Review

JOURNAL OF UNIVERSITY OF BABYLON

For Pure and Applied Sciences (JUBPAS)

Vol.32; No.3.| 2024

A Review of Applications, Forms, Extraction, and Dissolution of Chitin

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مراجعة للتطبيقات, الأشكال, الاستخلاص, و الذوبان للكيتين

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Accepted: **29/5/2024** **Published:** **30/9/2024**

ABSTRACT

Background:

Polymeric organic particles made by organisms or natural biopolymers, are considered as greener materials, more environmentally friendly and durable. Because of its exceptional structural properties, wide abundant, lack of toxicity, biocompatibility, simplicity of alteration and promised potentials, chitin is a sustainable material. It is composed of β(1,4)-linked N-acetyl-glucosamine units and represents the most abundant structural polysaccharide of invertebrates, including such marine phyla as sponges, corals, annelid worms, mollusks, and arthropods. This biopolymer is mostly found in the skeletal structures of invertebrates, and plays a crucial role in their rigidity, stiffness, and other mechanical properties. Chitin is recognized as one of the universal templates in biomineralization, with respect to both biocalcification and biosilicification.

Conclusion:

This review is concerned with chitin. For a set of uses, chitin with its derivatives are receiving more and more attention. The popularity of this plentiful biopolymer has skyrocketed in recent years. Studies on the use of chitin show that these biopolymers have a lot of potential for managing wounds, getting rid of toxic metals, farming, bone regenerative engineering, etc.

Key words:

Biopolymer; cancer cell line; chitin; extraction; ionic liquids.

ISSN: 2312-8135 | Print ISSN: 1992-0652

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INTRODUCTION

Chitin

Chitin is a natural polysaccharide. It has the chemical formula (N-acetyl-1,4-D-glucopyranosamine)[1]. Its structural is similar to cellulose, but it possesses an extra amine group and each monomer has a hydroxyl substituent. Because of its tight construction, chitin has no solubility in the majority of dissolvent. This restricts its use, and numerous chemical changes have been made in the effort to create a great solubility. Due to its advantageous biological characteristics, including biodegradability, biocompatibility, non-antigenicity, non-toxigenicity, capacity to form films, adsorption and ability to chelate mineral ions, chitin has recently attracted the attention of researchers[2]. This polymer has numerous applications in the realms of food, medical, agriculture, textiles, and other related industries because of its characteristics[3]. It is made up of structured, organized crystalline micro fibrils that exist in cell walls of yeast, fungi in addition to the exoskeletons of insects. Shells from crustaceans, such as crab and shrimp, are the most typical industrial sources of chitin. In its industrial production process, procedures for demineralization and deproteinization are used to separate $CaCO_3$ and proteins. To obtain the pure product free of pigments or contaminants, additional decolourization and purifying procedures are frequently necessary. Biopolymers have received more attention recently as a result of the focus on environmentally friendly technologies and their superior functionality and biodegradability compared to synthetic polymers. In response to the growing number of chitin uses, new biopolymer sources are emerging. These biopolymers may be obtained from insects[4]. More than 20% of chitin can be found in Puparia (insect shell) and Flakes, which have a lesser crystallinity than commercial shrimp chitin. The maximum amount of chitin was found in Puparia, marking that it is used as the valuable exporters for chitin[5]. Figure (1) shows the essential sources for chitin synthesis with its extraction[6].

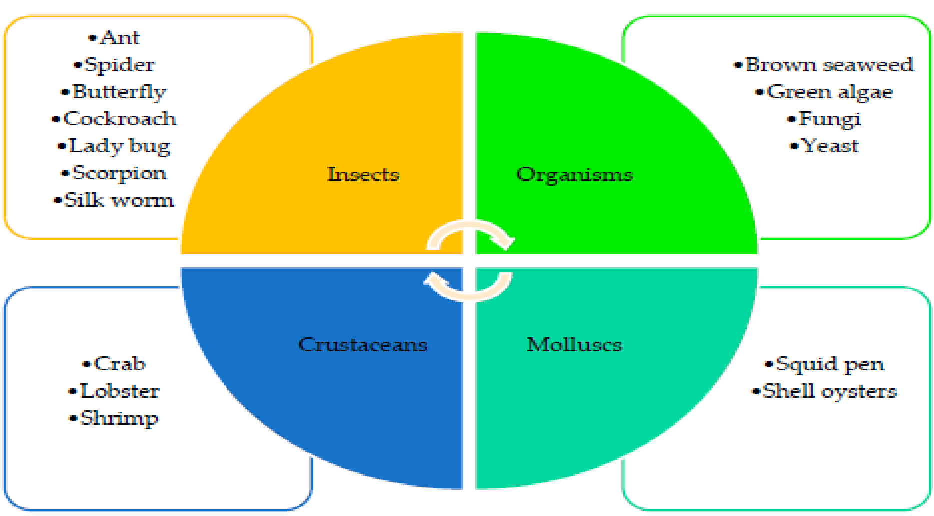

Figure (1): Sources of chitin production[6]

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JOURNAL OF UNIVERSITY OF BABYLON
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Chitin Analytics

Since 1950, novel structural, spectroscopic, and chromatographic analytical techniques have been developed, leading to the publication of numerous analytical publications on the identification of chitin. The expansion of qualitative and quantitative analysis about chitin for industrial applications was the main emphasis of the majority of these papers. Food study for goodness control and pollution prevention strategies used chitin identification heavily. Studies that looked specifically for chitin in fresh biological resources and fossils were few and far between. However, despite nearly 200 years of chitin identification research, those efforts continue to provide surprising scientific findings, as the 2007 detection of chitin in the sponges. Recent chitin identification investigations have opened new methods for the diagnosis of many parasite and immune disorders. For instance, some researchers (2008) hypothesized a connection between Crohn's disease and invasive Candida albicans contagion because these illnesses were associated for a markedly elevated standard for chitin antibodies [7]. As well as, chitin existed in tissue models taken of people who have Alzheimer's disease's central nervous system. This finding made possibility to propose mycoses as a potential cause of dementia and Alzheimer's disease. When used in conjunction, chitin identification is still a crucial tool for anthropological, biotechnological, and medicinal applications figure (2).Since chitin is a solitary polysaccharide made entirely from n-acetyl-D-glucosamine units [dGlcNAc], its molecular structure supports the identification of this polymer by a variety of spectroscopic, scattering and diffraction techniques. Raman, NEXAFS and IR. Chitin may be distinguished from other biopolymers because to information on the molecular moieties provided by spectroscopy, but it can also be misleading when analyzing complicated samples. Nondestructive techniques for substance analysis that supply information on the molecular structure and chemical structure of a model include X-ray, electron, X-ray scattering and in addition to X-ray diffraction. These techniques are together known as structural analyses. Compared with the another analytical technicalities, the methods of structural analysis request the substantial amount of the model (milligrams) for analyses[7].

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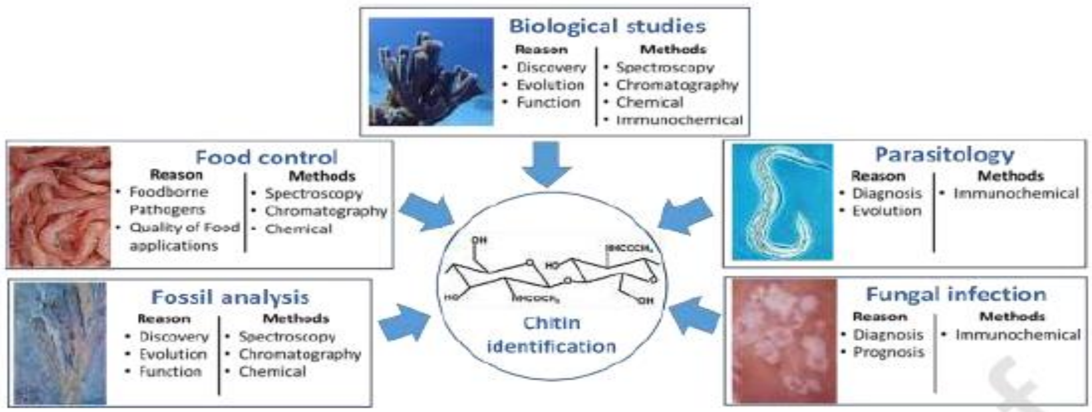

Figure(2) : Overview of the chitin identification-related scientific disciplines[7]

The forms of chitin

Chitin is a crucial biopolymer for biology that is present in more than 70% of organisms[8]. There are three crystalline forms from chitin in nature: γ-, β-, and α-chitin. Antiparallel chains are seen in α- chitin. It is the most prevalent type and gives the polymer its stiffness. In addition to intermolecular interactions, β-chitin has intramolecular interactions (hydrogen bonds) that result in monoclinic crystals. The pogonophoran tubes, squid pens, and spines of diatoms contain β-chitin. In fungus, yeasts, and insect cocoons, γ-chitin is a mix from antiparallel and parallel chains that combine the qualities from the β –formand α -form [9].The major sources of α-, β-, γ-chitin are shown in table (1)[10].Chitin has a low thermal expansion coefficient (β-chitin = 15.8×10^{-5} ºC^{-1}, α-chitin = 59.3×10^{-5} ºC^{-1})[11]. Because of the large chitin particles, β-chitin exhibits far higher reactivity and quicker crystalline structure degradation during the deacetylation process than α-chitin does[12].

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Table (1): the major sources of α-, β-, γ-chitin [10]

	α-chitin	β-chitin	γ-chitin
Main Sources	Bryozoa, Arthropoda, Porifera, Yeast, Fungi, Shrimp Shells, Crab and Lobster tendons, Barnacles, Coelenterate, Algae, Protozoa, Annelids	Squid pens, Diatoms, Cephalopods, Spines Annelids, Algae, Protozoa	Fungi, Ptinus beetle, Mushrooms, Diatoms, Mollusca polyplacophora
Configuration	Antiparallel lipo-chitooligosaccharide	Parallel lipo-chitooligosaccharide	Both parallel and antiparallel lipo-chitooligosaccharide
Abundancy	Most abundant	Less abundant	Moderate or less abundant

Chitin dissolution

Ionic liquids [ILs]are the class from salts with a variety of desirable qualities that are fluid in relatively little temperatures [lower than 100 ^{o}C]. In recent years, ILs are widely used to solve naturalist polymers such as chitin, agarose, cellulose, oligosaccharides, starch, etc.[13].In the last years, the green dissolvent system from alkali/urea aqueous solution is found out to completely dissolve chitin at down temperature[14]. In reality, chitin itself possesses desirable qualities for biomedical applications, including the ability to speed up wound cure, prevent the increase of tumor cells, and be biocompatible and nontoxic. The evolution of numerous goods based on chitin, including vascular implants, tumor inhibitors and artificial blood vessels, has been sparked by the chitin's above-mentioned main features. In spite of the reality that chitin is quite abundant, it is less dissoluble in many organic dissolvents because the strong intra- and intermolecular hydrogen binds that develop when a polymer chains are joined together. Therefore, only a small number of solvents, including DMAc-LiCl, and hexafluoroacetone, have been discovered for chitin.Numerous ILs have been reported to have the ability to dissolve chitin, including 1-allyl-3- methylimidazolium chloride [AMIMCl],1-allyl-3- methylimidazolium bromide [AMIMBr], 1-butyl-3- methylimidiazonium chloride [BMIMCl], 1-ethyl- 3-methylimidazolium chloride [EMIMCl], 1-allyl-3- methyl, the most popular ones are BMIMAc and BMIMCl, which include acetate and chloride, respectively. In order to enhance their ability to dissolve macromolecules by disruption hydrogen bonds, the tenability of ILs' can be determined by the independent selection of ions [15]. Chitin is a polymer with little reactivity and is virtually insoluble in all solvents except the pricey and toxic "dry DMAA (dimethylacetamide)/LiCl" combination. Chitin derivatives were successfully synthesized in water using ultrasound. This is the first example on highly regeoselective ultrasound assisted polymer analogous conversions from chitin. It was shown that the acoustic parameters

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effectively mediate the polymer analogous transition from chitin, allowing the preserve stability the spine of chitin and prevent deacetylation. As a result, fresh water-soluble chitin derivatives were produced, despite the reports heavy emphasis on water-soluble chitin derivatives.The produced water-soluble azido chitin derivatives have potent antibacterial properties comparable to those of the widely used antibiotics gentamicin and ampicillin, while being non-toxic. The azido moiety in the produced polymers' macromolecules is what gives them their antibacterial properties. It has been demonstrated that conjugating the azido part to the chitin backbone significantly reduces a toxicity of an azidopharmacophore while maintaining its antibacterial effects[16].

Applications of chitin

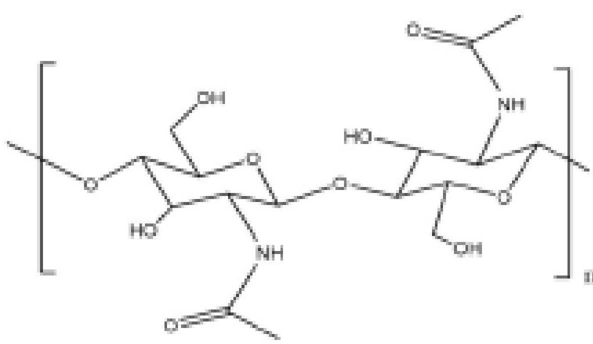
Chitin has a broad range of the uses in the wastewater treatment, food industry, cosmetics, agriculture, pharmaceuticals, applications of medicine, manufacture of paper, textiles, among other industries. Applications for chitin are numerous[17]. Due to its many biological, chemical and physical properties, chitin is intriguing[18 and 19].

The use of chitin in a wound Heal thing

Chitin is the good option for biomedical applications because of its appealing features, including as biocompatibility, adhesion, biodegradability, wound-healing, hemostasis, and antibacterial activities [20-22]. Sponge, powder, granules, filaments, and composites with cotton or polyester have all been utilized to make products out of chitin. Non-woven of Chitin textiles and strings are utilized as synthetic sutures and skins because they are biocompatible, biodegradable, and promote wound healing. Fibroblast activation, polymorphonuclear cell activation, stimulation of type IV collagen authorship, giant cell immigration and cytokine generation are the major biochemical actions of chitin in wound healing[23]. New antimicrobials are desperately needed to battle bacterial infection, which has historically posed a serious threat to the general public's health. The hydrophobic qualities of chitin are provided by its intact acetamido groups, and further cationic alteration may provide antibacterial capabilities, making it a more effective antibiotic for the treatment of bacterial illness. However, because of the ingrained characteristics of chitin, like strong intra and intermolecular hydrogen bonds between fixed solubility in the majority of commonly used dissolvents and chitin chains, the classical processes to synthesis derivatives of chitin have primarily used powerful bases in heterogeneous conditions. As a result, there are few reports of homogeneously changed chitin derivatives being used as antibacterial agents. An aqueous KOH/urea solution that recently came to light resolves α-chitin isolated from crab and lobster shells in a matter of few minutes. The hydrous solution of KOH/urea is used to create amphiphilic and cationic antibacterial quaternized $_{\beta}$-chitin derivatives. The original acetamido groups were kept, and on a main hydroxyl in the C-6 location of the spine of chitin, positive quaternary ammonium collections were substituted. These quaternized $_{\beta}$-chitin derivatives have great intrinsic biocompatibility and premium antibacterial activity against fungus and gram-negative / gram-positive bacteria. They easily self-gather to form positive micelles. Additionally, they significantly speed up wound healing by reducing inflammatory cell leak, promoting neovascularization, collagen fiber renovation and granulation tissue growth. The treatment of the infected wounds is one application where this novel family of the antimicrobial polymers founded on the polysaccharides has considerable potency as antimicrobial substances [24].

Using biopolymer chitin for wastewater treatment

The treatment and administration of the wastewaters, particularly these coming from the mineral industry, has become one of the largest issues in recent years. Heavy metals (in their ionic forms) are highly concentrated in these sorts of effluents. Zn, Cd, Cr, Pb, Cu, Ni, Pt, V, Ti, Ag, and other metals are the examples of those that can be found in these effluents and they primarily come from various businesses. Metal effluents are created by a variety of processes, including etching, conversion coating, electroplating, electroless depositions, and milling. Adsorption is one of the investigated techniques to purification of the wastewaters and is an economical, promised, effective, and ecofriendly process. Agricultural waste, compost, nanomaterials, algae, and other contaminants have all been removed using different types of adsorbents.Chitin has received interest from scientists as a cheap toxic metal adsorbent. It is a long polymeric chained polysaccharide, which gives it several features for modulation during the preparation of the derivatives. Chitin is the high molecular weight polymer from a structural perspective[25].In particular, polysaccharide-based adsorbents, nanosorbents and nanomaterials, exhibit large performance in the removing repellers from water flats as appeared of chitin toward the biosorption of the repellers. This could help wonderful remediate polluted waters. Indeed, chitin structure in addition to the kinetics and stereochemistry of the chemical reactions were governed through the presence of the hydroxyl groups[26].



(Chitin)

Figure (3):chemical composition of the chitin[27]

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JOURNAL OF UNIVERSITY OF BABYLON
For Pure and Applied Sciences (JUBPAS)
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Chitin that is shown in figure (3) is one of the most appealing possibilities to act as the mineral chelating factor to remove mineral contaminants from the wastewaters because of its chemical and physical properties. Some researchers have discussed the chitin's charged surface in the metal solution. Through electrostatic reactions between similarly charged mineral ions and the adversely charged flat of the biosorbents, the charged flat significantly affects on the stabilization of mineral ions and their anions in suspension or electrolyte solution. Repulsion between a metal ions reduces the applied chitin's ability to absorb biologically. As well known from earlier studies, the creation of a cloud of counter ions as a result of the surface adsorption of the ionic impurities like mineral ions and their anions results in the spread electrical double coat along the frontage, that is what causes an emergence the interior field. It is possible to ionize or dissociate surface groups, such as the separation of the protons from the carboxylic groups [-COOH], or the existence of the lone pairs of the electrons contributed by -OH and $-NH_3$ groups to nigh mineral ions through chelation or ion exchange. A first method involves the discriminatory adsorption of mineral ions from a solution on an initially not charged surface of a biosorbent. A positively charged metal ion solution with a charged surface of the chitin and a neutralizing spread coat of the counter ions create an electrical double layer. As depicted in figure (4), the potential of zeta is the gauge from the shipments carried by mineral ions and their the anions in hydrous solution. At neutral pH range, chitin surfaces in wastewater solutions and water contain pollutants have negative surface shipments. The negatively charged surface is drawn to the solution's positive ions, where they may become heavily adsorbed[27].

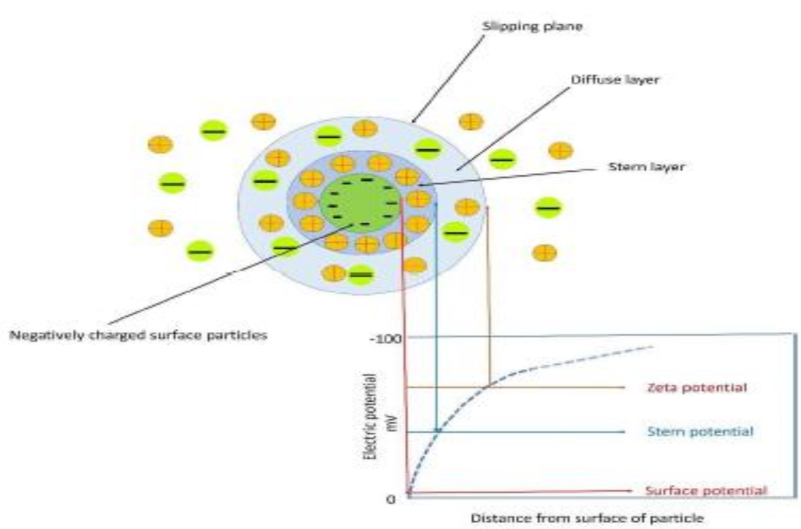

Figure (4): Zeta potential[27]

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The use of chitin in agriculture

In order to meet the rising food demands brought on by population growth and the continuous climate change, modern agriculture must be modified. Sustainable cropping is crucial given that natural resources are limited, especially for horticultural crops that are more sensitive to climatic extremes and require more agricultural inputs[28 and 29]. Chitin is a second utmost prominent biopolymer which may be exist in nature. The chitin mart is predictable to reach up by 2027 to US$ 2900 million due to its quick growth[30]. Because of the potential negative consequences on human health and the development of the pathogens with heightened impedance, synthetic bactericides, which are currently the primary tool for managing illnesses, have come under increasing scrutiny for their indiscriminate use on crops. As a result, there is a global movement to look into new options to decrease the use of the artificial chemical factors. Chitin serves a number of purposes, such as retaining nutritious in a soil and assisting with the cycle of nitrogen. COS have extracting activities that cause a different of protection responses in the plants in answer to the microbial infections, minimizing a detrimental effect of the diseases on crop yield and its quality[31].

The use of chitin in cosmetics

Chitin can be applied to several bodily parts, including the skin, hair, gums, and teeth. When used as an active component in skin, teeth, nail, and hair care, chitin with its derivatives demonstrate a broad range of the pertinent qualities. They also possess the best qualities for vehicularizing active compounds for the cosmeceutical and cosmetics industries. A precise polymer description is required to identify whose features are further pertinent for the certain usage because these valued properties are highly correlated with the physico-chemical properties of polymers[32].

The use of chitin in bone reconditioned engineering

Excellent biocompatibility with bone tissue has been shown for chitin nanofibers, which not only encourage osteogenic differentiation and seed cell proliferation but also speed up angiogenesis of metallic bone tissue in addition to make medicine delivery easier in bone reconditioned engineering. Further study is necessary, nevertheless, to move a chitin nanofibers of laboratory to the therapeutic usage. Yet some problems in the clinical usage of the chitin nanofibers, despite the fact that researchers can create a set of biomaterials which simulates the function, structure, and morphology of naturalist bone tissue and it can demonstrate their activity in enhancing bone reconditioned and reform at the animal and cellular level[33].

The use of chitin in Blood Anticoagulation

Heparin is one of the most often used blood thinners, but it is also highly expensive. Numerous efforts have been made to manufacture synthetic coagulants in an effort to lower costs, but none have been shown to be as harmless as heparin. It has been shown that chitin disulfuric acid is less hazardous than a sulfuric acid esters from starch and cellulose. It has also claimed that when chitin including material is introduced to the tissues of the higher animals, the inflammatory

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reaction is caused by the protein moiety of chitin[34]. According to Dutkiewicz et al., chitin is the good get-away point to the creation of the blood anticoagulants that resemble heparin[35].

The use of chitin in medicine delivery systems

Find out and evolution of drug in the clinical stage is an expensive and very difficult procedure due to the majority of the medication that do not have positive clinical effects because they can not get to the target location for action. The sizable portion of a medicine administered is distributed on healthy organs or tissues which are not affected by a disease operation, frequently resulting in sharp side effects[36].Regarding that, the cationic polysaccharide chitin has gained more and additional attention in the biomedical and pharmaceutical manufacture due to their wide abundance, ingrained pharmacological properties, and other advantageous biological characteristics like biodegradability, biocompatibility, low-immunogenicity and non-toxic profile which may lead to the potential usage in a designing of the carriers for the controlled releasing of the medicine delivery[37].

The use of chitin as anticancer characteristics versus ovarian cancer cell streak, PA-1

A biggest burden on general health, in developing and developed nations, is cancer. In India, there are roughly 5, 80,000 cancer-related deaths and 8, 50, 000 newly diagnosed cancer cases per year[38].With a predestined 12 million demises from cancer in the year 2030, cancer related fatalities are expected to increase globally. There are about 25 million cancer patients worldwide[39].One of a more common cancers in women, especially in the postmenopausal period, is ovarian cancer. A fifth most common cancer between women is ovarian cancer. It kills most women than any another malignancy of a female reproductive device. According to cancer statistics in 2017, its risk of death because of ovarian cancer is nearly 1 in 100. There are three possible origins for ovarian cancer: germ line, stromal, and epithelial. Ovarian cancer effects on 22,440 of women worldwide each year, and 14,080 of those deaths are documented, for a worrying ratio of nearly 62%. There have been about 480 incidences of malignant ovarian cancer documented in Chennai. Chitin has been tested for its capacity to kill ovarian cancer cell streak PA-1. Findings show which chitin had cytotoxic impacts with varied doses from10 into 50 g/ml and that, at a dosage of 50 g/ml, had the capacity to completely inhibit the proliferation of PA-1 tumor cells. These findings imply that chitin has the capacity to limit a reproduction of a PA-1 cell streak. According to Bouhenna and et al., the chitin derivatives are effective versus the cancer cell streaks Hep2 and RD. The chitin was cytotoxic to Hep2 cell lines with an IC50 of 400 g/ml. It came to conclusion that reactions among positive charged groups from the chitin and negative charged groups from the tumor cells are most likely what causes the cytotoxicity. Bouhenna and et al., whose investigated a cytotoxicity of the chitin derivatives toward humane cancer cell streaks, came to a same conclusion as the earlier scientists[40].

Extraction of chitin

So as to standardize the using of the chitin in the industry while taking cost-effectiveness and biocompatibility into consideration, progressive extraction methods are required[41].Crystallinity, purity, mechanical stability and thermal stability of an extracted chitin

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could all be affected by the chitin isolation process[42]. Chitin is often extracted using one of two methods: chemical or biological. Strong acids and bases are used in the chemical processes for dissolving $CaCO_3$ and the proteins, respectively. A quick time of extraction still makes chemical treatments the more often utilized therapy commercially despite their numerous drawbacks. Biological treatments provide an alternate method of chitin extraction in order to evade alkali and acidic Therapies, which are very harmful into an environment. For the demineralization and deproteinization processes, the lactic acid producing bacterial proteases and bacteria have been employed, respectively. Chitin deacetylase performs enzymatically-based chitin deacetylation. These extraction methods have been used to conduct extensive studies around an extraction of the chitin from the different resources[43].Methodological development is crucial for the active extraction of the pure chitin of marine resources, although it is typically constrained through a presence of the matching foreign organic and mineral phases.

As a result, Commercial chitin segregation techniques that are more frequently utilized in that situation are dependent on the chemical processes which permit hydrolysis of protein, depigmentation, and demineralization of inorganic materials[44 and 45]. After deproteinization with 5% NaOH and demineralization with 1% HCl, chitin may be successfully recovered from prawn shells [46].According to S. Kumari et al., demineralization and deproteinization processes including 1% HCl for a duration 36 hours with 0.5 N NaOH solution for a duration 18 hours, respectively, were used to extract chitin from fish scales, LabeoRohit. Chitin was treated for two hours at 80°C with a 50% NaOH solution using an oil bath[47].An extraction of the chitin of MetapenaeusStebbingi peels is described through A. Kucukgulmez et al. 1.7 N HCl in 25°C for a duration 6 hours with 2.5 N NaOH in 65°C for a duration of 6 hours, respectively, were used for a deproteinization and demineralization processes[48].The chitin extraction of the shrimp LitopenaeusVannamei wastes is described through M. Y. Arancibia and et al. The material underwent enzymatic hydrolysis using Viscozymeand Alcalase to remove a protein after being demineralized by lactic acid for a duration of 36 hours in 21°C. The remaining solid substance was deacetylated with a 40% NaOH for a duration 4 hours in 110°C[49]. Figure (5) shows the isolation of chitin from crustaceans shells, Chitin may now be extracted from verongiid demosponges quickly and effectively using microwave-assisted deproteinization and demineralization. It has been unequivocally proven that the novel methods allow for a large increase in time competence for the chitin extraction from the Verongiida sponges without compromising an isolated biological material's distinctive fibrous linked structure. The suggested method significantly cut the time required for chitin extraction while also reducing the use of harmful chemicals. To produce chitin scaffolds from marine sources, microwave aided extraction is a practical, economical, and quick process[50].

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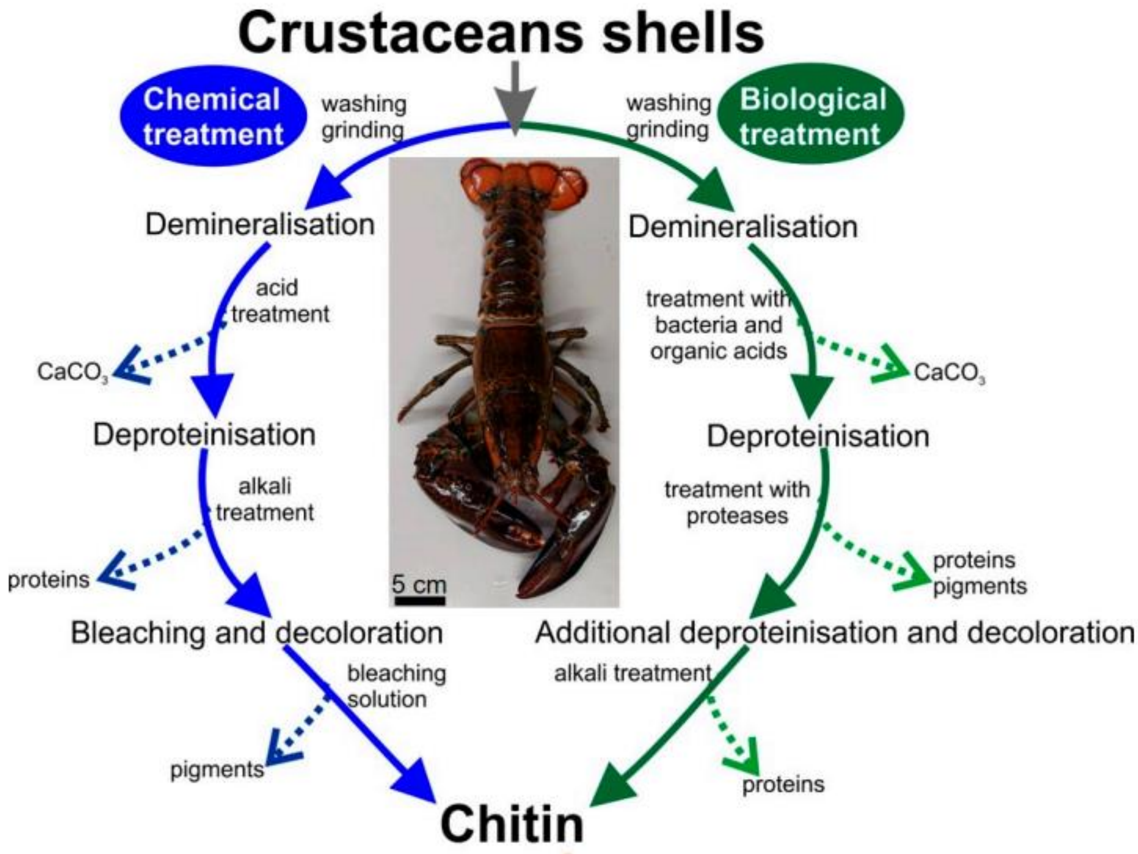

Figure (5): isolation of chitin from crustaceans shells[50]

CONCLUSIONS

This review is concerned with chitin. For a set of uses, chitin with its derivatives are receiving more and more attention. The popularity of this plentiful biopolymer has skyrocketed in recent years. The remarkably high level of current chitin research effort throughout academia and business, as shown by the sharp rise in the quantity of pertinent research publications and patents, is clear. As a result, applied and basic research has advanced significantly, it is now clear that chitin offers a broad area of the potential usages. Studies on the use of chitin show that these biopolymers have a lot of potential for managing wounds, getting rid of toxic metals, farming, bone regenerative engineering, etc. This biopolymer is often made using a variety of standard techniques; nevertheless, it has been demonstrated and stated that the new ecological extraction technique, helped by microwave irradiation, is crucial. Future research should concentrate on utilizing novel methods to speed up the extraction of chitin and utilize less toxic agents. In addition to the discovery of more abundant and less expensive solvents for dissolving chitin.

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Conflict of interests.

There are non-conflicts of interest

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الخلاصة

المقدمة:

تعتبر الجزيئات العضوية البوليميرية التي تصنعها الكائنات الحية أو البوليمرات الحيوية الطبيعية, مواد أكثر خضرة و أكثر صداقة للبيئة و متانة. نظرا لخصائصه الهيكلية الاستثنائية, وفرته الواسعة, نقص السمية, التوافق الحيوي, بساطة التغيير و الإمكانات الموعودة, فان الكيتين مادة مستدامة. و هو يتألف من وحدات β(1,4)–linked N–acetyl–glucosamine و يمثل عديد السكرايد الهيكلي الأكثر وفرة في اللافقاريات, بما في ذلك الشعب البحرية مثل الاسفنج و المرجان و الديدان الحلقية و الرخويات و المفصليات. يوجد هذا البوليمر الحيوي في الغالب في الهياكل الهيكلية للافقاريات, و يلعب دورا حاسما في صلابتها و خواصها الميكانيكية الاخرى. يعرف الكيتين بانه احد القوالب العالمية في التمعدن الحيوي, فيما يتعلق بكل من التكلس الحيوي و السيليكون الحيوي.

الاستنتاجات:

هذه المراجعة معنية بالكيتين. بالنسبة لمجموعه من الاستخدامات, يحظى الكيتين و مشتقاته باهتمام متزايد. ارتفعت شعبية هذا البوليمر الحيوي الوفير في السنوات الأخيرة. تظهر الدراسات التي اجريت على استخدام الكيتين ان هذه البوليمرات الحيوية لديها امكانات كبيرة لإدارة الجروح, التخلص من المعادن السامة, الزراعة, هندسة تجديد العظام و ما الى ذلك.

الكلمات المفتاحية:

البوليمر الحيوي, خط الخلايا السرطانية, الكيتين, الاستخلاص, السوائل الأيونية.

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