from good quality compared to cellulose. Chitosan is a copolymer of D-glucosamine and N-acetyl-D-glucosamine that is generated from N-deacetyl chitin. Its precise chemical name is poly- [β- (1 → 4) -N-acetyl-D-glucosamine]. Chitin, a homopolymer of β (1 → 4)-chain N-acetyl-D-glucosamine, is the source of chitosan, a fiber. Chitosan has a molecular mass of 1526,454 g/mol.

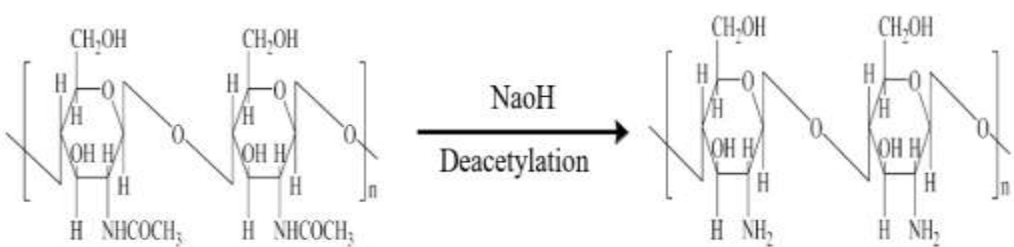

Fig: chitosan from chitin is through the process of deacetylation.

PROPERTIES:

Chitin is a high molecular weight, biodegradable polymer that is non-toxic (Kavitha et al., 2011). Chitin is a naturally occurring mucopolysaccharide made up of 2-acetamido-2-deoxy-β-D-glucose linked by β (1 → 4). N-acetyl glucosamine, a subunit found in the outer skeleton of crustaceans including shrimp shells, crabs, and insects, is the building block of the

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macromolecule chitin (Allan & Hadwiger, 1979). Many industrial industries advocate the use of chitin due to its biocompatibility, non-toxicity, and adaptability (Bharathi et al., 2020).

The physical characteristics of chitosan polymers include their minimal toxic content, unique chemical structure, multidimensional capabilities, biodegradability, and biocompatibility. Additionally, it is simple to dispose of trash and control the life cycles of products based on chitosan. It is also appropriate as a renewable energy source (Nwe et al., 2009).

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The distinct biological, chemical, and physical characteristics of chitosan make it stand out from other products. Chitosan has a high molecular weight and is non-toxic. Furthermore, chitosan is soluble in water. Its water solubility makes it simple and appropriate for use in the hydrolysis of chemicals or enzymes. Chitosan can therefore be used to create a variety of products, including fibers, hydrogels, beads, sponges, and membranes (Mano et al., 2007).

SOURCES:

Chitin is the second most common biopolymer on Earth after cellulose and is natural polysaccharide (Gbenebor et al., 2017). The primary constituents of chitin comprise the exoskeleton of insects, crustaceans, and invertebrates, as well as the cell walls of yeast and fungi (Tan et al., 1996; Knorr, 1984).

Chitin can be extracted from all the Crustaceans - crayfish, lobsters, shrimp, crabs, krill, barnacles, crayfish; Insects - scorpions, ants, cockroaches, spiders, beetles, brachiopods; Invertebrate animals, or mollusks -squids, oysters, diatoms, brown algae, green algae; algae - diatoms, brown algae, green algae; and specific microorganisms - fungi and bacteria.

According to Dima et al., (2017), the amount of chitin found in crustacean waste varies depending on the species and ranges from 10 to 25 percent (dry weight basis). It is possible to separate substantial amounts of chitosan (~30–35% dry weight) from some fungal species, as Mucor rouxii. According to Namboodiri and Pakshirajan (2020), insects like Agabus bipustulatus and Hydrophilus piceus have a chitin content that ranges from 10% to 20%.

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Aquatic Source:

Chitin that has been extracted from aquatic sources such diatoms, algae, krill, squid, lobsters, and crabs stays compact, solid, and insoluble. Consequently, Chitin is typically deacetylated to Chitosan in applications, offering excellent reactivity, solubility, and adaptability in an aqueous media (Roy et al., 2017). In the food systems as preservatives, coatings, antimicrobial and antioxidant agents (Abdelmalek, et al., 2017), in medicine as drugs, artificial organs, membranes, and fibers; in pharmacology as fungicides and drug carriers (Barbosa et al., 2019); and in cosmetology body creams, hair additives, and lotions (Huang et al., 2020) are the main applications for de-proteinated and demineralized Chitosan from marine sources.

Terrestrial Source:

Terrestrial sources such as mosquitoes, cockroaches, silkworms, honeybees, and Drosophila melanogaster can yield Chitin from their cuticles and wings. Insect cuticles are composed of Chitin, which is a matrix of lipids, cuticular proteins, and other constituents (Gonil & Sajomsang, 2012). Out of the 1.3 million species on the planet, insects make about 900,000 species. They are increasingly thought to be a great source of certain nutrients, such as protein, and natural polymers, such as Chitin (Abidin et al., 2020).

The extraction processes for insect cuticles are comparable to those for crustacean sources (Vasylchenko & Abramova, 2015), but they have significantly less mineral compounds than the shells of those sources, making them a convenient option for pharmaceutical uses (Liu et al., 2012).

According to Kaya et al., (2014), they can be an excellent source material for the manufacturing of carbon steel (CS) and a good supply of CT (~36.6%), comparable to marine sources. 15% chitin concentration and an 89.05% crystallinity index were reported in a moth (Hypotrix parallela) research, compared to 89.17% for shrimp. Furthermore, antibacterial effectiveness against S. aureus, E. coli, Listeria monocytogenes, and B. cereus was demonstrated by chitin derived from mealworm beetles (Shin, et al., 2019). According to Kaya et al. (2014), species such as the grasshopper, which is a notable insect problem, can also be employed in the manufacturing of Chitin.

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Microbial Source:

Fungal species are rich in Chitin and rank second in species richness, only surpassed by insects. Most fungi's structural component has 22–44% chitin and is chemically composed of branching $\beta-1$, 3- and $\beta-1$, 6-glucan linked to Chitin by $\beta-1$-4 links. Fungi contain large stores of Chitosan, N-glucan, and Chitin in their cell walls. Due to their possible antibacterial action, adsorption capabilities, biocompatibility, and chelating activity, yeast and fungal Chitin and Chitosan are valued (Darwesh, et al., 2018). According to Wan et al. (2017), other characteristics of fungal Chitosan that set it apart from other sources include its distinct MW homogeneity, charge and viscosity distribution, DA, and lack of heavy metals like nickel and copper.

Molds, chrysophyte algae, fungi, yeast, ciliates, prosthecate bacteria, and certain spore-forming bacteria, such Streptomyces sps, are among the organisms that contain Chitin (Knezevic-Jugovic, et al., 2010).

USAGE OF CHITOSAN:

In 2018, around 4 million tons of shrimp raised for food were produced worldwide (FAO, 2019a). Shrimp's dry weight is said to consist of 43% protein, 29% ash, 18% Chitin, and 10% fat. However, this shrimp biowaste could be turned into value-added products because it contains biological components such protein, lipids, Chitin, flavorings, colors, and CaCO3, (Wan et al., 2017).

There are many different forms of chitosan derivatives, including films, pastes, tablets, and fibers; porous structure scaffolds; hydrogels; microspheres; and nanoparticles with a specific use in a different industry such as clean water treatment systems, agricultural practices, and as an addition in cosmetic formulation (Moorjani et al., 1975; Marchessault et al., 2006).

Application of Chitosan as antimicrobial agent:

Numerous investigations have indicated that chitosan exhibits strong antibacterial properties. Important antibacterial properties have been noted against a variety of bacteria, including Salmonella typhymurium, E. Coli, B. cereus, Staphylococcus aureus, Lactobacillus plantarum, Bacillus megaterium, L. bulgaris, Pseudomonas fluorescens, and Vibrio parahaemolyticus (Coma et al., 2003; Joen et al., 2001 and Dutta et al., 2008).

There are a few proposed mechanisms of chitosan's antibacterial activity. One of them relies on the electrostatic interaction of chitosan with bacterial cell wall. The positively charged

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chitosan interacts with negatively charged bacterial cell wall components, causing disruption of the cell wall and its leakage. The other mechanism concerns the ability of low-molecular-weight chitosan to penetrate the bacterial membrane, combine with bacterial DNA and inhibit messenger RNA (mRNA) synthesis. Meanwhile, high-molecular-weight chitosan inhibits the growth of aerobic bacteria. It forms a dense film on the cell surface and prevents the uptake of nutrients and oxygen (Matica et al., 2019; Liu et al., 2018).

Application of Chitosan as Antifungal Agent :

The fungal cell wall is composed mainly of glucan, mannan and chitin. The structure of the cell wall is unique for each species (Masuoka, 2004). Chitosan nanoparticles can cause morphological, structural and molecular changes in fungal cells (Alberts et al., 2002; Divya et al., 2018).

Application of Chitosan in Agriculture:

Chitosan is used in agriculture as a fruit and plant filtration agent. Moreover, it stimulates crop production and is utilized as a hormone for plant growth stimulants. According to Uthairatanakij et al. (2007), chitosan improves the biosynthesis of phenol chemicals and acts as a secondary metabolism to boost plant immunity. It also has anti-severe disease properties. Chitosan is suitable for use as a soil treatment and as an organic fertiliser for growing plants and fruits (Crini & Pierre-Marie, 2008).

Application of Chitosan in Nutrition Industry:

Chitosan, has a hypo cholesterolemic activity, it is suitable for controlling appetite, reducing cholesterol and binding to mono glycerides in the body (Shen *et al*., 2020). It is also used as a food preservative from microbes and used as a bio-exchange to enhance the quality of food products such as fruit juices and beverages. Chitosan is important in animal feed additives, emulsifying agents and color stabilizers (Crini & Pierre-Marie, 2008).

Application of Chitosan as a Biomaterial:

Chitosan's has been clinically examined and authorized to use in the medical field, including contact lenses, sticky tissue, and bacterial adhesion to avoid sutures. It is evident that it has been critically analyzed in two biomedical fields. Originally, it was used in conjunction with chitin to treat burns and ulcers because of its hemostatic qualities and ability to speed up wound healing. Second, it was utilized in tissue engineering for tissue regeneration and reconstruction because of its biodegradability and cell attraction (Crini & Pierre-Marie, 2008).

Application of Chitosan in the Treatment of Water:

Over the past thirty years, chitosan has been used to purify water. Its positive charge helps to remove turbidity-causing substances from tributaries, such as colors, oils, grease, metal ions, and tiny particulate matter (Roller & Covill, 1999).

Application of Chitosan in Cosmetic:

Chitosan is used as an emulsifying agent in creams and lotions. Chitosan, which contains both hydrophilic and hydrophobic segments, is utilized to stabilize emulsions in the area between surface adsorption (Ramos et al., 2003). Chitosan has hydration characteristics. Because of its strong water resistance and anti-drying qualities, it can minimize dehydration on the skin's surface and improve skin moisture.

Chitosan is widely used in a variety of cosmetic industries including skincare, hair products, lipsticks etc. Its use in lipstick to protect the dryness of the lips moisturizes the lips and Chitosan is also uses as a deodorant because of its anti-bacterial. Chitosan is also used as a scent in perfumes to mask the stench of sweat for an extended period of time.

Application of Chitosan in Biotechnology and Biomedicine:

Chitosan is naturally cationic and is suitable for use in biotechnology and biomedical (Tan *et al*., 2020). Chitosan is used in pharmaceuticals to control medication distribution. It is also utilized to make microcapsules like gels and drugs, as well as anionic polymers. Finally, Chitosan is utilized in dermatology to cure acne and scars on the human body (Crini & Pierre Marie, 2008).

Chitosan is widely used in biomedical due to its properties such as biodegradability, biocompatibility and non- toxic nature. Because of its degradation properties, Chitosan is very suitable for wound healing such as wound bandages and surgical suture threads. Chitosan can increase tissue growth, tissue regeneration, stimulates cell proliferation and artificial skin (Crini & Pierre-Marie, 2008).

Environmental Protection:

Chitosan and its derivatives can be used to remove various environmental pollutants from the environment. These pollutants can be both inorganic and organic pollutants. For example,

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nitrate pollutants can be eliminated by polyethylene glycol (PEG)-chitosan and polyvinylalcohol (PVA)-chitosan, phosphates can be removed by Chitosan on which Cu (II) is immobilized, etc. (Dongre et a., 2017).

Table 1: Potential Applications of Chitosan

Table 1: Potential applications of chitosan and its derivatives

No	Area of Application	Mechanism of action/Used as
01	Anti microbial agent	The negatively charged microbial cell membrane interacts with the positively charged chitosan molecules, which tend to tear the membrane apart. Chitosan then starts to work as an antibacterial.
02	Environmental protection	Used to remove hazardous pesticides, heavy metals, and a variety of organic and inorganic contaminants from the environment.
03	Food technology	Many chitosan-based films are utilized in food coating as an antibacterial agent and as a flocculating and adsorbing agent.
04	Effluent treatment	Chitosan can be used to remove suspended particles from a variety of processing plants, including whey, dairy, poultry, and seafood processing plants, because of its coagulating treatment.
05	Agriculture	Plant pathogens can be inhibited by chitosan due to its antibacterial properties. In addition, it raises the soil's urea release and auxin concentration, germination potential, root length and activity, and seedling height. Animals can receive a supplement of protein from chitosan by-product.
06	Cosmetics	Because of its biocompatibility, UV absorption capacity, and fungicidal properties, chitosan finds application in a range of cosmetic products.
07	Drug delivery	Administration of different medications via different body entry points, such as the mouth, nose, etc.
08	Antioxidant	antioxidant properties against superoxide free radicals, hydroxyl, and DPPH.
09	Catalyst research	Utilized in biological and liquid phase chemical reactions.

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10	Bio-nanotechnology	Graphitic carbon nanocapsules and composites, tungsten carbide chitin whiskers, and other materials are utilized in the manufacturing of 3D networks and micro-electrochemical systems.
11	Genet herapy	delivering different genes that are utilized in siRNA technology, cancer therapy, and gene therapy.
12	Paper manufacture	Manufacturing of filter papers, papers that withstand water, biodegradable packaging, and papers that withstand water.
13	Absorption enhancer	Other chitosan complexes and systems with super porous hydrogels can improve the absorption of medications through intestine and Caco-2 cells.
14	Regenerative technology	utilized in heart regeneration therapy, bone regeneration, brain regenerative technology, corneal regenerative technology, and skin regenerative technology.
15	Electrolyte	A mixture of chitosan and sulfuric acid can discharge high voltage.
16	Wood industries	utilized as a preservative, fungicide, wood adhesive, and wood quality enhancer.
17	Energy production	Solid-state battery production can make use of chitosan because of its capacity to offer ionic conductivity in acetic acid solution.
18	Permeation enhancer	Chitosan and its derivatives can be utilized as a permeation enhancer in drug delivery systems because they can increase the permeability of intestinal, nasal, and buccal epithelial cells.
19	Immobilization of cells	Chitosan beads can be used to immobilize cells such as E. Coli.
20	Photography	utilized in the development of color films and color photography as a fixing agent.
21	Immune therapy	Chitosan has the power to stimulate CD4+ cells, the complement system, and humoral immunity.
22	Obesity treatment	Chitosan is used in the treatment of obesity by taking advantage of the reducing effects of LDL and cholesterol.

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Toxicity of Chitosan

- It is clear that chitosan is a biologically acceptable, non-toxic polymer.
- Chitosan will be rendered nearly hazardous by the alteration intended for it, and any remaining reactants may be appropriately eliminated.
- It is crucial to examine the chitosan's composition since a medication may take the place of the pharmacokinetic and bio-distribution profiles.
- The charge interaction can alter cellular uptake kinetics, for example in the case of DNA complexes.
- This lowering, or regulating, of the positive charges on the chitosan molecule affects how it interacts with cells and the microenvironment. It is also usually associated with decreased toxicity and absorption.
- However, no histological analysis, enzyme analysis, or other pathological measurements were provided; life for longer than one month does not generate sufficient toxicity.
- Shellfish are used to extract chitosan from their outer skeletons. There's a worry that those who have shellfish allergies could also have chitosan sensitivities. Those who are allergic to shellfish, however, are allergic to the flesh. Therefore, some specialists think that those who have a shellfish allergy might not have an issue with chitosan.
- Another blood thinner is warfarin. There is some worry that consuming chitosan could intensify the effects of warfarin (Coumadin), a medication that thins blood. When taking warfarin (Coumadin) and chitosan together, there may be a higher risk of bleeding or bruises. Refrain from consuming chitosan if you take warfarin.

CONCLUSION:

This review paper provides an overview of the improvements and applications of chitosan in the treatment of different disorders. Chitosan is a non-toxic, biocompatible, and biodegradable substance with a wide range of uses. Chitosan has antioxidant and antibacterial qualities. Drug delivery, biotechnology, food technology, regenerative medicine, medicine, gene therapy, cancer therapy, agriculture, and environmental protection are just a few of its many applications.There are numerous uses for chitosan in biology. Even if chitosan might not be used extensively in every field, its effects are anticipated to be significant. To develop chitosan as a versatile chemical with a wide range of applications, more research is required.

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