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## PHYSICOCHEMICAL PROPERTIES AND ANTIMICROBIAL ACTIVITY OF CHITOSAN FROM VARIOUS NATURAL SOURCES FOR USE IN THE FOOD INDUSTRY

**Abstract:** *in the article the authors present the results of research on the synthesis of chitosan from various sources of raw materials, their molecular weight, physicochemical characteristics, as well as studied their applications in various industries. It is shown that the use of chitosan and its derivatives in food industries as packaging materials contributes to the preservation of freshness of food products and increasing their shelf life when chitosan exhibits high antibacterial and antimicrobial properties. This is especially important for products with short shelf life, such as meat, fish, dairy products, and fresh fruits and vegetables. The use of chitosan as food additives in foods improves the quality and digestibility of products by the human body, and increases their antioxidant properties. Chitosan additives because of their antibacterial and antimicrobial activity help in lowering blood cholesterol levels, improving metabolism and are safe for human health. The ability of chitosan to bind fats in the gastrointestinal tract prevents cardiovascular diseases. Chitosan's antioxidant properties protect the body from free radicals, lower lipid levels, and maintain normal body cells.*

**Key words:** *chitin, chitosan, natural polysaccharide, crustaceans, bee subpestilence, fungi, mulberry pupae, diacetylation, antimicrobial and antibacterial activity, biocompatibility and biodegradation.*

### Introduction

Chitosan is a polymer that is produced by depolymerization of chitin, which is present in the exoskeletons of many invertebrates such as crustaceans, as well as in the cell walls of fungi,

mulberry silkworm pupae and other natural sources. Chitosan has a number of unique physicochemical and biological properties that make it in demand in the medical, pharmaceutical, cosmetic, food and agricultural industries.

The chemical structure of chitosan consists of glucosamine and N-acetylglucosamine, which gives it unique physicochemical properties such as water solubility, biodegradation and antibacterial activity.

However, the properties of chitosan can vary significantly depending on the starting material from which it was obtained. This is due to differences in molecular weight characteristics, structure and degree of degradation of chitin, as well as to the peculiarities of processing of the starting material. In this article, the authors review the molecular weight and physicochemical properties of chitosan obtained from various raw material sources, such as crustaceans, bee subpestilence, mushrooms, mulberry silkworm pupae, and its application in the food industry.

### **Research Methods**

The following research methods were applied to evaluate the molecular weight and physicochemical characteristics of chitosan obtained from different raw material sources:

- Determination of molecular weight by gel permeation chromatography;
- Measurement of the degree of deacetylation by spectrophotometric method;
- Solubility study in aqueous acid solutions;
- Viscosity analysis of chitosan solutions;
- Evaluation of antimicrobial activity.

### **Results**

Chitosan derived from crustaceans. Crustaceans (shrimps, crabs, etc.) are the main source of chitosan production. Chitin extracted from crustacean shells is a polysaccharide composed of N-acetylglucosamine and glucosamine. The process for producing chitosan involves treating chitin in an alkaline medium to remove acetyl groups, which converts it to a more amine polymer.

The molecular weight of crustacean-derived chitosan ranges from 100 to 500 kDa, which makes this chitosan suitable for use in the pharmaceutical industry. Because of its high molecular weight, such chitosan has good mechanical properties, including elasticity and strength.

The solubility of chitosan obtained from crustacean shells in water is rather low, but it improves significantly in slightly acidic media. The degree of deacetylation is about 85%, which is quite high. The antimicrobial activity against Gram-positive bacteria is high, especially against *Staphylococcus aureus*.

Crustacean-derived chitosan is soluble in acidic solutions (e.g., acetic acid), making it suitable for use in medicine and biotechnology. Crustacean chitosan is characterized by higher crystallinity than chitosan obtained from other sources, which affects its heat resistance. It is highly biocompatible and biodegradable and is actively used in medical applications such as tissue engineering and wound healing [1-3].

Chitosan derived from bee subpestilence. Bee subpestilence contains chitin in their exoskeleton, which can be converted into chitosan. To obtain chitosan from bee subpestilence, a chitin extraction and degradation method is used, similar to the methods used for crustaceans, but taking into account the peculiarities of the chitin structure in bee bodies.

Bee subpestilence contain active biological components that can improve tissue regeneration, while the chitosan itself retains its biodegradability.

Chitosan isolated from bee subpestilence shows a high degree of deacetylation (about 90%), which indicates the high quality of the product. The molecular weight is in the range of 30-150 kDa, which demonstrates pronounced antibacterial properties and allows its use in food storage and agriculture. The antimicrobial activity of such chitosan is moderate, directed mainly against Gram-negative bacteria. Due to its low molecular weight, chitosan from bee subpestilence has less pronounced mechanical properties but has good adsorption properties [4, 5].

The solubility of chitosan from bee subpestilence in water is limited, but it improves in an acidic environment. Like chitosan from crustaceans, this species is also soluble in acids, making it convenient for pharmaceutical use.

Chitosan derived from mushrooms. Mushrooms, especially mushrooms such as fly agaric, represent another source of chitin. Chitosan derived from mushrooms has several distinctive features due to the characteristics of the cell wall of mushrooms, which contain large amounts of chitin.

The molecular weight of chitosan from mushrooms is typically between 20 and 100 kDa, making it suitable for food and biotechnology applications.

The degree of deacetylation is about 75%. Water solubility is better than chitosan from other sources due to its low molecular weight values, but its mechanical performance is lower than that of chitosan derived from crustaceans. Antimicrobial activity is medium, with the greatest efficacy against yeast and mold.

Anti-inflammatory and antioxidant properties: Mushroom chitosan has anti-inflammatory and antioxidant properties, it shows potential in anti-inflammatory therapy, which opens up its application in the field of medicine and cosmetology [6].

**Chitosan derived from mulberry silkworm pupae.** Mulberry pupae are another source of chitin. This material, unlike crustacean chitin, contains fewer proteins and other impurities, making it easier to obtain pure chitosan.

Chitosan obtained from mulberry silkworm pupae has a molecular weight ranging from 30 to 150 kDa. The degree of deacetylation reaches 95%, which indicated the high quality of the material. Solubility in water is limited but improves under acidic conditions. Antimicrobial activity is most pronounced against Gram-positive and Gram-negative bacteria.

Chitosan from mulberry silkworm pupae is characterized by its stability and good mechanical properties, as well as its tendency to form stronger films compared to chitosan obtained from other sources.

Chitosan from mulberry silkworm pupae is readily soluble in acids, but its solubility may be limited depending on conditions. Such chitosan is actively used to create gels and films in medical and cosmetic applications due to its ability to form strong structures.

Chitosan from mulberry silkworm pupae is also highly biodegradable and is widely used in pharmaceuticals [7, 8].

The average molecular weight of chitosan obtained from different raw material sources was determined by viscometric method using the Mark-Hauvinck-Sakurady equation.

$$M = \left( \frac{[\eta]}{K} \right)^{\frac{1}{a}}$$

A system containing 0,25 M sodium acetate solution and 0,25 M acetic acid solution was used as solvent at  $K = 1,4 \cdot 10^{-4}$  and  $a = 0,83$ .

The following conclusions can be drawn from the data presented in Table 1:

Table 1 – Molecular weight and physicochemical characteristics of chitosan samples synthesized from different raw material sources

| №  | Chitosan sample                               | N, % | Degree of diacetylation, % | Mv, kDa | $[\eta]$ | Insoluble residue, % | Humidity, % |
|----|-----------------------------------------------|------|----------------------------|---------|----------|----------------------|-------------|
| 1  | Chitosan derived from crustaceans             | 8,10 | 94,50                      | 112,3   | 2,85     | 1,30                 | 9,70        |
| 2  |                                               | 8,25 | 96,10                      | 278,5   | 3,50     | 1,10                 | 10,00       |
| 3  |                                               | 8,40 | 97,30                      | 492,7   | 4,10     | 0,95                 | 10,50       |
| 4  | Chitosan derived from bee subpestilence       | 7,70 | 91,20                      | 32,4    | 1,95     | 2,60                 | 10,80       |
| 5  |                                               | 7,85 | 93,00                      | 78,9    | 2,40     | 2,10                 | 11,20       |
| 6  |                                               | 8,00 | 94,60                      | 145,6   | 2,95     | 1,75                 | 11,00       |
| 7  | Chitosan derived from mushrooms               | 6,50 | 83,40                      | 22,7    | 1,60     | 4,20                 | 12,80       |
| 8  |                                               | 6,70 | 86,10                      | 58,5    | 2,15     | 3,60                 | 12,30       |
| 9  |                                               | 6,90 | 88,90                      | 97,3    | 2,60     | 3,00                 | 11,90       |
| 10 | Chitosan derived from mulberry silkworm pupae | 7,20 | 88,50                      | 35,6    | 2,00     | 2,10                 | 10,60       |
| 11 |                                               | 7,40 | 90,80                      | 82,1    | 2,55     | 1,75                 | 10,40       |
| 12 |                                               | 7,60 | 93,10                      | 148,3   | 3,05     | 1,40                 | 10,20       |

Chitosan from crustaceans is the most highly deacetylated and high-molecular-weight with good solubility compared to other samples. It is preferable where high molecular weight and stable properties are important (Figure1).

Chitosan from bee subpestilence has balanced indicators. In terms of mass and solubility, it is inferior to crustaceans, but better than chitosan obtained from mushrooms.

Chitosan obtained from mushrooms is the least deacetylated and has a low molecular weight. To achieve high solubility and stable properties, more thorough purification is necessary.

Chitosan from silkworm pupae is a good compromise in terms of solubility and has moderate molecular weight. Based on the data, it is close to bee subpestilence and slightly inferior to crustaceans.

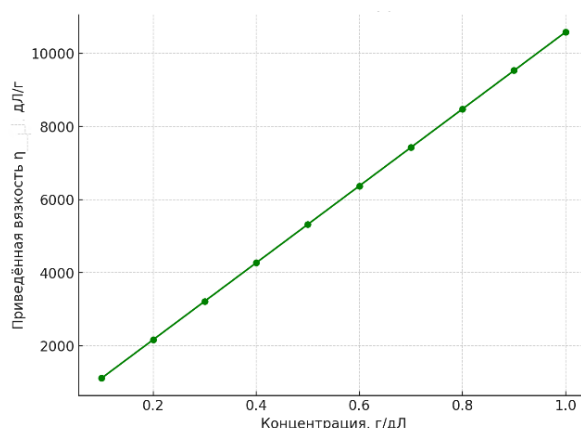


Figure1 – Concentration dependence of the reduced viscosity for chitosan with molecular weight  $M_v = 78,9$  kDa

## Discussion

With the development of industrialization and increasing food production, problems related to food storage and packaging arise. To solve these problems, scientists and industry are beginning to actively explore new materials that can provide long-term storage of products without reducing their quality. One such material is chitosan, a natural polysaccharide derived from chitin. Chitosan has unique properties such as antimicrobial activity, biocompatibility and the ability to form films, which makes it promising for use in the food industry.

One of the most valuable properties of chitosan for the food industry is its ability to form films and coatings that can be used in the packaging of products such as fruits, vegetables, meat, dairy products and fish. They provide a barrier function, protecting the product from external influences such as moisture, oxygen, and microbial contamination. In addition, chitosan has antimicrobial activity, making it effective against bacterial and fungal contaminants in food [9].

Chitosan films are environmentally friendly as they are biodegradable and do not pollute the environment. In addition, such films can be used to create functional packaging that will not only protect the product but also extend its shelf life [10].

The antimicrobial activity of chitosan is due to its ability to interact with the cell membranes of microorganisms, disrupting their integrity and leading to the death of bacteria and fungi. This property is also used in the creation of antibacterial packaging, which not only extends shelf life but also preserves the nutritional quality of foods [11].

The use of chitosan in packaging can significantly extend the shelf life of food products, improving their freshness and nutritional properties. This is especially important for products with a short shelf life, such as meat, fish, dairy products, and fresh fruits and vegetables.

Chitosan films and coatings are biodegradable, making them environmentally friendly. This reduces plastic waste, which is currently a major environmental concern.

Chitosan is a natural product that does not cause allergic reactions and is safe for human health, making it ideal for use in food packaging.

In recent decades, there has been a growing interest in the use of chitosan as a food additive due to its many beneficial properties. This substance exhibits antimicrobial activity, helps to reduce blood cholesterol levels, improves metabolism and is safe for human health.

Chitosan has antibacterial and antimicrobial effects, making it useful in preventing food poisoning and improving food quality. One of the best-known effects of chitosan is its ability to bind fats in the gastrointestinal tract, which helps lower blood cholesterol levels and prevent cardiovascular disease. Chitosan helps normalize the gastrointestinal tract, improves digestion and helps with metabolic disorders. Chitosan has the ability to reduce the level of free radicals in the body, which helps protect cells from oxidative stress and slows down the aging process.

Chitosan is actively used to lower blood cholesterol levels. Its ability to bind fats and eliminate them from the body helps to lower total cholesterol concentrations as well as low-density lipoprotein (LDL) levels, which is an important factor in the prevention of cardiovascular disease. Chitosan is often used as part of complexes to improve cardiovascular health, making it a useful dietary supplement for people suffering from hypercholesterolemia.

Chitosan exhibits antioxidant properties that are important in protecting the body from free radicals. Chitosan supplements may be useful in the prevention of oxidative stress related diseases such as cancer, cardiovascular disease and diseases of aging. Chitosan reduces oxidized lipid levels and maintains normal cellular health in the body.

One of the most popular uses of chitosan in dietary supplements is as a weight loss aid. Chitosan can bind fats, preventing them from being absorbed in the intestines. This helps to reduce the calorie content of food and helps to reduce fat storage in the body. Studies have shown that chitosan supplements can help in weight control, especially when following a balanced diet.

Chitosan is also considered a source of soluble fiber, which is important for improving digestion and normalizing intestinal function. Fiber helps prevent constipation, improves intestinal peristalsis, and helps improve overall gastrointestinal function. Chitosan supplements may be beneficial for people suffering from digestive problems or those who wish to improve their diet.

The data obtained by the authors of the article not only provide a scientific description of the differences between chitosan sources, but also demonstrate their practical application in the industry: the selection of raw materials for a specific task (film, coating, or solution), the predicted properties of finished materials, and the technological modes of solution preparation, which are directly related to extending shelf life and reducing packaging waste in the food industry.

### Conclusion

With the increasing interest in natural and functional supplements, it can be expected that the use of chitosan in the food industry will continue to expand. Research into improving the properties of chitosan and finding new uses for chitosan will contribute to the development of more effective additives. The future may also see the use of chitosan in more convenient forms, such as capsules or powders, which will be easily integrated into the daily human diet.

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## **ТАҒАМ ӨНДІРІСІНДЕ ҚОЛДАНУ ҮШІН ТҮРЛІ ТАБИҒИ КӨЗДЕРДЕН АЛҒАН ХИТОЗАНДЫҢ ФИЗИКАЛЫҚ-ХИМИЯЛЫҚ ҚАСИЕТТЕРІ ЖӘНЕ МИКРОБҚА ҚАРСЫ ӨРЕКЕТІ**

*Мақалада авторлар әртүрлі шикізат көздерінен хитозан синтезі бойынша зерттеулердің нәтижелерін, олардың молекулалық-массалық, физика-химиялық сипаттамаларын, сондай-ақ оларды әртүрлі салаларда қолдану салаларын зерттеді. Хитозан мен оның туындыларын тамақ өнеркәсібінде орау материалдары ретінде қолдану тағамның балғындығын сақтауға және хитозан жоғары бактерияға қарсы және микробқа қарсы қасиеттерін көрсеткен кезде олардың сақтау мерзімін ұзартуға ықпал ететіндігі көрсетілген. Хитозанды өнімге тағамдық қоспалар ретінде қолдану адам ағзасына өнімнің сіңімділігін жақсартады және олардың антиоксиданттық қасиеттерін арттырады.*

**Түйін сөздер:** хитин, хитозан, табиғи полисахарид, шаян тәрізділер, ара құрттары, саңырауқұлақтар, жібек құртының қуыршақтары, диацетилдену, микробқа қарсы және бактерияға қарсы белсенділік, биоүйлесімділік және биодеградация.

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## **ФИЗИКО-ХИМИЧЕСКИЕ СВОЙСТВА И АНТИМИКРОБНАЯ АКТИВНОСТЬ ХИТОЗАНА ИЗ РАЗЛИЧНЫХ ПРИРОДНЫХ ИСТОЧНИКОВ ДЛЯ ИСПОЛЬЗОВАНИЯ В ПИЩЕВОЙ ПРОМЫШЛЕННОСТИ**

*В статье авторами приведены результаты исследований по синтезу хитозана из различных источников сырья, их молекулярно-массовые, физико-химические характеристики, а также изучены сферы их применения в различных отраслях. Показано, что применение хитозана и его производных в отраслях пищевой промышленности в качестве упаковочных материалов, способствует сохранению свежести продуктов питания и увеличению их сроков хранения при проявлении хитозаном высоких антибактериальных и антимикробных свойств. Это особенно важно для продуктов с коротким сроком хранения, таких, как мясо, рыба, молочные продукты, а также свежие фрукты и овощи. Применение хитозана в качестве пищевых добавок в продукты питания улучшает качество и усваиваемость продукции организмом человека, увеличивает их антиоксидантные свойства. Хитозановые добавки из-за своих антибактериальной и антимикробной активности помогают в снижении уровня холестерина в крови, улучшению обмена веществ и являются безопасными для здоровья человека. Способность хитозана связывать жиры в желудочно-кишечном тракте предотвращает сердечно-сосудистые заболевания. Антиоксидантные свойства хитозана защищают организм от свободных радикалов, снижают уровень липидов и поддерживают нормальное состояние клеток организма.*

**Ключевые слова:** хитин, хитозан, природный полисахарид, ракообразные, пчелиный подмор, грибы, куколки тутового шелкопряда, диацетилирование, антимикробная и антибактериальная активность, биосовместимость и биодеградация.

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### **ВЛИЯНИЕ УЛЬТРАЗВУКОВЫХ КОЛЕБАТЕЛЬНЫХ ВОЛН НА НАПРЯЖЕНИЕ СРЕЗА МЯСНОГО СЫРЬЯ**

**Аннотация:** В работе исследовано влияние ультразвуковых колебательных волн на напряжение среза различных видов мясного сырья – мяса марала, мясной обрезки и говяжьего рубца. Эксперименты проводили с использованием ультразвуковых ванн частотой 35 и 60 кГц, а в качестве среды обработки применяли воду и 2% раствор аскорбиновой кислоты. Методика включала нарезку образцов стандартных размеров, ультразвуковую обработку в течение 30–300