MICROCRYSTALLINE, POWDER NANOCELLULOSE, PROPERTIES AND APPLICATION (OVERVIEW)

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The article describes the characteristics of wood pulp fibers. The types of regenerated cellulose modifications, properties of microfibre materials, and areas of application of nanocellulose materials are considered.

Keywords: cellulose, microcrystalline, powder, microfibrillar, acid, hydrolysis, fibre mass, degree of polymerization

Wood pulp fibers have the following characteristics: the length of the fibers is from 1 to 3 mm, the width is from 10 to 50 μm, the thickness of the fiber wall is about 1 and 5 μm . The cell wall of wood fiber has several layers: the primary, which is called the outer fiber shell, and the secondary (the wall, which consists of three layers: the outer, middle and inner). The thickness of the primary wall is 0.1...0.3 μm. Each of these layers is characterized by a specific arrangement of fibrils. Cellulose fibers are obtained by pulp cooking, as a result of which lignin and hemicellulose are extracted. Further they are used as additives in the initial material in the form of various modifications not only in the pulp and paper industry (PPI), the volume of which is constantly expanding, but in the chemical, medical, pharmaceutical, food and other sectors of the national economy.

Currently, there is no unified international classification of natural cellulose modifications: terms, methods of production, evaluation and application of the finished product. Depending on the size of the fibers, cellulose is classified as fibrillar (5-6 nm), crystalline (2-20 nm), and bacterial (20-100 nm). Depending on the type, there is fibrillar cellulose (FB), powder cellulose (PC), and nanocellulose (NC). In Western countries, the division of cellulose materials from microfibres is used: nanocrystalline cellulose (NCC), cellulose nanocrystals (CNC), cellulose whiskers, nanofibrillated cellulose (NFC), cellulose nanofibrils (CNF), microfibrillated cellulose (MFC), carboxymethylated cellulose (CMC), microcrystalline cellulose (MCC) and cellulose filaments (CF) [1, 2]. The differentiation of the names of natural cellulose (nanocellulose) modifications is not accidental. For example, cellulose nanofibrils (CNF) can be used most effectively to make final products more stable, make materials lighter, and improve technological processes. Thus, the additive of 1-2% cellulose nanofibrils (CNF) to the paper mass gives a significant increase in the strength of cardboard and sheet paper, reduces the product weight without losing its density and elasticity.

The variety of natural cellulose modifications depends on the type of processing of the fibre mass. Depending on the type of processing, its degree of polymerization decreases, the degree of purity increases, the content of the ordered part with the crystal orientation of macromolecules increases, and specific properties appear [3].

For example, powder cellulose is obtained by the destruction of fibrous raw materials and contains at least 92% of cellulose and has the properties slightly different from those of fibrillated cellulose. PC is an odorless white powder that is insoluble in water, ethanol, ether, and dilute mineral acids, as well as slightly soluble in sodium hydroxide solution. PC can swell in water, dilute acids, and most solvents, while alkaline solutions lead to swelling and dissolution of the hemicellulose in it [3]. In comparison with MCC and NCC, powder cellulose has a lower degree of crystallinity (DC), lower chemical purity, and contains impurities of hemicellulose and lignin.

Microcrystalline cellulose is a finely dispersed product, crystallites of cellulose microfibrils (without amorphous part), powder of modified natural (fibrillated) cellulose. Depending on the initial cellulose material and its production conditions, the average particle size of powder cellulose is in the range from 1 to 400 μm, and the degree of polymerization is in the range from 30 to 350. MCC can be obtained from wood pulp, cotton fibers, reeds, cereals and sunflowers, jute and flax stems as a result of mechanical, thermomechanical, chemical processing of the initial fiber, by precipitation of cellulose from its solutions in powder form, as well as by radiation-chemical method. MCC, in contrast to MFC, NFC, and PC with a low crystallinity degree, is able to form thixotropic gel dispersions in water due to a highly developed hydrophilic surface containing a large number of active hydroxyl groups and at the same time having a low molecular weight [4].

а) б) в)

a - powder cellulose, b - microcrystalline cellulose, c - microfibrillated cellulose

Figure 1 - Cellulose crystallites

Microfibrillated cellulose is a non-uniform fibrillated material containing various structural components (cellulose fibers and its fragments, finely dispersed fibrillar particles and nanofibrils) [5]. Cellulose fibrils are obtained as a result of mechanical impact, grinding, due to transverse splitting along the longitudinal axis of the microfibrillar structure of cellulose.

Nanocrystalline cellulose can expand the potential use of natural cellulose modification. Nanocrystalline cellulose is extracted from cellulose fibrils by acid hydrolysis.

The main properties of cellulose materials made of microfibres include: super strength (stronger than stainless steel), pseudoplasticity and ultralightness. They can improve the properties of materials, making it possible to create them with qualitatively and quantitatively new characteristics. This is due to the fact that for a material of such small scales (compared to conventional ones), such fundamental characteristics as the elastic modulus, specific heat, diffusion coefficient, magnetic properties and others significantly change, which, in turn, leads to changes in the electrical, optical and mechanical properties of the initial substance.

Application of nanocellulose materials includes:

- ultra-light and ultra-strength materials (the strength/weight ratio is 8 times greater than that of stainless steel), such as aerogel, durable body armor, machine designs;
- transparent, flexible and durable material for super-thin and flexible screens (instead of plastic and glass);
- analogs of nanocarbon tubes that do not threaten the environment;
- cellulose nitrates have prospects for the defense industry;
- filters for various purposes, when the structure of the NC resembles graphene, and can be used for obtaining fresh water from the sea, cleaning indoor air contaminated with smoke and suspended harmful particles;
- sorbents for collecting spilled oil and petroleum products (the sponge structure has oleophilic and hydrophobic properties);

- medical and pharmacological adhesives and dressings that tightly cover the wound surface, prevent its infection, absorb wound secretions, and medications in the bandage, anesthetize, cool the temperature of inflamed skin, and promote wound healing. For example, scientists of the national Academy of Sciences of Ukraine have developed a series of wound-healing and anti-burn hydrogels based on NC synthesized by Komagataeibacter bacteria to provide medical care in the field and in clinical conditions for skin injuries and second-degree burns, as well as for transdermal delivery of medicine and biologically active drugs;

- decorative elements, textiles and 3-D printed elements of animal and human organs required for transplantation;

- thickeners and stabilizers for the production of food products that do not oxidize and retain their consumer properties for a long time.

- cement, automotive and painting and coatings industries,

- packaging and paper coatings for cohesive products. The packaging is based on CNF film, which protects the paper from oxygen damage, moisture and contamination.

Thus, the growing demand for various modifications of regenerated cellulose, in particular nanocellulose, beyond the paper industry represent completely new opportunities for using cellulose as a raw material.

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