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Chitosan from black soldier fly: A versatile tool towards sustainable development

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Abstract
The black soldier fly, *Hermetia illucens* (Stratiomyidae), is a ubiquitous and common fly that lives in nutrient-rich settings and produces large quantities of commercially valuable larvae. It is a good and environmentally acceptable biological source of fat and protein for animal and fish feed. Chitin is a structural element found in the exoskeleton of arthropods, including insects and crustaceans. The special functional qualities of chitin and chitosan include biocompatibility, biodegradability, and lack of harmful side effects. Chitosan is also utilized in the medical field to prevent wound infections and to create drug delivery systems because of its strong air permeability, good antibacterial, and antioxidation properties. Chitin is also extensively utilized in a variety of fields, including heavy-metal recovery, waste water treatment, cosmetics, Agriculture, and Medicine. Due to the emergence of multiple large-scale insect breeding facilities throughout numerous nations, there has been a recent surge in interest in exploiting insects as a source of chitin and chitosan. Its high-value products have applications in the pharmaceutical, cosmetic, environmental, and industrial sectors. Potential new applications for this material are found almost daily, which is driving up demand for it worldwide.

Keywords: Black soldier fly, chitin, chitosan, water treatment, agriculture and pharmaceutical

Introduction
The black soldier fly, *Hermetia illucens* (Stratiomyidae), is a ubiquitous and common fly that lives in nutrient-rich settings and produces large quantities of commercially valuable larvae. According to Li *et al*. (2023) [6] and Shamshina *et al*. (2019) [9], this fly is a good and environmentally acceptable biological source of fat and protein for animal and fish feed. It is also recognized for reproducing quickly. Originally, their larvae were thought to be a promising bio-converter that could turn a variety of organic waste types that were decomposing into fertilizer for compost piles. Larval biomass generation has been considered a promising source of novel biomaterials recently. However, because of the relatively high chitin content in their membranes, there are some limitations on the usage of larval biomass in animal feed (Imen *et al*., 2016 and Lv, *et al*., 2023) [4, 7].
Green microalgae, fungi, and invertebrate animals are among the living things that contain chitin, also known as (1→4)−2-acetamido-2-deoxy-β-d-glucopyranan, a naturally occurring polysaccharide (Croisier and Jérôme, 2013) [1]. It is a structural element found in the exoskeleton of arthropods, including insects and crustaceans (crabs, shrimp, etc.). The limiting value of this raw material for chitin extraction is shown by a notable decline in the industrial production of crabs or other sea crustaceans. As an alternative to sea crustaceans, which are becoming fewer and fewer in number each year, chitin and chitosan from insects have been extracted for several decades. Consequently, it is imperative to explore novel sources of raw materials for the synthesis of chitin and chitosan, which are then employed to generate auspicious biomaterials for diverse industrial applications. Consequently, the physicochemical characteristics of chitin may be the most crucial element in determining its precise and possible uses in a variety of industries, including tissue engineering, the immobilization of enzymes, and the creation of functional foods. However, because to its hardness, limited solubility, chemical inertness, and poor affinity for both organic and inorganic components, chitin itself is not very useful. As a result, in many applications,

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The crystalline index values of chitins from adult flies and H. illucens larvae were found to be roughly 25% and35%, respectively, in a prior study. Additionally, the X-ray diffraction patterns of these chitins showed that they were both in the normal α-crystalline form, indicating that they are structurally identical to chitin that is widely used from crab shells. FT-IR spectroscopy may also typically be used to identify the crystalline forms of chitin. Chitin extracted from H. illucens larvae has been reported to have an α-crystallinity with distinct bands near 1650, 1620, and 1550 cm−1 (Wang *et al*., 2020) [14]. According to Shah and Hashmi (2020) [8], chitosan is one of the most promising biopolymers for this use. It is a linear cationic polysaccharide that is produced when chitin, the primary structural element of arthropod exoskeletons, is deacetylated. The conventional method of producing chitosan involves the alkaline hydrolysis of chitin that is recovered from fishing debris, primarily the shells of crustaceans (Thomas *et al*., 2020, Hahn, *et al*., 2020) [11, 3]. The special functional qualities of chitin and chitosan include biocompatibility, biodegradability, and lack of harmful side effects. Chitosan is also utilized in the medical field to prevent wound infections and to create drug delivery systems because of its strong air permeability, good antibacterial, and antioxidation properties. Chitin is also extensively utilized in a variety of fields, including heavy-metal recovery, wastewater treatment, cosmetics, agriculture, and medicine. Due to the emergence of multiple large-scale insect breeding facilities throughout numerous nations, there has been a recent surge in interest in exploiting insects as a source of chitin and chitosan. These farms produce waste products, mostly pupal exuviae produced by insects molting from one developmental stage to another, which can be used as a chitin-rich biomass (Leceta *et al*., 2015) [5]. The most commonly raised species in Europe for feed production and waste management is the black soldier fly (Hermetia illucens L.) (BSF) (Sultana *et al*., 2019) [10]. In fact, BSF larvae can feed on a variety of organic substrates and are drawn to particular organic volatile compounds (Vilaplana *et al*., 2020) [13]. This results in a body mass with a high protein and lipid content that can be used to produce animal feed, biofuels, and products for the cosmetic and biomedical industries (Vieira *et al*., 2016) [12].

One of the primary waste products of BSF's breeding process is the pupal exuviae, which is expelled when the animal reaches the adult stage. It includes up to 25% chitin, which can be processed to create chitosan. By using H. illucens to produce chitosan, issues with the processing of the product's commercial source crustaceans can be resolved in addition to meeting market demand for the product. Undoubtedly, the utilization of the ocean's depths is leading to a significant environmental issue that could potentially be extremely detrimental to the Earth. Nevertheless, by using this substitute source, a biopolymer with the same properties as the crustacean one may be produced that has no negative ecological effects. Insect chitosan showed promise as a substitute for crustacean chitosan when its effects were compared to those of commercial chitosan.

Global Chitin and Chitosan Demand Is Growing Strongly

More than 60.000 T of chitin were needed worldwide in 2015. In the same year, chitin output reached over 28.000 T worldwide. According to a survey by Global Industry Analysts Inc. (chitin and chitosan derivatives market report – 2015), the global market for chitin derivatives (including chitosans) is expected to reach 63 billion USD by 2024. Applications for chitosan include agrochemistry, food and beverage production, bioplastics, pharmaceuticals, food and beverage purification, waste water treatment, and many more, both known and unknown.

A Biopolymer with Several Uses

Among possible applications, chitosan's general uses in waste water treatment and water purification had the largest market share by 2015—roughly 30%. The requirement for potable water and waste treatment has become essential due to the BRICS countries' rapid industrialization and population concentration in urban areas. In water, chitosan functions as a coagulant for both organic and inorganic substances. When filtering water, its purifying action is also utilized by dosing it before filters. Additionally, it works incredibly well as a chelating agent for heavy metals found in industrial waterways. Based on its complete biodegradability, non-toxic nature, and natural origin, together with the increasing demand for water treatment and purification, the market share of chitosan in this application is anticipated to rise dramatically over the next ten years. The agrochemical, health/pharmaceutical, and agricultural sectors are other rising factors. By 2024, demand in pharmacology and the biomedical fields should rise by 17%. Chitosan is actively involved in several patents for its use in the treatment of cancerous tumors (as a vector or carrier), vaccinations, and the battle against cholesterol and obesity. Furthermore, only the chitosan's recognized uses are included in these 17%. Chitosan is a natural alternative to hyaluronic acid, which is frequently found in anti-aging cosmetic formulas. Chitosans are replacing hyaluronic acid in several anti-aging products. These ingredients can be found in skin care product formulas, moisturizing creams, lipsticks, lotions, and some packaging. They are utilized in hair conditioning and buccal care in addition to skin care. They have the capacity to create a protective layer, and their flexibility and superior physical resistance allow them to give long hair longevity and gentleness. In summary, the global customer base's increasing sensitivity to physical appearance will support the expansion of the chitosan industry.

Principal Uses for Chitosan

- Production of synthetic skin
- Biodegradable suture fiber
- Dietary supplement that helps the body absorb proteins
- Substrate used to immobilize enzymes or microorganisms
- Fungicide Fertilizer Membranes for dialysis
- Controller of Pesticide Mobility
- Paper production
- Bolstering fiber for use in papermaking
- Textile fiber (increases some pigments' affinity for the tissue)
- Producing vibrators for use in acoustic loudspeakers
- In favor of medication release under controlled conditions
- Dietary supplement that helps the body absorb proteins
- Agent for reducing cholesterol
- Hemostatic agent: encourages blood clotting
- For seed coating and food preservation, use fungicidal and bactericidal agents.
- agent that clarifies substrate used to immobilize enzymes or microorganisms
- Fertilizer
- Water treatment flocculating agent
- Making of contact lenses
- component of cosmetics and hair care items
- Waveguide made of optics

Conclusion

The manufacturing of chitin and chitosan from shrimp and crab shells can be substituted with sustainable and fully traceable products made from *Hermetia illucens* larvae. Its high-value products have applications in the pharmaceutical, cosmetic, environmental, and industrial sectors. Potential new applications for this material are found almost daily, which is driving up demand for it worldwide. The existing global production capacities are not keeping up with the rapidly increasing demand. In addition, the extremely sustainable bioconverter insect *H. illucens*, whose reproduction is constantly accessible, offers a valuable and alternative source for producing chitosan, which can be obtained in a zero-waste circular economy system. it is possible to preserve food in the future, protect the environment, and recover waste materials to create high-value biological products.

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