Chitin nanofibers and their applications

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1. Introduction

Chitin is a component of the exoskeletons of crustaceans such as crabs and shrimp, as well as insects, and is an abundant renewable resource in nature. Chitin is obtained industrially by deproteinizing the shells of crabs and shrimps through a thermal alkali treatment, followed by a decalcification process using a strong acid.

Chitin has a linear structure consisting of β-(1-4)-poly-*N*-acetyl-D-glucosamine (Figure 1). Chitosan is a deacetylated derivative of chitin, which forms salts with formic acid, acetic acid, and propionic acid, making it soluble in water under acidic conditions.

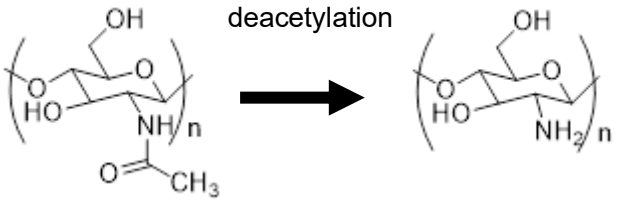

Figure 1. Structure of Chitin/Chitosan

The main effects of Chitin/chitosan are as follows.

- Moisturizing
- Control of fat absorption[1)2)]
- Lowering of blood cholesterol[1)2)]
- Regulation of immune function
- Regeneration of skin and granulation tissue
- Antimicrobial

Chitin dissolved in special solvents and processed into nonwoven fabrics and cotton-like materials have been commercialized for wound dressings and other medical applications for humans and animals.

On the other hand, although various studies have been conducted on other applications of chitin, only a limited number of cases have led to practical use. Chitin is insoluble in most solvents and water, making it difficult to process, and this has been a major obstacle to its industrial use.

2. About Chitin Nanofibers

Chitin nanofiber is a nano-level defibrated chitin fiber. Chitin is originally a crystalline fiber but can be transformed into nanofibers with a width of approximately 10 to 20 nanometers defibration method developed at Tottori University ,Japan.[3)]

One of the characteristics of chitin nanofibers is high dispersibility into water. As shown in Figure 2, while chitin powder quickly precipitates when mixed with water, chitin nanofibers can form a translucent gel and remain dispersed in water. Therefore, in addition to being able to be blended into water-based products such as cosmetics, various forming processes are now possible, such as removing water to form sheets, or freeze-drying to make cotton-like products.

Fundamental research on chitin nanofibers has

been actively conducted mainly at Tottori University, and various functions of this material have been revealed. For example, it has been reported that applying chitin nanofibers to wounds and inflamed areas alleviates wounds and inflammation.[4)5)]

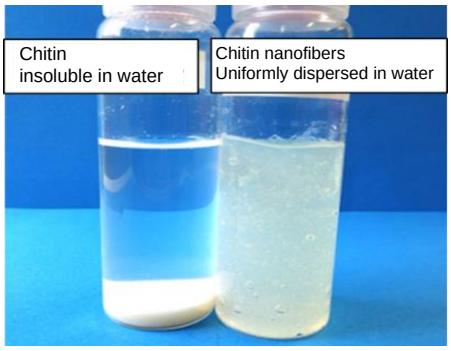

Figure 2. Water Dispersibility of Chitin and Chitin Nanofibers

Interestingly, chitin nanofibers are as effective as or more effective than chitin in treating wounds and inflammation, with some results showing healing effects comparable to those of steroid drugs. It can be said that the physiological effects of chitin have been enhanced by being nanofibers. Other findings include the fact that a thin film of chitin nanofibers moisturize when applied to the skin[6)], that it promotes growth and improves disease resistance when used on plants[7)], and that it has a reinforcing effect when combined with plastics[8)]. Thus, chitin nanofibers are an excellent material with potential applications in a wide range

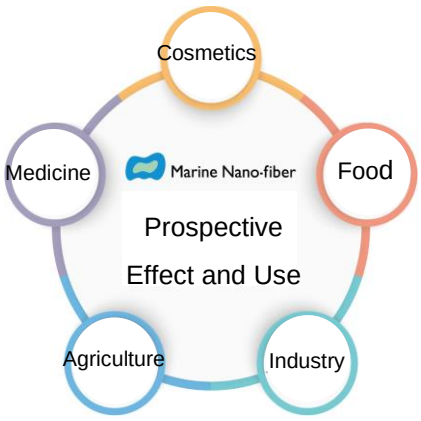

Figure3. Potential Applications for Chitin Nanofibers

of fields, including medicine, agriculture, and engineering (Figure 3).

Marine Nano-fiber Co., Ltd. manufactures and develops chitin nanofibers, and even sells the final products. Next, we report on the characteristics of chitin nanofibers produced by Marine Nano-fiber Co., Ltd. and their industrial applications.

3. Production and Properties of Chitin Nanofibers

Marine Nano-fiber Co., Ltd. manufactures chitin nanofibers from chitin using its patented wet milling method. Some of these chitin nanofibers are deacetylated before defibration, and some of them become chitosan.

The properties of the chitin nanofiber products are shown in Table 1. They are long and thin fibers, several tens of nanometers in width and several micrometers in length. Since these high aspect ratio fibers are dispersed in water, the aqueous dispersion of chitin nanofibers exhibits high thixotropy. Figure 4 shows the relationship between the rotation speed and viscosity of the chitin nanofiber product S-HL-02 using a Brookfield viscometer. The graph shows that the viscosity under high rotation speed is low and that the viscosity under the low rotation speed is high. This indicates S-HL-02 is a thixotropic material. Thixotropy is the ability to move smoothly when spread or stirred, but not to flow or spread when at rest. Thixotropy has many advantages in cosmetics, food, and industrial applications. For example, when chitin nanofibers are mixed with paint, they spread easily but remain stable after painted without dripping. In addition, cosmetics containing chitin nanofibers spread easily when applied to the skin, but do not run off after application.

Table 1. Chitin Nanofiber Product Properties

Molecular weight	Tens of thousands -hundreds of thousands
Size of nanofiber	Width: tens of nanometers Length: several micrometers
State	Water dispersion
pH	Acidic–neutral
Others	Emulsifying

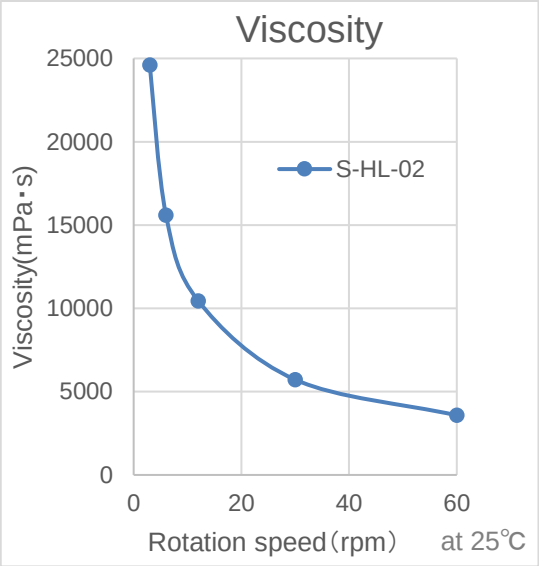

Figure4. Viscosity of Chitin Nanofibers by B-type Viscometer

It is known that the physical properties of chitin nanofiber dispersion vary greatly depending on the degree of deacetylation of chitin before defibration. Marine Nano-fiber Co., Ltd. can design chitin nanofibers for specific applications by unique skills based on research results at Tottori University.

4. Industrial Applications of Chitin Nanofibers

Currently, Marine Nano-fiber Co., Ltd. is developing a B-to-B business in which it supplies chitin nanofibers manufactured in-house to manufacturers and others as raw materials, and a B-to-C business in which it manufactures final products containing chitin nanofibers in-house.

4-1 Application to the Cosmetics Field

The effects of chitin nanofibers, which have been clarified in the basic research described above, can be utilized in the field of health care.

Table 2 shows the safety data of representative product of chitin nanofibers manufactured by Marine Nano-fiber Co., Ltd. The safety of chitin nanofibers has been confirmed for the skin and eyes, and they can be used as raw materials for cosmetics for human use. Chitin nanofibers are already being utilized mainly by cosmetics manufacturers, and dozens of products containing chitin nanofibers have been created so far.

Marine Nano-fiber Co., Ltd. has also obtained a license to manufacture and sell cosmetics and manufactures and sells its own brand of cosmetics containing chitin nanofibers.

Table 2: Safety Test Results

Product name	Marine Nano-fiber S-HL-02
24-hour occlusion patch test for sensitive skin	Safety product
Stinging test (using lactic acid stinger)	Non-irritant
Eye irritation (SIRC cells)	Not classified*

*Not classified as a substance with eye-damaging/irritating effects in the hazard classifications defined by the UN GHS according to the criteria in accordance with OECD Test Guideline 491.

Because chitin has various functions for the skin, Marine Nano-fiber Co., Ltd. has developed a line of cosmetics for people suffering from skin problems. The lineup includes hand cream, hand gel, face pack, and scalp lotion.

Figure 5: Products of Marine Nano-fiber Co., Ltd. (KANI DANOMI™ series)

4-2 Application in the Pet Care Field

Since chitin has been utilized in the field of animal medicine, it is believed that chitin nanofibers can be similarly applied in the field of animal care. Conventional chitin products are limited to powder, cotton, and cloth forms due to the above-mentioned processability issues, and when used, they need to be fixed to the skin in some form, such as wrapped with a bandage. In contrast, chitin nanofiber water dispersion can be applied to the skin for external use. Furthermore, since chitin is a safe ingredient derived from food components, it can be applied to oral care by licking chitin dispersion.

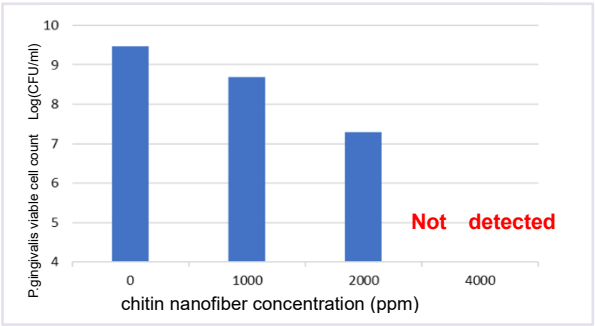

Figure 6: Antimicrobial Performance of Chitin Nanofibers Against Zygomycetes

In fact, fundamental research at Tottori University reported that administration of chitin nanofibers improved symptoms of gingivitis in cats[9]. Marine Nano-fiber Co., Ltd. experiments revealed that chitin nanofibers have antibacterial activity against Porphyromonas gingivalis, one of the oral bacteria. Porphyromonas gingivalis is known as a causative agent of periodontal disease in humans and dogs, and is known to be a factor in halitosis because it emits thiol compounds as metabolites during reproduction. Figure 6 shows the results of a culture test of B. gingivalis with and without chitin nanofibers. The number of viable B. gingivalis bacteria decreased (i.e., the growth of the bacteria was inhibited) according to the concentration of chitin nanofibers, and at 4,000 ppm, the antibacterial performance was so great that the bacteria hardly grew at all. These results indicate that chitin nanofibers are very effective in maintaining the oral health of dogs and cats.

Based on these research results, Marine Nano-fiber Co., Ltd. manufactures and sells skin moisturizing care products for dogs and cats and oral care products for veterinary clinics.

5. Conclusion

In this paper, we described chitin nanofibers and their applications. Chitin nanofibers can be dispersed uniformly in water, overcoming conventional processing issues. The use of chitin nanofibers in foods, cosmetics, and animal care products has expanded the potential of chitin.

Research on chitin nanofibers is still being conducted in various fields, and Marine Nano-fiber Co., Ltd. is currently studying ways to expand the use of chitin nanofibers into the industrial and agricultural fields, where there is a large market for them. All of us at Marine Nano-fiber Co., Ltd. are committed to bringing smiles to as many people as possible through this "eco-friendly technology" that utilize crab shells, which are a waste material.

《References》

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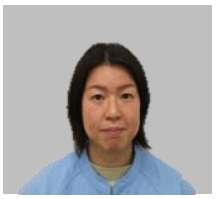

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